Homework 6

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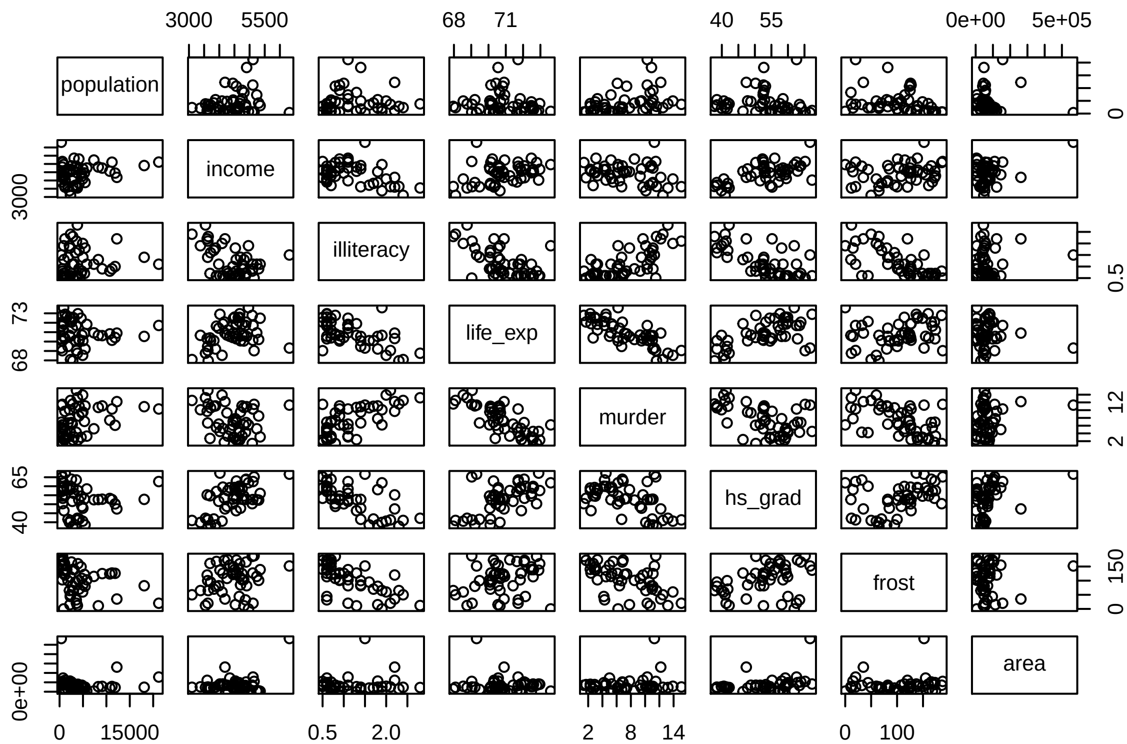
```
states = state.x77 %>% # load data from faraway package
  as.data.frame() %>%
  janitor::clean_names()
```

1. Explore the dataset and generate appropriate descriptive statistics and relevant graphs for all variables of interest (continuous and categorical) – no test required. Be selective! Even if you create 20 plots, you don't want to show them all.

```
# table of summary stats
states %>%
  skimr::skim_to_list() %>%
  as.data.frame %>%
  dplyr::select(1, 2, 5:11) %>%
  `colnames<-`(c(' ', 'NA', 'Mean', 'Std. Dev.', 'Min', '1st Q', 'Median', '3rd Q', 'Max')) %>%
  knitr::kable()
```

	NA	Mean	Std. Dev.	Min	1st Q	Median	3rd Q	Max
area	0	70735.88	85327.3	1049	36985.25	54277	81162.5	566432
frost	0	104.46	51.98	0	66.25	114.5	139.75	188
hs_grad	0	53.11	8.08	37.8	48.05	53.25	59.15	67.3
illiteracy	0	1.17	0.61	0.5	0.62	0.95	1.58	2.8
income	0	4435.8	614.47	3098	3992.75	4519	4813.5	6315
life_exp	0	70.88	1.34	67.96	70.12	70.67	71.89	73.6
murder	0	7.38	3.69	1.4	4.35	6.85	10.67	15.1
population	0	4246.42	4464.49	365	1079.5	2838.5	4968.5	21198

```
# scatterplot to assess correlation between vars
states %>%
  pairs
```




```r
# correlation matrix to evaluate what is seen in scatterplots
states %>%
  cor
```

```
##              population     income  illiteracy    life_exp     murder
## population   1.00000000  0.2082276  0.10762237 -0.06805195  0.3436428
## income       0.20822756  1.0000000 -0.43707519  0.34025534 -0.2300776
## illiteracy   0.10762237 -0.4370752  1.00000000 -0.58847793  0.7029752
## life_exp    -0.06805195  0.3402553 -0.58847793  1.00000000 -0.7808458
## murder       0.34364275 -0.2300776  0.70297520 -0.78084575  1.0000000
## hs_grad     -0.09848975  0.6199323 -0.65718861  0.58221620 -0.4879710
## frost       -0.33215245  0.2262822 -0.67194697  0.26206801 -0.5388834
## area         0.02254384  0.3633154  0.07726113 -0.10733194  0.2283902
##                 hs_grad     frost        area
## population  -0.09848975 -0.3321525  0.02254384
## income       0.61993232  0.2262822  0.36331544
## illiteracy  -0.65718861 -0.6719470  0.07726113
## life_exp     0.58221620  0.2620680 -0.10733194
## murder      -0.48797102 -0.5388834  0.22839021
## hs_grad      1.00000000  0.3667797  0.33354187
## frost        0.36677970  1.0000000  0.05922910
## area         0.33354187  0.0592291  1.00000000
```

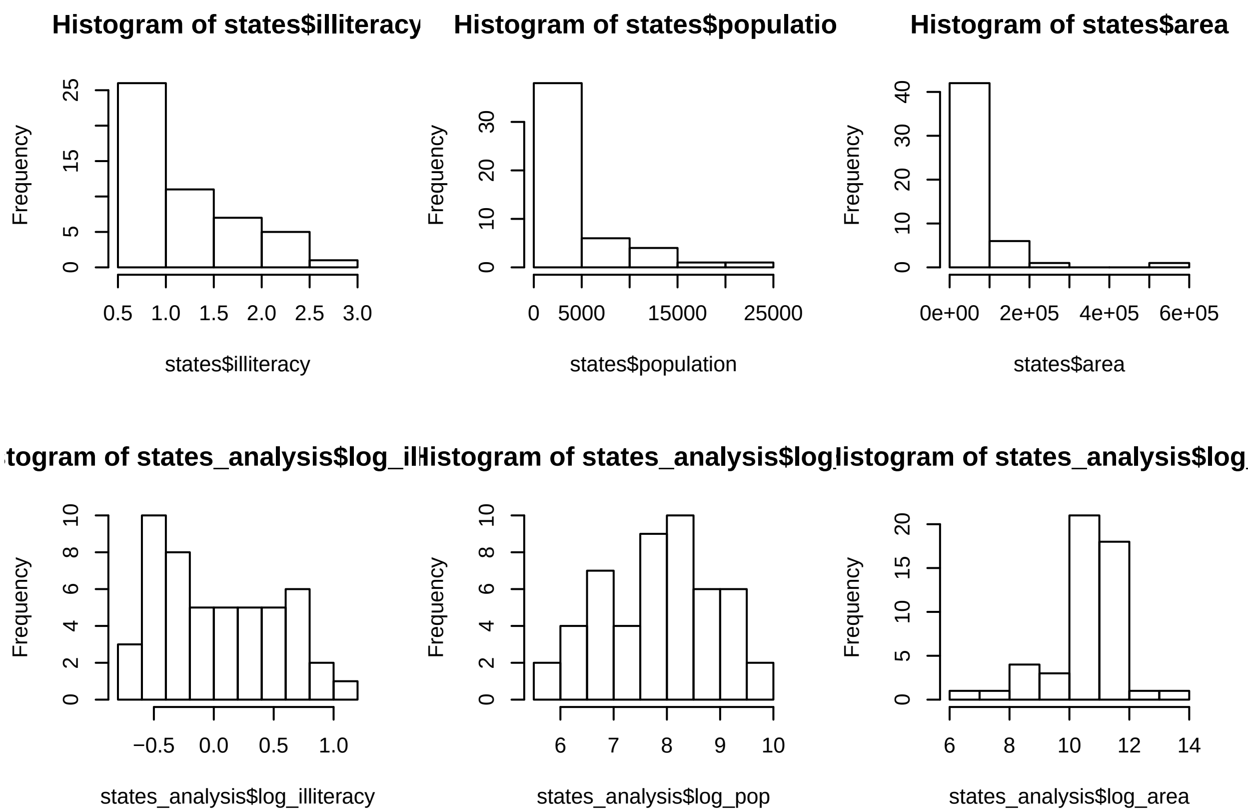
It looks like murder is correlated both with life expectancy and illiteracy, suggesting that it is a potential confounder. Specifically, murder is positively associated with illiteracy (higher murder rate = higher illiteracy rate) and negatively associated with life expectancy (higher murder rate = lower life expectancy).

After examining the distribution of each vriable in the dataset, I chose to perform a log transformation on the estimates for area size, illiteracy rate, and population size, which were all skewed.

```r
states_analysis = states %>%
  mutate(log_area = log(area),
```

```
         log_illiteracy = log(illiteracy),
         log_pop = log(population)) %>%
  dplyr::select(-area, -population, -illiteracy)

par(mfrow = c(2, 3))
hist(states$illiteracy)
hist(states$population)
hist(states$area)
hist(states_analysis$log_illiteracy)
hist(states_analysis$log_pop)
hist(states_analysis$log_area)
```



2. Use automatic procedures to find a 'best subset' of the full model. Present the results and comment on the following

```
## backwards elimination
summary(lm(life_exp ~ ., data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ ., data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.44702 -0.42901  0.04546  0.50742  1.68911
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)     6.799e+01  1.798e+00  37.809  < 2e-16 ***
```

```
## income         -4.417e-06  2.475e-04  -0.018   0.9858
## murder         -3.114e-01  4.659e-02  -6.684 4.12e-08 ***
## hs_grad         5.482e-02  2.552e-02   2.148   0.0375 *
## frost          -4.669e-03  3.173e-03  -1.471   0.1487
## log_area        7.314e-02  1.102e-01   0.663   0.5107
## log_illiteracy  1.883e-01  4.204e-01   0.448   0.6565
## log_pop         2.537e-01  1.311e-01   1.936   0.0597 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7335 on 42 degrees of freedom
## Multiple R-squared:  0.7441, Adjusted R-squared:  0.7014
## F-statistic: 17.45 on 7 and 42 DF,  p-value: 1.368e-10
```

```
summary(lm(life_exp ~ murder + hs_grad + frost + log_area + log_illiteracy + log_pop, data = states_anal
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + frost + log_area +
##     log_illiteracy + log_pop, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.44406 -0.42783  0.04462  0.50722  1.68851
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    67.991653   1.777131  38.259  < 2e-16 ***
## murder         -0.311495   0.045635  -6.826  2.3e-08 ***
## hs_grad         0.054521   0.018818   2.897   0.0059 **
## frost          -0.004684   0.003022  -1.550   0.1284
## log_area        0.073696   0.104455   0.706   0.4843
## log_illiteracy  0.187064   0.409816   0.456   0.6504
## log_pop         0.252730   0.118609   2.131   0.0389 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7249 on 43 degrees of freedom
## Multiple R-squared:  0.7441, Adjusted R-squared:  0.7084
## F-statistic: 20.84 on 6 and 43 DF,  p-value: 2.834e-11
```

```
summary(lm(life_exp ~ murder + hs_grad + frost + log_illiteracy + log_pop, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + frost + log_illiteracy +
##     log_pop, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.42070 -0.45738  0.05513  0.53826  1.57824
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    68.428995   1.655984  41.322  < 2e-16 ***
```

```
## murder         -0.296227   0.039947  -7.415 2.83e-09 ***
## hs_grad         0.058095   0.018019   3.224  0.00238 **
## frost          -0.004596   0.003002  -1.531  0.13290
## log_illiteracy  0.140797   0.402220   0.350  0.72797
## log_pop         0.257589   0.117731   2.188  0.03403 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7208 on 44 degrees of freedom
## Multiple R-squared:  0.7411, Adjusted R-squared:  0.7117
## F-statistic: 25.19 on 5 and 44 DF,  p-value: 6.734e-12
```

```r
b.fit = lm(life_exp ~ murder + hs_grad + frost + log_pop, data = states_analysis)
summary(b.fit)
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + frost + log_pop, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.41760 -0.43880  0.02539  0.52066  1.63048
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 68.720810   1.416828  48.503  < 2e-16 ***
## murder      -0.290016   0.035440  -8.183 1.87e-10 ***
## hs_grad      0.054550   0.014758   3.696 0.000591 ***
## frost       -0.005174   0.002482  -2.085 0.042779 *
## log_pop      0.246836   0.112539   2.193 0.033491 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7137 on 45 degrees of freedom
## Multiple R-squared:  0.7404, Adjusted R-squared:  0.7173
## F-statistic: 32.09 on 4 and 45 DF,  p-value: 1.17e-12
```

```r
## forwards process
summary(lm(life_exp ~ murder, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.81690 -0.48139  0.09591  0.39769  2.38691
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 72.97356    0.26997  270.30  < 2e-16 ***
## murder      -0.28395    0.03279   -8.66 2.26e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 0.8473 on 48 degrees of freedom
## Multiple R-squared:  0.6097, Adjusted R-squared:  0.6016
## F-statistic: 74.99 on 1 and 48 DF,  p-value: 2.26e-11
```

```r
summary(lm(life_exp ~ hs_grad, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ hs_grad, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -3.01867 -0.67517 -0.07538  0.64483  2.17311
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 65.73965    1.04748  62.760  < 2e-16 ***
## hs_grad      0.09676    0.01950   4.961  9.2e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.103 on 48 degrees of freedom
## Multiple R-squared:  0.339,  Adjusted R-squared:  0.3252
## F-statistic: 24.61 on 1 and 48 DF,  p-value: 9.196e-06
```

```r
summary(lm(life_exp ~ frost, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ frost, data = states_analysis)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.6515 -0.7852 -0.1183  0.9382  3.4284
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 70.171631   0.418883 167.521   <2e-16 ***
## frost        0.006768   0.003597   1.881    0.066 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.309 on 48 degrees of freedom
## Multiple R-squared:  0.06868,    Adjusted R-squared:  0.04928
## F-statistic:  3.54 on 1 and 48 DF,  p-value: 0.06599
```

```r
summary(lm(life_exp ~ log_area, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ log_area, data = states_analysis)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.9618 -0.7841 -0.1655  1.0537  2.4849
##
```

```
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  72.2098     1.7685  40.831   <2e-16 ***
## log_area     -0.1248     0.1649  -0.757    0.453
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.348 on 48 degrees of freedom
## Multiple R-squared:  0.0118, Adjusted R-squared:  -0.008786
## F-statistic: 0.5732 on 1 and 48 DF,  p-value: 0.4527
```

```r
summary(lm(life_exp ~ log_illiteracy, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ log_illiteracy, data = states_analysis)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.9536 -0.8010  0.0038  0.6943  3.6527
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)     70.9263     0.1579 449.148  < 2e-16 ***
## log_illiteracy  -1.5253     0.3174  -4.806 1.55e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.114 on 48 degrees of freedom
## Multiple R-squared:  0.3249, Adjusted R-squared:  0.3108
## F-statistic:  23.1 on 1 and 48 DF,  p-value: 1.555e-05
```

```r
summary(lm(life_exp ~ log_pop, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ log_pop, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.90739 -0.70580 -0.05555  1.05171  2.56688
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  71.9860     1.4665  49.086   <2e-16 ***
## log_pop      -0.1408     0.1849  -0.762     0.45
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.348 on 48 degrees of freedom
## Multiple R-squared:  0.01194,    Adjusted R-squared:  -0.008646
## F-statistic:  0.58 on 1 and 48 DF,  p-value: 0.4501
```

```r
# murder has lowest p-val. Start adding secondary vars
summary(lm(life_exp ~ murder + hs_grad, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.66758 -0.41801  0.05602  0.55913  2.05625
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 70.29708    1.01567  69.213  < 2e-16 ***
## murder      -0.23709    0.03529  -6.719 2.18e-08 ***
## hs_grad      0.04389    0.01613   2.721  0.00909 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7959 on 47 degrees of freedom
## Multiple R-squared:  0.6628, Adjusted R-squared:  0.6485
## F-statistic:  46.2 on 2 and 47 DF,  p-value: 8.016e-12
```

```r
summary(lm(life_exp ~ murder + frost, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + frost, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.76265 -0.55772  0.07629  0.44294  1.73190
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 73.900325   0.500294 147.714  < 2e-16 ***
## murder      -0.327777   0.037505  -8.739 2.05e-11 ***
## frost       -0.005776   0.002664  -2.169   0.0352 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8164 on 47 degrees of freedom
## Multiple R-squared:  0.6452, Adjusted R-squared:  0.6301
## F-statistic: 42.74 on 2 and 47 DF,  p-value: 2.655e-11
```

```r
summary(lm(life_exp ~ murder + log_area, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + log_area, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.83475 -0.54368  0.06741  0.44642  2.66277
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 71.43176    1.10270  64.779  < 2e-16 ***
```

```
## murder      -0.29845    0.03395  -8.790 1.73e-11 ***
## log_area     0.15463    0.10730   1.441    0.156    
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 0.838 on 47 degrees of freedom
## Multiple R-squared:  0.6262, Adjusted R-squared:  0.6103 
## F-statistic: 39.37 on 2 and 47 DF,  p-value: 9.038e-11
```

```
summary(lm(life_exp ~ murder + log_illiteracy, data = states_analysis))
```

```
## 
## Call:
## lm(formula = life_exp ~ murder + log_illiteracy, data = states_analysis)
## 
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -1.80926 -0.47370  0.09391  0.41515  2.48964 
## 
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)    
## (Intercept)    72.87888    0.35332 206.269  < 2e-16 ***
## murder         -0.27051    0.04598  -5.883 4.05e-07 ***
## log_illiteracy -0.14233    0.33839  -0.421    0.676    
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 0.8547 on 47 degrees of freedom
## Multiple R-squared:  0.6112, Adjusted R-squared:  0.5946 
## F-statistic: 36.94 on 2 and 47 DF,  p-value: 2.286e-10
```

```
summary(lm(life_exp ~ murder + log_pop, data = states_analysis))
```

```
## 
## Call:
## lm(formula = life_exp ~ murder + log_pop, data = states_analysis)
## 
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -1.70906 -0.42411  0.09279  0.45195  2.63524 
## 
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 71.16651    0.89471  79.541  < 2e-16 ***
## murder      -0.30972    0.03394  -9.125 5.64e-12 ***
## log_pop      0.25399    0.12029   2.111   0.0401 *  
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 0.8184 on 47 degrees of freedom
## Multiple R-squared:  0.6435, Adjusted R-squared:  0.6284 
## F-statistic: 42.42 on 2 and 47 DF,  p-value: 2.968e-11
```

```
# murder + hs_grad
summary(lm(life_exp ~ murder + hs_grad + frost, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + frost, data = states_analysis)
##
## 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 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## 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
```

```r
summary(lm(life_exp ~ murder + hs_grad + log_area, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_area, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.68415 -0.36849  0.06854  0.54491  2.16838
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 70.00002    1.22868  56.972  < 2e-16 ***
## murder      -0.24513    0.04005  -6.121 1.91e-07 ***
## hs_grad      0.04069    0.01783   2.282   0.0272 *
## log_area     0.04935    0.11268   0.438   0.6634
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8028 on 46 degrees of freedom
## Multiple R-squared:  0.6642, Adjusted R-squared:  0.6423
## F-statistic: 30.34 on 3 and 46 DF,  p-value: 5.681e-11
```

```r
summary(lm(life_exp ~ murder + hs_grad + log_illiteracy, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_illiteracy, data = states_analysis)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -1.6515 -0.5034  0.1132  0.5889  1.6629
##
## Coefficients:
```

```
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    69.88243    1.07409  65.062  < 2e-16 ***
## murder         -0.26505    0.04271  -6.206 1.42e-07 ***
## hs_grad         0.05533    0.01889   2.930  0.00527 **
## log_illiteracy  0.42558    0.36902   1.153  0.25476
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7931 on 46 degrees of freedom
## Multiple R-squared:  0.6723, Adjusted R-squared:  0.6509
## F-statistic: 31.46 on 3 and 46 DF,  p-value: 3.264e-11
```

```
summary(lm(life_exp ~ murder + hs_grad + log_pop, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_pop, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.50380 -0.59250  0.06207  0.42032  2.31066
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 67.52120    1.34101  50.351  < 2e-16 ***
## murder      -0.26121    0.03380  -7.727 7.48e-10 ***
## hs_grad      0.05187    0.01523   3.406  0.00138 **
## log_pop      0.32172    0.11046   2.912  0.00552 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7392 on 46 degrees of freedom
## Multiple R-squared:  0.7153, Adjusted R-squared:  0.6968
## F-statistic: 38.53 on 3 and 46 DF,  p-value: 1.32e-12
```

```
# murder + hs_grad + log_pop
summary(lm(life_exp ~ murder + hs_grad + log_pop + frost, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_pop + frost, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.41760 -0.43880  0.02539  0.52066  1.63048
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 68.720810   1.416828  48.503  < 2e-16 ***
## murder      -0.290016   0.035440  -8.183 1.87e-10 ***
## hs_grad      0.054550   0.014758   3.696 0.000591 ***
## log_pop      0.246836   0.112539   2.193 0.033491 *
## frost       -0.005174   0.002482  -2.085 0.042779 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 0.7137 on 45 degrees of freedom
## Multiple R-squared:  0.7404, Adjusted R-squared:  0.7173
## F-statistic: 32.09 on 4 and 45 DF,  p-value: 1.17e-12
```

```r
summary(lm(life_exp ~ murder + hs_grad + log_pop + log_area, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_pop + log_area,
##     data = states_analysis)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -1.5157 -0.5875  0.0417  0.4582  2.3833
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 67.34149    1.47257  45.730  < 2e-16 ***
## murder      -0.26638    0.03798  -7.014  9.7e-09 ***
## hs_grad      0.04971    0.01688   2.945  0.00509 **
## log_pop      0.31979    0.11174   2.862  0.00637 **
## log_area     0.03263    0.10495   0.311  0.75732
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7466 on 45 degrees of freedom
## Multiple R-squared:  0.7159, Adjusted R-squared:  0.6907
## F-statistic: 28.36 on 4 and 45 DF,  p-value: 8.603e-12
```

```r
summary(lm(life_exp ~ murder + hs_grad + log_pop + log_illiteracy, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_pop + log_illiteracy,
##     data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.48154 -0.57675  0.00752  0.51252  1.87366
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)    66.98373    1.38078  48.511  < 2e-16 ***
## murder         -0.29334    0.04049  -7.244 4.43e-09 ***
## hs_grad         0.06497    0.01771   3.669 0.000643 ***
## log_pop         0.32985    0.10946   3.013 0.004231 **
## log_illiteracy  0.47971    0.34081   1.408 0.166130
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7314 on 45 degrees of freedom
## Multiple R-squared:  0.7273, Adjusted R-squared:  0.7031
## F-statistic: 30.01 on 4 and 45 DF,  p-value: 3.476e-12
```

```r
# murder + hs_grad + log_pop + frost
summary(lm(life_exp ~ murder + hs_grad + log_pop + frost + log_area, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_pop + frost +
##     log_area, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.43763 -0.46147  0.00721  0.48073  1.74473
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 68.414712   1.502603  45.531  < 2e-16 ***
## murder      -0.301875   0.040110  -7.526 1.95e-09 ***
## hs_grad      0.050302   0.016243   3.097   0.0034 **
## log_pop      0.239312   0.113870   2.102   0.0413 *
## frost       -0.005424   0.002528  -2.146   0.0374 *
## log_area     0.066067   0.102178   0.647   0.5213
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7184 on 44 degrees of freedom
## Multiple R-squared:  0.7429, Adjusted R-squared:  0.7136
## F-statistic: 25.42 on 5 and 44 DF,  p-value: 5.833e-12
```

```r
summary(lm(life_exp ~ murder + hs_grad + log_pop + frost + log_illiteracy, data = states_analysis))
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_pop + frost +
##     log_illiteracy, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.42070 -0.45738  0.05513  0.53826  1.57824
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    68.428995   1.655984  41.322  < 2e-16 ***
## murder         -0.296227   0.039947  -7.415 2.83e-09 ***
## hs_grad         0.058095   0.018019   3.224  0.00238 **
## log_pop         0.257589   0.117731   2.188  0.03403 *
## frost          -0.004596   0.003002  -1.531  0.13290
## log_illiteracy  0.140797   0.402220   0.350  0.72797
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7208 on 44 degrees of freedom
## Multiple R-squared:  0.7411, Adjusted R-squared:  0.7117
## F-statistic: 25.19 on 5 and 44 DF,  p-value: 6.734e-12
```

```r
f.fit = lm(life_exp ~ murder + hs_grad + log_pop + frost, data = states_analysis)
summary(f.fit)
```

```
##
## Call:
## lm(formula = life_exp ~ murder + hs_grad + log_pop + frost, data = states_analysis)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.41760 -0.43880  0.02539  0.52066  1.63048
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 68.720810   1.416828  48.503  < 2e-16 ***
## murder      -0.290016   0.035440  -8.183 1.87e-10 ***
## hs_grad      0.054550   0.014758   3.696 0.000591 ***
## log_pop      0.246836   0.112539   2.193 0.033491 *
## frost       -0.005174   0.002482  -2.085 0.042779 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7137 on 45 degrees of freedom
## Multiple R-squared:  0.7404, Adjusted R-squared:  0.7173
## F-statistic: 32.09 on 4 and 45 DF,  p-value: 1.17e-12
```

```
## Stepwise
step.fit = step(lm(life_exp ~ ., data = states_analysis))
```

```
## Start:  AIC=-23.71
## life_exp ~ income + murder + hs_grad + frost + log_area + log_illiteracy +
##     log_pop
##
##                  Df Sum of Sq    RSS     AIC
## - income          1    0.0002 22.596 -25.712
## - log_illiteracy  1    0.1079 22.704 -25.475
## - log_area        1    0.2368 22.833 -25.192
## <none>                        22.596 -23.713
## - frost           1    1.1645 23.760 -23.200
## - log_pop         1    2.0155 24.611 -21.441
## - hs_grad         1    2.4822 25.078 -20.502
## - murder          1   24.0347 46.631  10.512
##
## Step:  AIC=-25.71
## life_exp ~ murder + hs_grad + frost + log_area + log_illiteracy +
##     log_pop
##
##                  Df Sum of Sq    RSS      AIC
## - log_illiteracy  1    0.1095 22.705 -27.4708
## - log_area        1    0.2616 22.858 -27.1370
## <none>                        22.596 -25.7125
## - frost           1    1.2628 23.859 -24.9936
## - log_pop         1    2.3859 24.982 -22.6937
## - hs_grad         1    4.4112 27.007 -18.7959
## - murder          1   24.4834 47.079   8.9907
##
## Step:  AIC=-27.47
## life_exp ~ murder + hs_grad + frost + log_area + log_pop
##
```

```
##            Df Sum of Sq    RSS     AIC
## - log_area  1    0.2157 22.921 -28.998
## <none>                  22.705 -27.471
## - log_pop   1    2.2792 24.985 -24.688
## - frost     1    2.3760 25.082 -24.495
## - hs_grad   1    4.9491 27.655 -19.612
## - murder    1   29.2296 51.935  11.899
##
## Step:  AIC=-29
## life_exp ~ murder + hs_grad + frost + log_pop
##
##           Df Sum of Sq    RSS     AIC
## <none>                 22.921 -28.998
## - frost    1     2.214 25.135 -26.387
## - log_pop  1     2.450 25.372 -25.920
## - hs_grad  1     6.959 29.881 -17.741
## - murder   1    34.109 57.031  14.578
```

All automatic processes conclude the same model, using percent increase in population size (log(population)), rate of high school graduation (hs_grad), murder rate per 100,000 (murder), and average number of days annually with temperatures below freezing (frost) as predictors of life expectancy.

'Frost' is the least significant predictor, with a p-value of 0.043. No variables were seen to be a "close call" at the 5% significance level.

There is a correlation between illiteracy (with and without log transformation) and high school graduation rate (-0.6571886), but my model includes only high school graduation rate as a predictor.

3. Use criterion-based procedures studied in class to guide your selection of the 'best subset'. Summarize your results (tabular or graphical)

```r
best <- function(model, ...)
{
  subsets <- regsubsets(formula(model), model.frame(model), ...)
  subsets <- with(summary(subsets),
                  cbind(p = as.numeric(rownames(which)), which, rss, rsq, adjr2, cp, bic))

  return(subsets)
}

best(lm(life_exp ~ ., data = states_analysis)) %>%
  knitr::kable(., 'latex', caption = 'Criterion-based model building') %>%
  kableExtra::kable_styling(latex_options = c("hold_position")) %>%
  kableExtra::landscape()
```

Table 2: Criterion-based model building

p	(Intercept)	income	murder	hs_grad	frost	log_area	log_illiteracy	log_pop	rss	rsq	adjr2	cp	bic
1	1	0	1	0	0	0	0	0	34.46133	0.6097201	0.6015893	18.054999	-39.22051
2	1	0	1	1	0	0	0	0	29.77036	0.6628461	0.6484991	11.335656	-42.62472
3	1	0	1	1	0	0	0	1	25.13538	0.7153378	0.6967729	4.720403	-47.17452
4	1	0	1	1	1	0	0	1	22.92123	0.7404135	0.7173392	2.604837	-47.87315
5	1	0	1	1	1	1	0	1	22.70549	0.7428568	0.7136360	4.203829	-44.43397
6	1	0	1	1	1	1	1	1	22.59600	0.7440968	0.7083894	6.000318	-40.76364
7	1	1	1	1	1	1	1	1	22.59583	0.7440987	0.7014485	8.000000	-36.85199

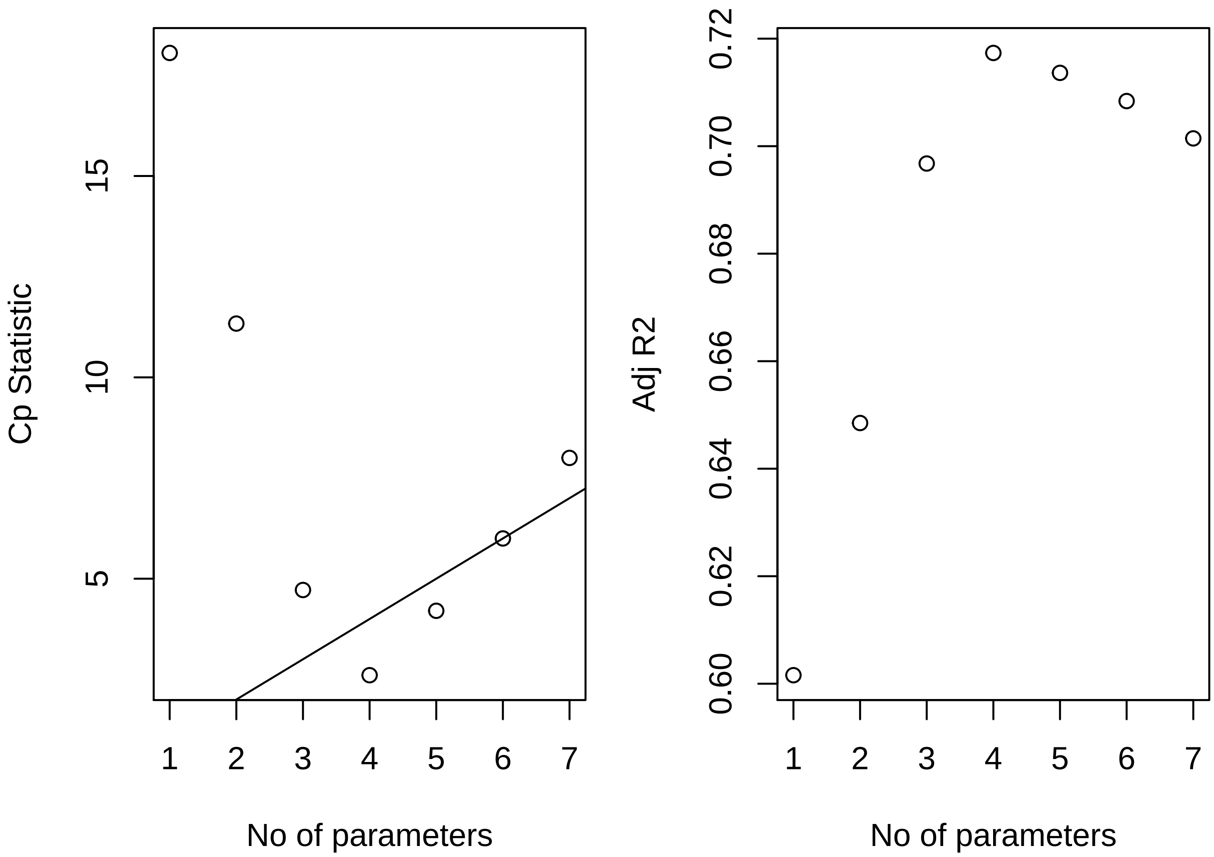
```r
# leaps::leaps(x = states_analysis[, c(1, 3:8)], y = states_analysis$life_exp, nbest = 2, method = "Cp"

# leaps::leaps(x = states_analysis[, c(1, 3:8)], y = states_analysis$life_exp, nbest = 2, method = "adj

# Summary of models for each size (one model per size)
b = leaps::regsubsets(life_exp ~ ., data = states_analysis)
rs = summary(b)

# Plots of Cp and Adj-R2 as functions of parameters
par(mar = c(4, 4, 1, 1))
par(mfrow = c(1, 2))

plot(1:7, rs$cp, xlab = "No of parameters", ylab = "Cp Statistic")
abline(0, 1)
plot(1:7, rs$adjr2, xlab = "No of parameters", ylab = "Adj R2")
```



According to the Cp statistics and Adjusted R^2, the ideal number of parameters is 4; as seen in the table above, those parameters are murder, hs_grad, frost, and log_pop.

4. Compare the two 'subsets' from parts 2 and 3 and recommend a 'final' model. Using this 'final' model do the following. a) Identify any leverage and/or influential points and take appropriate measures. b) Check the model assumptions.

All analyses above recommend the same model using percent increase in population size (log(population)), rate of high school graduation (hs_grad), murder rate per 100,000 (murder), and average number of days annually with temperatures below freezing (frost) as predictors of life expectancy.

(a)