

Assignment #3

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Question 1.

```
library(olsrr) #package for model selections
##
## Attaching package: 'olsrr'
## The following object is masked from 'package:datasets':
##
## rivers
library(ggplot2) #package for plots
library(dplyr) #package for filtering subplots
##
## Attaching package: 'dplyr'
## The following objects are masked from 'package:stats':
##
## filter, lag
## The following objects are masked from 'package:base':
##
## intersect, setdiff, setequal, union
#import data
bass = read.csv("hw3_bass.csv", header=T)

#fit linear regression model
bass.lm = lm(Avg_Mercury ~ Alkalinity + pH + Calcium + Chlorophyll, data=bass)

#fit all possible regressions
bass.all = ols_step_all_possible(bass.lm)
#details of all possible regression models
bass.all
```

	Index	N	Predictors	R-Square	Adj. R-Square	Mallow's Cp
## 1	1	1	Alkalinity	0.4254905	0.4142256	3.223111
## 2	2	1	pH	0.3310853	0.3179693	11.804576
## 3	3	1	Calcium	0.2386129	0.2236838	20.210347
## 4	4	1	Chlorophyll	0.2130176	0.1975865	22.536973
## 6	5	2	Alkalinity Calcium	0.4478582	0.4257726	3.189877
## 7	6	2	Alkalinity Chlorophyll	0.4436411	0.4213868	3.573211
## 5	7	2	Alkalinity pH	0.4292584	0.4064287	4.880607
## 9	8	2	pH Chlorophyll	0.3444788	0.3182580	12.587099
## 8	9	2	pH Calcium	0.3348995	0.3082955	13.457860
## 10	10	2	Calcium Chlorophyll	0.3009248	0.2729618	16.546176
## 13	11	3	Alkalinity Calcium Chlorophyll	0.4705171	0.4380997	3.130182
## 11	12	3	Alkalinity pH Calcium	0.4576077	0.4244001	4.303642
## 12	13	3	Alkalinity pH Chlorophyll	0.4436478	0.4095855	5.572602
## 14	14	3	pH Calcium Chlorophyll	0.3484270	0.3085347	14.228213
## 15	15	4	Alkalinity pH Calcium Chlorophyll	0.4719492	0.4279450	5.000000

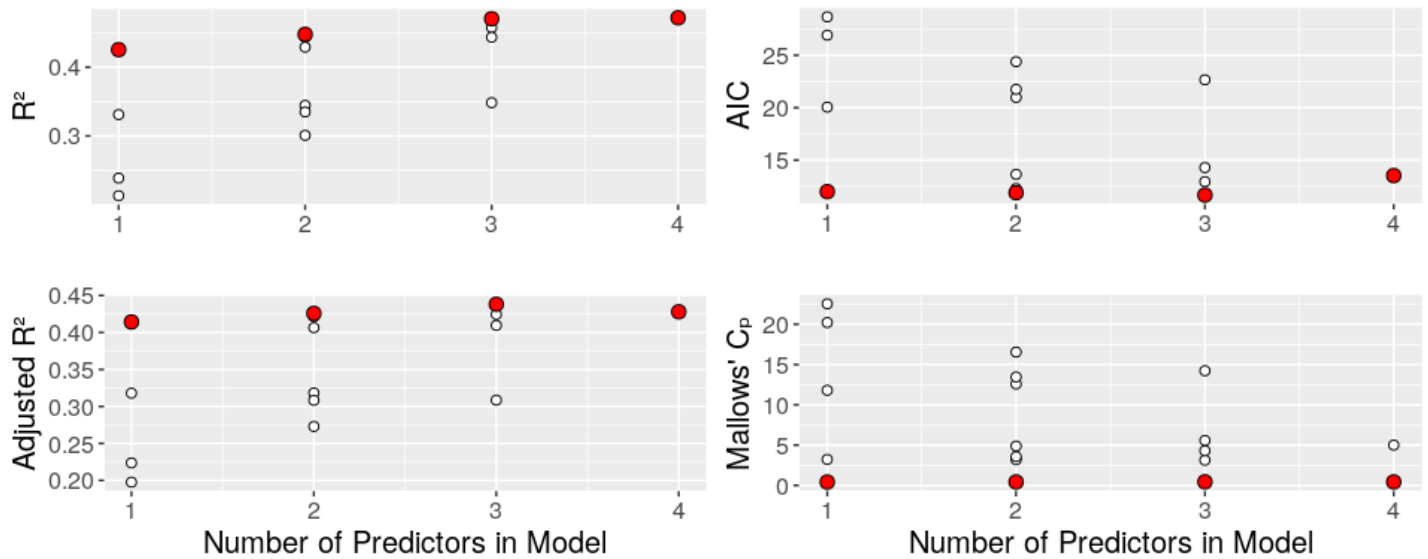
```
#r^2 & adjusted r^2, and aic & mallows cp subplots of all possible regressions
#max r^2 by n
p1max = bass.all %>% group_by(n) %>% filter(rsquare==max(rsquare, na.rm=FALSE))
#ggplot of r^2 vs n
p1.1 <- ggplot(bass.all, aes(n, rsquare)) + geom_point(aes(n, rsquare), shape=21, size=2, fill='white') + geom_point(data=p1max, aes(n, rsquare), shape=21, size=3, fill='red') + labs(x="", y = "R\u00B2") + theme(text = element_text(size = 15), plot.title=element_text(hjust=0.5))
#max r^2 by n
p2max = bass.all %>% group_by(n) %>% filter(adjr==max(adjr, na.rm=FALSE))
#ggplot of adjusted r^2 vs n
p1.2 <- ggplot(bass.all, aes(n, adjr)) + geom_point(aes(n, adjr), shape=21, size=2, fill='white') + geom_point(data=p2max, aes(n, adjr), shape=21, size=3, fill='red') + labs(x = "Number of Predictors in Model", y = "Adjusted R\u00B2") + theme(text = element_text(size = 15), plot.title=element_text(hjust=0.5))
#min aic by n
p3min = bass.all %>% group_by(n) %>% filter(aic==min(aic, na.rm=FALSE))
#ggplot of adjusted r^2 vs n
p1.3 <- ggplot(bass.all, aes(n, aic)) + geom_point(aes(n, aic), shape=21, size=2, fill='white') + geom_point(data=p3min, aes(n, aic), shape=21, size=3, fill='red') + labs(x="", y = "AIC") + theme(text = element_text(size = 15), plot.title=element_text(hjust=0.5))
#min cp by n
p4min = bass.all %>% group_by(n) %>% filter(cp==min(cp, na.rm=FALSE))
#ggplot of adjusted r^2 vs n
p1.4 <- ggplot(bass.all, aes(n, cp)) + geom_point(aes(n, cp), shape=21, size=2, fill='white') + geom_point(data=p4min, aes(n, adjr), shape=21,
```

```
size=3, fill='red') + labs(x = "Number of Predictors in Model", y = "Mallows' C\u2099A") + theme(text = element_text(size = 15),
plot.title=element_text(hjust=0.5))
```

```
#subplots
```

```
gridExtra::grid.arrange(p1.1, p1.2, nrow=2)
```

```
gridExtra::grid.arrange(p1.3, p1.4, nrow=2)
```



1A. The best model with one predictor and based off adjusted R^2 selection criterion, uses Alkalinity to explain Average Mercury, and has an R^2 of 0.4254905 and an adjusted R^2 of 0.4142256.

The best model with two predictors and based off adjusted R^2 selection criterion, uses Alkalinity and Calcium to explain Average Mercury, and has an R^2 of 0.4478582 and an adjusted R^2 of 0.4257726.

The best model with three predictors and based off adjusted R^2 selection criterion, uses Alkalinity, Calcium, and Chlorophyll to explain Average Mercury, and has an R^2 of 0.4705171 and an adjusted R^2 of 0.4380997.

The best model with four predictors and based off adjusted R^2 selection criterion, uses Alkalinity, pH, Calcium, and Chlorophyll to explain Average Mercury, and has an R^2 of 0.4719492 and an adjusted R^2 of 0.4279450.

Alkalinity is common to all “best” models and appears to explain the most variation of the data. The single linear regression model using only the Alkalinity predictor explains over 42.5% of variation, which only increases by a few percent with the other “best” MLR models. Comparing all models with their adjusted R^2 values, the three-predictor MLR model using Alkalinity, Calcium, and Chlorophyll has the highest adjusted R^2 value (0.4380997), explains over 47% of the variability in the dataset, and provides the best model for predicting average mercury concentrations in fish.

1B. There is a minor difference between average mercury predictions when using the four-predictor versus three-predictor models. When we compare the given means 0.545 and 0.532 of the four- and three-predictor models, respectively, we see that the three-predictor model gives a lower mean. When we compare prediction intervals of (0.0164 to 1.073) and (0.0133 to 1.051) of the four- and three-predictor models, respectively, we see that means of both models fall within the prediction interval of both models, indicating similarity of the two models. However, when comparing the prediction intervals themselves, we see that the three-predictor model has a more narrow range of predicted values and thus a greater precision versus the four-predictor model.

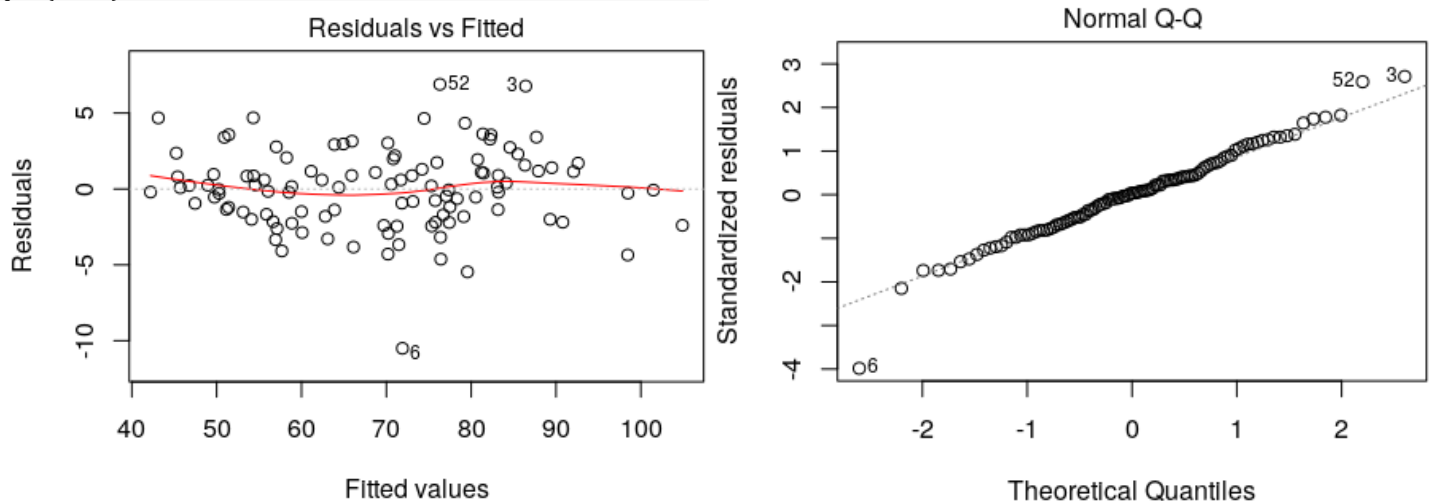
1C. All “best fit” models give similar results in this example as can be seen by comparing their adjusted R^2 values, which range from 0.4142256 (one predictor) to 0.4380997 (three predictors), although the three-predictor MLR using Alkalinity, Calcium, and Chlorophyll predictors provides the best model and explains over 47% of the variability. These results agree with the predicted values given in question 1B, which indicate that the three-predictor MLR using Alkalinity, Calcium, and Chlorophyll provides the most precision (most narrow prediction interval) of average mercury in fish as compared to the four-predictor MLR.

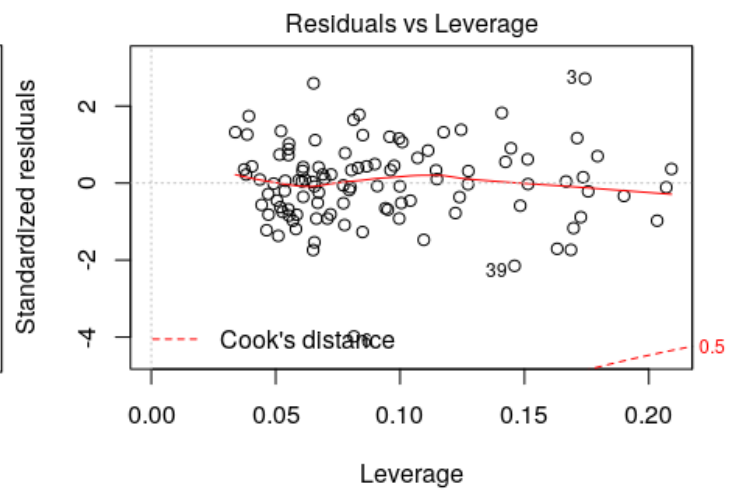
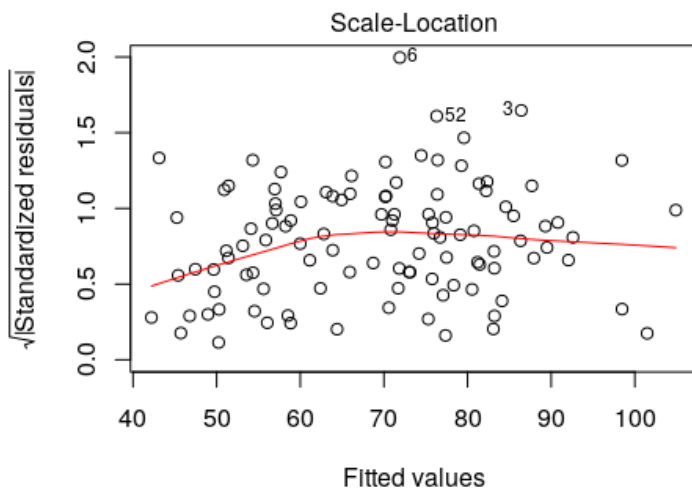
Question 2.

```
library(MASS) #package for stepAIC function
##
## Attaching package: 'MASS'
## The following object is masked from 'package:dplyr':
##
## select
## The following object is masked from 'package:olsrr':
##
## cement
#import data
bd = read.csv("hw3_body.csv", header=T)

#fit linear regression model
bd.lm <- lm(weight ~ chest_diam + chest_depth + ankle_diam + waist_girth + wrist_girth + wrist_diam + age + height + gender, data=bd)
#linear regression summary
summary(bd.lm)
##
## Call:
## lm(formula = weight ~ chest_diam + chest_depth + ankle_diam +
## waist_girth + wrist_girth + wrist_diam + age + height + gender,
## data = bd)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.5003   -1.7345   0.0929   1.4414   6.8888
##
## Coefficients:
##              Estimate      Std. Error    t value    Pr(>|t|)
## (Intercept)  -119.33349         6.83670    -17.455 < 2e-16 ***
## chest_diam     1.39294         0.21325     6.532  2.91e-09 ***
## chest_depth    0.59732         0.20463     2.919  0.00436 **
## ankle_diam     1.26351         0.44921     2.813  0.00594 **
## waist_girth    0.64234         0.05178    12.404 < 2e-16 ***
## wrist_girth    0.80607         0.42221     1.909  0.05916 .
## wrist_diam     0.08803         0.55213     0.159  0.87366
## age           -0.14840         0.03199    -4.639  1.08e-05 ***
## height         0.38080         0.04747     8.022  2.28e-12 ***
## gender        -7.64330         1.12288    -6.807  8.02e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.75 on 98 degrees of freedom
## Multiple R-squared:  0.9678, Adjusted R-squared:  0.9648
## F-statistic: 327.1 on 9 and 98 DF, p-value: < 2.2e-16

plot(bd.lm)
```





2A.

#calculate forward selection model with OSLRR::ols_step_forward_aic

```
bd.forward = ols_step_forward_aic(bd.lm)
```

#forward selection model summary

```
bd.forward
```

```
##
```

```
##           Selection Summary
```

```
## -----
```

## Variable	AIC	Sum Sq	RSS	R-Sq	Adj. R-Sq
## waist_girth	701.054	19057.564	3943.939	0.82854	0.82692
## height	624.158	21101.854	1899.648	0.91741	0.91584
## age	602.394	21477.054	1524.449	0.93372	0.93181
## chest_diam	583.729	21742.548	1258.954	0.94527	0.94314
## gender	567.787	21935.244	1066.258	0.95364	0.95137
## ankle_diam	548.390	22126.878	874.624	0.96198	0.95972
## chest_depth	537.700	22223.839	777.664	0.96619	0.96382
## wrist_girth	534.503	22260.379	741.123	0.96778	0.96518

```
## -----
```

#final forward selection model

```
bd.forward$model
```

```
##
```

```
## Call:
```

```
## lm(formula = paste(response, "~", paste(preds, collapse = " + ")),
```

```
##   data = l)
```

```
##
```

```
## Coefficients:
```

```
## (Intercept)  waist_girth  height  age  chest_diam  gender  ankle_diam  chest_depth  wrist_girth
```

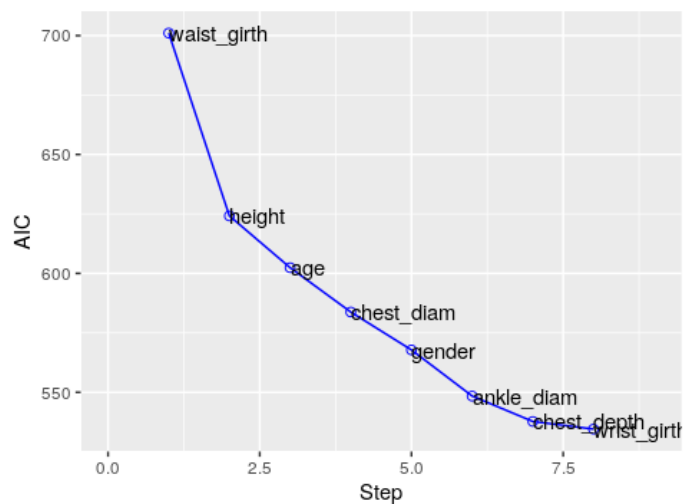
## -119.2782	0.6440	0.3806	-0.1478	1.3969	-7.6488	1.2813	0.5941	0.8354
--------------	--------	--------	---------	--------	---------	--------	--------	--------

```
##
```

#aic vs forward selection step

```
plot(bd.forward)
```

Stepwise AIC Forward Selection



```

#best forward selection model with MASS::stepAIC
step_forward = stepAIC(bd.lm, direction = "forward")
## Start: AIC=227.98
## weight ~ chest_diam + chest_depth + ankle_diam + waist_girth +
##   wrist_girth + wrist_diam + age + height + gender

#details of best model
summary(step_forward)
##
## Call:
## lm(formula = weight ~ chest_diam + chest_depth + ankle_diam +
##   waist_girth + wrist_girth + wrist_diam + age + height + gender,
##   data = bd)
##
## Residuals:
##   Min       1Q   Median       3Q      Max
## -10.5003  -1.7345    0.0929    1.4414    6.8888
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -119.33349    6.83670   -17.455 < 2e-16 ***
## chest_diam     1.39294    0.21325     6.532 2.91e-09 ***
## chest_depth    0.59732    0.20463     2.919 0.00436 **
## ankle_diam     1.26351    0.44921     2.813 0.00594 **
## waist_girth    0.64234    0.05178    12.404 < 2e-16 ***
## wrist_girth    0.80607    0.42221     1.909 0.05916 .
## wrist_diam     0.08803    0.55213     0.159 0.87366
## age           -0.14840    0.03199    -4.639 1.08e-05 ***
## height         0.38080    0.04747     8.022 2.28e-12 ***
## gender        -7.64330    1.12288    -6.807 8.02e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.75 on 98 degrees of freedom
## Multiple R-squared:  0.9678, Adjusted R-squared:  0.9648
## F-statistic: 327.1 on 9 and 98 DF, p-value: < 2.2e-16

#ANOVA of best model
step_forward$anova
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## weight ~ chest_diam + chest_depth + ankle_diam + waist_girth +
##   wrist_girth + wrist_diam + age + height + gender
##
## Final Model:
## weight ~ chest_diam + chest_depth + ankle_diam + waist_girth +
##   wrist_girth + wrist_diam + age + height + gender
##
##
##   Step      Df    Deviance   Resid.  Df Resid. Dev   AIC
##   1         98    740.9312   227.9839

```

The final model calculated by forward selection using OSLR::ols_step_forward_aic is given by the equation:

$$\text{weight} = -119.2782 + 0.6440(\text{waist_girth}) + 0.3806(\text{height}) - 0.1478(\text{age}) + 1.3969(\text{chest_diam}) - 7.6488(\text{gender}) + 1.2813(\text{ankle_diam}) + 0.5941(\text{chest_depth}) + 0.8354(\text{wrist_girth})$$

The final model calculated by forward selection using MASS::stepAIC is slightly different than that shown above calculated with OSLR::ols_step_forward_aic, and is given by the equation:

$$\text{weight} = -119.33349 + 0.64234(\text{waist_girth}) + 0.38080(\text{height}) - 0.14840(\text{age}) + 1.39294(\text{chest_diam}) - 7.64330(\text{gender}) + 1.26351(\text{ankle_diam}) + 0.59732(\text{chest_depth}) + 0.80607(\text{wrist_girth})$$

2B.

#calculate backward elimination model using OSLRR::ols_step_backward

```
bd.back = ols_step_backward_aic(bd.lm)
```

#backward elimination model summary

```
bd.back
```

```
##
```

```
##
```

```
##           Backward Elimination Summary
```

```
## -----
```

```
## Variable    AIC     RSS   Sum Sq   R-Sq   Adj. R-Sq
```

```
## -----
```

```
## Full Model  536.475  740.931 22260.571 0.96779  0.96483
```

```
## wrist_diam  534.503  741.123 22260.379 0.96778  0.96518
```

```
## -----
```

```
bd.back$model
```

```
##
```

```
## Call:
```

```
## lm(formula = paste(response, "~", paste(preds, collapse = " + ")),
```

```
##   data = l)
```

```
##
```

```
## Coefficients:
```

```
## (Intercept) chest_diam chest_depth ankle_diam waist_girth wrist_girth
```

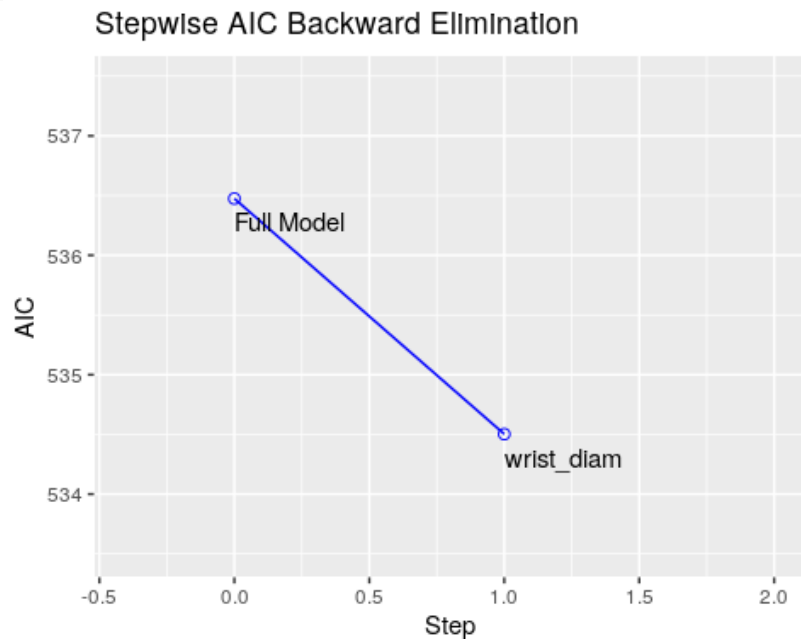
```
## -119.2782    1.3969    0.5941    1.2813    0.6440    0.8354
```

```
##   age   height  gender
```

```
## -0.1478    0.3806   -7.6488
```

#plot AIC vs step of backward elimination

```
plot(bd.back)
```



#calculate backward elimination model using MASS::stepAIC

```
step_backward = stepAIC(bd.lm, direction = "backward")
```

```
## Start: AIC=227.98
```

```
## weight ~ chest_diam + chest_depth + ankle_diam + waist_girth +
```

```
##   wrist_girth + wrist_diam + age + height + gender
```

```
##
```

```
##           Df Sum of Sq    RSS    AIC
```

```
## - wrist_diam  1    0.19   741.12  226.01
```

```
## <none>         740.93   227.98
```

```
## - wrist_girth  1   27.56   768.49  229.93
```

```
## - ankle_diam  1   59.81   800.75  234.37
```

```
## - chest_depth  1   64.42   805.35  234.99
```

```
## - age         1  162.71   903.64  247.42
```

```
## - chest_diam  1  322.59  1063.52  265.02
```

```

## - gender      1  350.30      1091.23 267.80
## - height      1  486.54      1227.47 280.50
## - waist_girth 1 1163.30      1904.23 327.93
##
## Step: AIC=226.01
## weight ~ chest_diam + chest_depth + ankle_diam + waist_girth +
##   wrist_girth + age + height + gender
##
##           Df      Sum of Sq      RSS      AIC
## <none>          741.12      226.01
## - wrist_girth  1       36.54      777.66 229.21
## - chest_depth  1       64.37      805.49 233.01
## - ankle_diam   1       65.56      806.68 233.17
## - age          1      163.73      904.85 245.57
## - chest_diam   1      328.81     1069.93 263.67
## - gender       1      351.14     1092.26 265.90
## - height       1      486.38     1227.50 278.51
## - waist_girth  1     1215.83     1956.95 328.88

#details of model
summary(step_backward)
##
## Call:
## lm(formula = weight ~ chest_diam + chest_depth + ankle_diam +
##   waist_girth + wrist_girth + age + height + gender, data = bd)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.5112  -1.7170  0.0759    1.4250   6.8222
##
## Coefficients:
##              Estimate      Std. Error    t value    Pr(>|t|)
## (Intercept)  -119.27818      6.79419    -17.556 < 2e-16 ***
## chest_diam    1.39688      0.21077     6.627 1.81e-09 ***
## chest_depth   0.59405      0.20259     2.932 0.00418 **
## ankle_diam    1.28130      0.43298     2.959 0.00386 **
## waist_girth   0.64395      0.05053    12.744 < 2e-16 ***
## wrist_girth   0.83541      0.37813     2.209 0.02946 *
## age          -0.14779      0.03160     -4.677 9.24e-06 ***
## height        0.38058      0.04722     8.060 1.78e-12 ***
## gender       -7.64878      1.11682     -6.849 6.36e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.736 on 99 degrees of freedom
## Multiple R-squared:  0.9678, Adjusted R-squared:  0.9652
## F-statistic: 371.7 on 8 and 99 DF, p-value: < 2.2e-16

#ANOVA of model
step_backward$anova
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## weight ~ chest_diam + chest_depth + ankle_diam + waist_girth +
##   wrist_girth + wrist_diam + age + height + gender
##
## Final Model:
## weight ~ chest_diam + chest_depth + ankle_diam + waist_girth +
##   wrist_girth + age + height + gender
##
## ##           Step           Df      Deviance      Resid. Df      Resid. Dev      AIC
## ##      1              98      740.9312      227.9839
## ## 2 - wrist_diam    1      0.1921794      99      741.1234      226.0119

```


The final model calculated by backward elimination using OLSRR::ols_step_backward_aic is given by the equation:

$$\text{weight} = -119.2782 + 1.3969(\text{chest_diam}) + 0.5941(\text{chest_depth}) + 1.2813(\text{ankle_diam}) + 0.6440(\text{waist_girth}) + 0.8354(\text{wrist_girth}) - 0.1478(\text{age}) + 0.3806(\text{height}) - 7.6488(\text{gender})$$

This is the same as that calculated by backward elimination with MASS::stepAIC. This is also the same as that calculated by forward selection with OSLRR::ols_step_forward_aic.

2C.

#fit all possible regression models

bd.all = ols_step_all_possible(bd.lm)

bd.all

	Index	N	Predictors	R-Square	Adj. R-Square	Mallow's Cp
4	1	1	waist_girth	0.8285356	0.8269180	417.648929
1	2	1	chest_diam	0.8049210	0.8030806	489.492049
2	3	1	chest_depth	0.7171416	0.7144732	756.544656
3	4	1	ankle_diam	0.6763765	0.6733234	880.565142
5	5	1	wrist_girth	0.6538421	0.6505765	949.121757
8	6	1	height	0.6481209	0.6448013	966.527599
6	7	1	wrist_diam	0.6439702	0.6406114	979.155309
9	8	1	gender	0.5379359	0.5335768	1301.745153
7	9	1	age	0.1583909	0.1504512	2456.441263
34	10	2	waist_girth height	0.9174120	0.9158389	149.258844
12	11	2	chest_diam waist_girth	0.8908871	0.8888088	229.955943
25	12	2	ankle_diam waist_girth	0.8833744	0.8811529	252.812021
31	13	2	waist_girth wrist_girth	0.8765049	0.8741526	273.711148
10	14	2	chest_diam chest_depth	0.8706237	0.8681594	291.603521
32	15	2	waist_girth wrist_diam	0.8567145	0.8539852	333.919913
19	16	2	chest_depth waist_girth	0.8506084	0.8477628	352.496612
16	17	2	chest_diam height	0.8492376	0.8463659	356.667079
11	18	2	chest_diam ankle_diam	0.8465629	0.8436403	364.804333
33	19	2	waist_girth age	0.8456397	0.8426995	367.612906
35	20	2	waist_girth gender	0.8317010	0.8284953	410.018826
13	21	2	chest_diam wrist_girth	0.8283602	0.8250909	420.182488
14	22	2	chest_diam wrist_diam	0.8278896	0.8246113	421.614444
23	23	2	chest_depth height	0.8235375	0.8201763	434.854723
15	24	2	chest_diam age	0.8050297	0.8013160	491.161320
17	25	2	chest_diam gender	0.8049210	0.8012052	491.491983
18	26	2	chest_depth ankle_diam	0.7864137	0.7823454	547.797024
21	27	2	chest_depth wrist_diam	0.7855686	0.7814842	550.368227
20	28	2	chest_depth wrist_girth	0.7741367	0.7698345	585.147737
41	29	2	wrist_diam height	0.7654901	0.7610233	611.453212
29	30	2	ankle_diam height	0.7491479	0.7443698	661.171331
38	31	2	wrist_girth height	0.7474135	0.7426023	666.448164
24	32	2	chest_depth gender	0.7402606	0.7353132	688.209555
27	33	2	ankle_diam wrist_diam	0.7320764	0.7269731	713.108357
26	34	2	ankle_diam wrist_girth	0.7300732	0.7249317	719.202866
22	35	2	chest_depth age	0.7216916	0.7163905	744.702329
45	36	2	height gender	0.7084730	0.7029201	784.917496
36	37	2	wrist_girth wrist_diam	0.7018849	0.6962065	804.960446
30	38	2	ankle_diam gender	0.6984320	0.6926879	815.465214
42	39	2	wrist_diam gender	0.6794899	0.6733850	873.093075
28	40	2	ankle_diam age	0.6788782	0.6727616	874.954095
39	41	2	wrist_girth gender	0.6747190	0.6685232	887.607607
43	42	2	age height	0.6647213	0.6583350	918.024019
37	43	2	wrist_girth age	0.6556133	0.6490535	945.733404
40	44	2	wrist_diam age	0.6440550	0.6372751	980.897273
44	45	2	age gender	0.5384088	0.5296166	1302.306519
117	46	3	waist_girth age height	0.9337240	0.9318121	101.632702
62	47	3	chest_diam waist_girth height	0.9309804	0.9289894	109.979598
119	48	3	waist_girth height gender	0.9229523	0.9207297	134.403586
98	49	3	ankle_diam waist_girth height	0.9228973	0.9206731	134.570959
112	50	3	waist_girth wrist_girth height	0.9224027	0.9201643	136.075621
83	51	3	chest_depth waist_girth height	0.9207834	0.9184983	141.002008
115	52	3	waist_girth wrist_diam height	0.9198223	0.9175095	143.925913
53	53	3	chest_diam ankle_diam waist_girth	0.9101826	0.9075917	173.253103
61	54	3	chest_diam waist_girth age	0.9038720	0.9010991	192.451759
97	55	3	ankle_diam waist_girth age	0.9032383	0.9004471	194.379718
59	56	3	chest_diam waist_girth wrist_girth	0.9020358	0.8992099	198.038111

47	57	3	chest_diam chest_depth waist_girth	0.9018337	0.8990019	198.653092
111	58	3	waist_girth wrist_girth age	0.8983821	0.8954508	209.153820
63	59	3	chest_diam waist_girth gender	0.8973232	0.8943614	212.375276
60	60	3	chest_diam waist_girth wrist_diam	0.8952254	0.8922031	218.757355
51	61	3	chest_diam chest_depth height	0.8947332	0.8916967	220.254771
95	62	3	ankle_diam waist_girth wrist_girth	0.8919153	0.8887975	228.827728
99	63	3	ankle_diam waist_girth gender	0.8884033	0.8851842	239.512455
74	64	3	chest_depth ankle_diam waist_girth	0.8859786	0.8826895	246.889303
96	65	3	ankle_diam waist_girth wrist_diam	0.8852017	0.8818902	249.252729
113	66	3	waist_girth wrist_girth gender	0.8826589	0.8792741	256.988716
46	67	3	chest_diam chest_depth ankle_diam	0.8801531	0.8766959	264.612344
80	68	3	chest_depth waist_girth wrist_girth	0.8795321	0.8760570	266.501554
114	69	3	waist_girth wrist_diam age	0.8795228	0.8760475	266.529762
52	70	3	chest_diam chest_depth gender	0.8791380	0.8756516	267.700486
50	71	3	chest_diam chest_depth age	0.8780673	0.8745501	270.957733
110	72	3	waist_girth wrist_girth wrist_diam	0.8773480	0.8738100	273.146111
49	73	3	chest_diam chest_depth wrist_diam	0.8749145	0.8713062	280.549761
82	74	3	chest_depth waist_girth age	0.8747128	0.8710988	281.163269
48	75	3	chest_diam chest_depth wrist_girth	0.8726475	0.8689739	287.446641
81	76	3	chest_depth waist_girth wrist_diam	0.8679082	0.8640979	301.865075
57	77	3	chest_diam ankle_diam height	0.8636659	0.8597332	314.771480
69	78	3	chest_diam wrist_diam height	0.8596690	0.8556210	326.931224
116	79	3	waist_girth wrist_diam gender	0.8570095	0.8528848	335.022384
66	80	3	chest_diam wrist_girth height	0.8556656	0.8515022	339.110781
58	81	3	chest_diam ankle_diam gender	0.8545798	0.8503850	342.414293
118	82	3	waist_girth age gender	0.8544821	0.8502844	342.711615
73	83	3	chest_diam height gender	0.8515085	0.8472251	351.758012
84	84	3	chest_depth waist_girth gender	0.8507874	0.8464831	353.952078
55	85	3	chest_diam ankle_diam wrist_diam	0.8497970	0.8454642	356.964993
71	86	3	chest_diam age height	0.8492422	0.8448934	358.653002
54	87	3	chest_diam ankle_diam wrist_girth	0.8491558	0.8448045	358.915812
56	88	3	chest_diam ankle_diam age	0.8471190	0.8427090	365.112357
90	89	3	chest_depth wrist_diam height	0.8445742	0.8400907	372.854524
78	90	3	chest_depth ankle_diam height	0.8341539	0.8293699	404.556372
64	91	3	chest_diam wrist_girth wrist_diam	0.8340926	0.8293068	404.742932
67	92	3	chest_diam wrist_girth gender	0.8334751	0.8286715	406.621424
87	93	3	chest_depth wrist_girth height	0.8321789	0.8273379	410.564804
70	94	3	chest_diam wrist_diam gender	0.8306205	0.8257345	415.306073
68	95	3	chest_diam wrist_diam age	0.8287887	0.8238499	420.879004
65	96	3	chest_diam wrist_girth age	0.8286850	0.8237432	421.194587
92	97	3	chest_depth age height	0.8273246	0.8223436	425.333260
94	98	3	chest_depth height gender	0.8242095	0.8191387	434.810195
76	99	3	chest_depth ankle_diam wrist_diam	0.8061516	0.8005598	489.748202
72	100	3	chest_diam age gender	0.8050502	0.7994267	493.098928
75	101	3	chest_depth ankle_diam wrist_girth	0.7987932	0.7929892	512.134617
89	102	3	chest_depth wrist_diam age	0.7975824	0.7917434	515.818431
85	103	3	chest_depth wrist_girth wrist_diam	0.7938355	0.7878884	527.217685
77	104	3	chest_depth ankle_diam age	0.7918665	0.7858626	533.208111
79	105	3	chest_depth ankle_diam gender	0.7873465	0.7812123	546.959178
91	106	3	chest_depth wrist_diam gender	0.7866919	0.7805388	548.950673
105	107	3	ankle_diam wrist_diam height	0.7854868	0.7792989	552.617014
86	108	3	chest_depth wrist_girth age	0.7805573	0.7742272	567.614279
121	109	3	wrist_girth wrist_diam height	0.7768537	0.7704168	578.881757
88	110	3	chest_depth wrist_girth gender	0.7751372	0.7686508	584.103683
102	111	3	ankle_diam wrist_girth height	0.7741678	0.7676534	587.053031
128	112	3	wrist_diam height gender	0.7703598	0.7637355	598.638261
126	113	3	wrist_diam age height	0.7655048	0.7587405	613.408749
109	114	3	ankle_diam height gender	0.7571439	0.7501385	638.844981
93	115	3	chest_depth age gender	0.7541138	0.7470210	648.063553
125	116	3	wrist_girth height gender	0.7527511	0.7456189	652.209443
107	117	3	ankle_diam age height	0.7510369	0.7438553	657.424488
123	118	3	wrist_girth age height	0.7486551	0.7414048	664.670647
100	119	3	ankle_diam wrist_girth wrist_diam	0.7468260	0.7395229	670.235531
106	120	3	ankle_diam wrist_diam gender	0.7366560	0.7290596	701.175714
103	121	3	ankle_diam wrist_girth gender	0.7326199	0.7249070	713.454884
104	122	3	ankle_diam wrist_diam age	0.7322273	0.7245031	714.649212
101	123	3	ankle_diam wrist_girth age	0.7301435	0.7223591	720.988967
122	124	3	wrist_girth wrist_diam gender	0.7100766	0.7017135	782.038646
129	125	3	age height gender	0.7085955	0.7001896	786.544665
120	126	3	wrist_girth wrist_diam age	0.7019484	0.6933507	806.767414
108	127	3	ankle_diam age gender	0.6985786	0.6898838	817.019204
127	128	3	wrist_diam age gender	0.6830985	0.6739571	864.114696

124	129	3	wrist_girth age gender	0.6749694	0.6655935	888.845867
175	130	4	chest_diam waist_girth height gender	0.9472124	0.9451624	62.596596
173	131	4	chest_diam waist_girth age height	0.9452664	0.9431409	68.516842
244	132	4	waist_girth wrist_girth age height	0.9406773	0.9383735	82.478372
228	133	4	ankle_diam waist_girth age height	0.9404305	0.9381171	83.229343
208	134	4	chest_depth waist_girth age height	0.9401391	0.9378144	84.115910
247	135	4	waist_girth wrist_diam age height	0.9381249	0.9357220	90.243617
246	136	4	waist_girth wrist_girth height gender	0.9359698	0.9334832	96.799999
250	137	4	waist_girth age height gender	0.9352096	0.9326935	99.112844
230	138	4	ankle_diam waist_girth height gender	0.9344082	0.9318610	101.550899
139	139	4	chest_diam chest_depth waist_girth height	0.9339305	0.9313647	103.004288
154	140	4	chest_diam ankle_diam waist_girth height	0.9335766	0.9309970	104.081127
168	141	4	chest_diam waist_girth wrist_girth height	0.9320814	0.9294438	108.629859
171	142	4	chest_diam waist_girth wrist_diam height	0.9312378	0.9285674	111.196328
155	143	4	chest_diam ankle_diam waist_girth gender	0.9298356	0.9271107	115.462402
249	144	4	waist_girth wrist_diam height gender	0.9286979	0.9259289	118.923643
210	145	4	chest_depth waist_girth height gender	0.9283333	0.9255502	120.032654
153	146	4	chest_diam ankle_diam waist_girth age	0.9259672	0.9230921	127.231357
223	147	4	ankle_diam waist_girth wrist_girth height	0.9245900	0.9216614	131.421107
189	148	4	chest_depth ankle_diam waist_girth height	0.9241587	0.9212134	132.733280
203	149	4	chest_depth waist_girth wrist_girth height	0.9236359	0.9206703	134.323724
226	150	4	ankle_diam waist_girth wrist_diam height	0.9232356	0.9202544	135.541741
242	151	4	waist_girth wrist_girth wrist_diam height	0.9225010	0.9194913	137.776626
206	152	4	chest_depth waist_girth wrist_diam height	0.9223510	0.9193355	138.232822
169	153	4	chest_diam waist_girth wrist_girth gender	0.9198639	0.9167518	145.799498
138	154	4	chest_diam chest_depth waist_girth age	0.9196452	0.9165246	146.464716
167	155	4	chest_diam waist_girth wrist_girth age	0.9186272	0.9154671	149.561883
222	156	4	ankle_diam waist_girth wrist_girth age	0.9135541	0.9101970	164.995839
140	157	4	chest_diam chest_depth waist_girth gender	0.9134897	0.9101300	165.191803
130	158	4	chest_diam chest_depth ankle_diam waist_girth	0.9129739	0.9095942	166.761028
151	159	4	chest_diam ankle_diam waist_girth wrist_girth	0.9116785	0.9082485	170.701977
170	160	4	chest_diam waist_girth wrist_diam age	0.9111467	0.9076961	172.319943
152	161	4	chest_diam ankle_diam waist_girth wrist_diam	0.9101848	0.9066969	175.246141
150	162	4	chest_diam chest_depth height gender	0.9086425	0.9050947	179.938333
188	163	4	chest_depth ankle_diam waist_girth age	0.9085431	0.9049914	180.240717
225	164	4	ankle_diam waist_girth wrist_diam age	0.9066693	0.9030448	185.941544
136	165	4	chest_diam chest_depth waist_girth wrist_girth	0.9063656	0.9027293	186.865446
174	166	4	chest_diam waist_girth age gender	0.9057679	0.9021084	188.683883
172	167	4	chest_diam waist_girth wrist_diam gender	0.9055568	0.9018891	189.326038
229	168	4	ankle_diam waist_girth age gender	0.9043117	0.9005956	193.114209
224	169	4	ankle_diam waist_girth wrist_girth gender	0.9042515	0.9005331	193.297268
202	170	4	chest_depth waist_girth wrist_girth age	0.9040541	0.9003281	193.897703
137	171	4	chest_diam chest_depth waist_girth wrist_diam	0.9037092	0.8999697	194.947225
166	172	4	chest_diam waist_girth wrist_girth wrist_diam	0.9020753	0.8982724	199.917787
148	173	4	chest_diam chest_depth age height	0.9009742	0.8971285	203.267866
241	174	4	waist_girth wrist_girth wrist_diam age	0.9001373	0.8962591	205.814081
245	175	4	waist_girth wrist_girth age gender	0.9000211	0.8961384	206.167450
135	176	4	chest_diam chest_depth ankle_diam gender	0.8962280	0.8921980	217.707288
146	177	4	chest_diam chest_depth wrist_diam height	0.8961331	0.8920995	217.995873
134	178	4	chest_diam chest_depth ankle_diam height	0.8960793	0.8920436	218.159566
205	179	4	chest_depth waist_girth wrist_diam age	0.8953673	0.8913039	220.325872
143	180	4	chest_diam chest_depth wrist_girth height	0.8947458	0.8906582	222.216710
186	181	4	chest_depth ankle_diam waist_girth wrist_girth	0.8927167	0.8885504	228.389623
221	182	4	ankle_diam waist_girth wrist_girth wrist_diam	0.8919218	0.8877245	230.808221
227	183	4	ankle_diam waist_girth wrist_diam gender	0.8917891	0.8875868	231.211753
190	184	4	chest_depth ankle_diam waist_girth gender	0.8917539	0.8875502	231.318941
133	185	4	chest_diam chest_depth ankle_diam age	0.8876482	0.8832851	243.809607
187	186	4	chest_depth ankle_diam waist_girth wrist_diam	0.8876276	0.8832637	243.872311
147	187	4	chest_diam chest_depth wrist_diam gender	0.8871963	0.8828155	245.184625
204	188	4	chest_depth waist_girth wrist_girth gender	0.8861848	0.8817648	248.261792
144	189	4	chest_diam chest_depth wrist_girth gender	0.8854300	0.8809807	250.558129
145	190	4	chest_diam chest_depth wrist_diam age	0.8844265	0.8799383	253.611012
243	191	4	waist_girth wrist_girth wrist_diam gender	0.8839860	0.8794807	254.951163
149	192	4	chest_diam chest_depth age gender	0.8826401	0.8780824	259.045956
132	193	4	chest_diam chest_depth ankle_diam wrist_diam	0.8809379	0.8763142	264.224443
201	194	4	chest_depth waist_girth wrist_girth wrist_diam	0.8804938	0.8758528	265.575696
142	195	4	chest_diam chest_depth wrist_diam age	0.8803567	0.8757103	265.992815
131	196	4	chest_diam chest_depth ankle_diam wrist_girth	0.8801683	0.8755146	266.565992
248	197	4	waist_girth wrist_diam age gender	0.8799008	0.8752368	267.379686
209	198	4	chest_depth waist_girth age gender	0.8772834	0.8725178	275.342585
141	199	4	chest_diam chest_depth wrist_girth wrist_diam	0.8750800	0.8702287	282.046146
165	200	4	chest_diam ankle_diam height gender	0.8727357	0.8677934	289.178232

207	201	4	chest_depth waist_girth wrist_diam gender	0.8694316	0.8643610	299.230305
161	202	4	chest_diam ankle_diam wrist_diam height	0.8665706	0.8613888	307.934596
184	203	4	chest_diam wrist_diam height gender	0.8661354	0.8609368	309.258426
158	204	4	chest_diam ankle_diam wrist_girth height	0.8645465	0.8592862	314.092305
163	205	4	chest_diam ankle_diam age height	0.8639907	0.8587088	315.783226
181	206	4	chest_diam wrist_girth height gender	0.8627415	0.8574111	319.583716
159	207	4	chest_diam ankle_diam wrist_girth gender	0.8606305	0.8552181	326.006108
177	208	4	chest_diam wrist_girth wrist_diam height	0.8604725	0.8550539	326.486938
182	209	4	chest_diam wrist_diam age height	0.8602988	0.8548736	327.015147
162	210	4	chest_diam ankle_diam wrist_diam gender	0.8597500	0.8543034	328.684759
179	211	4	chest_diam wrist_girth age height	0.8558267	0.8502278	340.620742
164	212	4	chest_diam ankle_diam age gender	0.8547090	0.8490667	344.021065
217	213	4	chest_depth wrist_diam age height	0.8524397	0.8467092	350.925274
185	214	4	chest_diam age height gender	0.8520804	0.8463359	352.018244
160	215	4	chest_diam ankle_diam wrist_diam age	0.8511054	0.8453231	354.984589
156	216	4	chest_diam ankle_diam wrist_girth wrist_diam	0.8506300	0.8448292	356.430806
157	217	4	chest_diam ankle_diam wrist_girth age	0.8500308	0.8442068	358.253748
196	218	4	chest_depth ankle_diam wrist_diam height	0.8465745	0.8406162	368.768967
219	219	4	chest_depth wrist_diam height gender	0.8454741	0.8394731	372.116763
212	220	4	chest_depth wrist_girth wrist_diam height	0.8447352	0.8387055	374.364655
178	221	4	chest_diam wrist_girth wrist_diam gender	0.8404698	0.8342745	387.341231
198	222	4	chest_depth ankle_diam age height	0.8384787	0.8322060	393.398989
193	223	4	chest_depth ankle_diam wrist_girth height	0.8373428	0.8310260	396.854760
214	224	4	chest_depth wrist_girth age height	0.8368332	0.8304966	398.405130
176	225	4	chest_diam wrist_girth wrist_diam age	0.8351860	0.8287854	403.416379
200	226	4	chest_depth ankle_diam height gender	0.8342477	0.8278107	406.271043
180	227	4	chest_diam wrist_girth age gender	0.8335626	0.8270990	408.355278
216	228	4	chest_depth wrist_girth height gender	0.8323731	0.8258634	411.973982
183	229	4	chest_diam wrist_diam age gender	0.8307683	0.8241961	416.856527
220	230	4	chest_depth age height gender	0.8297193	0.8231065	420.047735
195	231	4	chest_depth ankle_diam wrist_diam age	0.8160058	0.8088604	461.768540
191	232	4	chest_depth ankle_diam wrist_girth wrist_diam	0.8084673	0.8010291	484.703097
197	233	4	chest_depth ankle_diam wrist_diam gender	0.8062418	0.7987172	491.473650
192	234	4	chest_depth ankle_diam wrist_girth age	0.8050621	0.7974917	495.062843
211	235	4	chest_depth wrist_girth wrist_diam age	0.8046449	0.7970583	496.332146
218	236	4	chest_depth wrist_diam age gender	0.8016272	0.7939234	505.512724
194	237	4	chest_depth ankle_diam wrist_girth gender	0.7988855	0.7910753	513.853852
199	238	4	chest_depth ankle_diam age gender	0.7951731	0.7872187	525.148203
213	239	4	chest_depth wrist_girth wrist_diam gender	0.7938508	0.7858450	529.171237
232	240	4	ankle_diam wrist_girth wrist_diam height	0.7899803	0.7818242	540.946328
239	241	4	ankle_diam wrist_diam height gender	0.7862211	0.7779190	552.383014
237	242	4	ankle_diam wrist_diam age height	0.7855323	0.7772034	554.478685
215	243	4	chest_depth wrist_girth age gender	0.7841529	0.7757705	558.675247
253	244	4	wrist_girth wrist_diam height gender	0.7780328	0.7694127	577.294508
251	245	4	wrist_girth wrist_diam age height	0.7768680	0.7682026	580.838251
236	246	4	ankle_diam wrist_girth height gender	0.7749229	0.7661820	586.755871
234	247	4	ankle_diam wrist_girth age height	0.7743936	0.7656322	588.365994
255	248	4	wrist_diam age height gender	0.7709040	0.7620070	598.982593
240	249	4	ankle_diam age height gender	0.7571906	0.7477611	640.703176
254	250	4	wrist_girth age height gender	0.7527957	0.7431956	654.073589
233	251	4	ankle_diam wrist_girth wrist_diam gender	0.7477762	0.7379811	669.344613
231	252	4	ankle_diam wrist_girth wrist_diam age	0.7471366	0.7373167	671.290463
238	253	4	ankle_diam wrist_diam age gender	0.7381407	0.7279714	698.658748
235	254	4	ankle_diam wrist_girth age gender	0.7327500	0.7223714	715.058936
252	255	4	wrist_girth wrist_diam age gender	0.7119058	0.7007177	778.473603
300	256	5	chest_diam ankle_diam waist_girth height gender	0.9559948	0.9538377	37.877800
316	257	5	chest_diam waist_girth wrist_girth height gender	0.9541234	0.9518746	43.571115
320	258	5	chest_diam waist_girth age height gender	0.9536440	0.9513716	45.029696
280	259	5	chest_diam chest_depth waist_girth height gender	0.9536013	0.9513269	45.159415
278	260	5	chest_diam chest_depth waist_girth age height	0.9509397	0.9485348	53.256849
319	261	5	chest_diam waist_girth wrist_diam height gender	0.9493286	0.9468447	58.158549
298	262	5	chest_diam ankle_diam waist_girth age height	0.9489104	0.9464060	59.430612
314	263	5	chest_diam waist_girth wrist_girth age height	0.9476734	0.9451084	63.193931
379	264	5	waist_girth wrist_girth age height gender	0.9473583	0.9447778	64.152649
317	265	5	chest_diam waist_girth wrist_diam age height	0.9465265	0.9439052	66.683430
370	266	5	ankle_diam waist_girth age height gender	0.9455727	0.9429046	69.585212
349	267	5	chest_depth waist_girth wrist_girth age height	0.9436443	0.9408818	75.451874
333	268	5	chest_depth ankle_diam waist_girth age height	0.9436156	0.9408516	75.539291
352	269	5	chest_depth waist_girth wrist_diam age height	0.9431101	0.9403214	77.077038
364	270	5	ankle_diam waist_girth wrist_girth age height	0.9430942	0.9403047	77.125495
355	271	5	chest_depth waist_girth age height gender	0.9427368	0.9399298	78.212784
380	272	5	waist_girth wrist_diam age height gender	0.9417226	0.9388659	81.298172

367	273	5	ankle_diam waist_girth wrist_diam age height	0.9415866	0.9387232	81.712004
376	274	5	waist_girth wrist_girth wrist_diam age height	0.9411801	0.9382968	82.948679
366	275	5	ankle_diam waist_girth wrist_girth height gender	0.9408913	0.9379938	83.827524
351	276	5	chest_depth waist_girth wrist_girth height gender	0.9375481	0.9344867	93.998517
299	277	5	chest_diam ankle_diam waist_girth age gender	0.9367053	0.9336026	96.562546
335	278	5	chest_depth ankle_diam waist_girth height gender	0.9363740	0.9332551	97.570491
378	279	5	waist_girth wrist_girth wrist_diam height gender	0.9363354	0.9332146	97.687718
294	280	5	chest_diam ankle_diam waist_girth wrist_girth gender	0.9359954	0.9328579	98.722337
369	281	5	ankle_diam waist_girth wrist_diam height gender	0.9359104	0.9327688	98.980768
259	282	5	chest_diam chest_depth ankle_diam waist_girth height	0.9351477	0.9319687	101.301122
260	283	5	chest_diam chest_depth ankle_diam waist_girth gender	0.9344350	0.9312211	103.469395
273	284	5	chest_diam chest_depth waist_girth wrist_girth height	0.9341309	0.9309020	104.394718
276	285	5	chest_diam chest_depth waist_girth wrist_diam height	0.9339767	0.9307403	104.863697
293	286	5	chest_diam ankle_diam waist_girth wrist_girth height	0.9337397	0.9304917	105.584781
296	287	5	chest_diam ankle_diam waist_girth wrist_diam height	0.9336021	0.9303473	106.003569
354	288	5	chest_depth waist_girth wrist_diam height gender	0.9328506	0.9295590	108.289682
312	289	5	chest_diam waist_girth wrist_girth wrist_diam height	0.9320856	0.9287565	110.616969
258	290	5	chest_diam chest_depth ankle_diam waist_girth age	0.9311948	0.9278220	113.327156
297	291	5	chest_diam ankle_diam waist_girth wrist_diam gender	0.9301826	0.9267601	116.406740
292	292	5	chest_diam ankle_diam waist_girth wrist_girth age	0.9286660	0.9251693	121.020464
315	293	5	chest_diam waist_girth wrist_girth age gender	0.9280641	0.9245378	122.851766
295	294	5	chest_diam ankle_diam waist_girth wrist_diam age	0.9263364	0.9227254	128.108060
274	295	5	chest_diam chest_depth waist_girth wrist_girth gender	0.9257224	0.9220813	129.976046
272	296	5	chest_diam chest_depth waist_girth wrist_girth age	0.9254553	0.9218011	130.788591
328	297	5	chest_depth ankle_diam waist_girth wrist_girth height	0.9252788	0.9216160	131.325405
362	298	5	ankle_diam waist_girth wrist_girth wrist_diam height	0.9245916	0.9208951	133.416181
331	299	5	chest_depth ankle_diam waist_girth wrist_diam height	0.9244552	0.9207520	133.831171
279	300	5	chest_diam chest_depth waist_girth age gender	0.9244026	0.9206968	133.991363
347	301	5	chest_depth waist_girth wrist_girth wrist_diam height	0.9237677	0.9200308	135.922771
275	302	5	chest_diam chest_depth waist_girth wrist_diam age	0.9233484	0.9195909	137.198488
313	303	5	chest_diam waist_girth wrist_girth wrist_diam gender	0.9200384	0.9161187	147.268614
311	304	5	chest_diam waist_girth wrist_girth wrist_diam age	0.9190283	0.9150591	150.341605
365	305	5	ankle_diam waist_girth wrist_girth age gender	0.9189293	0.9149552	150.642779
277	306	5	chest_diam chest_depth waist_girth wrist_diam gender	0.9183426	0.9143398	152.427563
327	307	5	chest_depth ankle_diam waist_girth wrist_girth age	0.9159557	0.9118359	159.689243
318	308	5	chest_diam waist_girth wrist_diam age gender	0.9153577	0.9112086	161.508590
361	309	5	ankle_diam waist_girth wrist_girth wrist_diam age	0.9136713	0.9094395	166.639301
256	310	5	chest_diam chest_depth ankle_diam waist_girth wrist_girth	0.9136009	0.9093657	166.853271
270	311	5	chest_diam chest_depth ankle_diam height gender	0.9134468	0.9092040	167.322279
257	312	5	chest_diam chest_depth ankle_diam waist_girth wrist_diam	0.9129748	0.9087089	168.758183
289	313	5	chest_diam chest_depth wrist_diam height gender	0.9127383	0.9084608	169.477669
291	314	5	chest_diam ankle_diam waist_girth wrist_girth wrist_diam	0.9119768	0.9076620	171.794389
330	315	5	chest_depth ankle_diam waist_girth wrist_diam age	0.9117521	0.9074262	172.478026
290	316	5	chest_diam chest_depth age height gender	0.9103406	0.9059455	176.772325
334	317	5	chest_depth ankle_diam waist_girth age gender	0.9098944	0.9054774	178.129844
286	318	5	chest_diam chest_depth wrist_girth height gender	0.9097113	0.9052854	178.686774
368	319	5	ankle_diam waist_girth wrist_diam age gender	0.9085981	0.9041176	182.073596
271	320	5	chest_diam chest_depth waist_girth wrist_girth wrist_diam	0.9064300	0.9018433	188.669437
346	321	5	chest_depth waist_girth wrist_girth wrist_diam age	0.9061267	0.9015251	189.592177
350	322	5	chest_depth waist_girth wrist_girth age gender	0.9058179	0.9012011	190.531795
329	323	5	chest_depth ankle_diam waist_girth wrist_girth gender	0.9050667	0.9004131	192.817156
363	324	5	ankle_diam waist_girth wrist_girth wrist_diam gender	0.9042531	0.8995596	195.292423
287	325	5	chest_diam chest_depth wrist_diam age height	0.9035984	0.8988729	197.284088
268	326	5	chest_diam chest_depth ankle_diam age height	0.9024696	0.8976887	200.718407
377	327	5	waist_girth wrist_girth wrist_diam age gender	0.9020404	0.8972385	202.024092
284	328	5	chest_diam chest_depth wrist_girth age height	0.9009744	0.8961202	205.267309
269	329	5	chest_diam chest_depth ankle_diam age gender	0.8983219	0.8933376	213.337065
267	330	5	chest_diam chest_depth ankle_diam wrist_diam gender	0.8982606	0.8932734	213.523370
264	331	5	chest_diam chest_depth ankle_diam wrist_girth gender	0.8973923	0.8923625	216.165075
282	332	5	chest_diam chest_depth wrist_girth wrist_diam height	0.8967742	0.8917142	218.045430
266	333	5	chest_diam chest_depth ankle_diam wrist_diam height	0.8967353	0.8916733	218.163909
263	334	5	chest_diam chest_depth ankle_diam wrist_girth height	0.8963722	0.8912925	219.268422
353	335	5	chest_depth waist_girth wrist_diam age gender	0.8953745	0.8902458	222.303915
332	336	5	chest_depth ankle_diam waist_girth wrist_diam gender	0.8949785	0.8898303	223.508766
326	337	5	chest_depth ankle_diam waist_girth wrist_girth wrist_diam	0.8927168	0.8874578	230.389481
288	338	5	chest_diam chest_depth wrist_diam age gender	0.8916701	0.8863598	233.573944
265	339	5	chest_diam chest_depth ankle_diam wrist_diam age	0.8895076	0.8840913	240.152723
283	340	5	chest_diam chest_depth wrist_girth wrist_diam gender	0.8888946	0.8834483	242.017786
285	341	5	chest_diam chest_depth wrist_girth age gender	0.8882134	0.8827336	244.090299
348	342	5	chest_depth waist_girth wrist_girth wrist_diam gender	0.8876969	0.8821918	245.661708
262	343	5	chest_diam chest_depth ankle_diam wrist_girth age	0.8876962	0.8821911	245.663671
281	344	5	chest_diam chest_depth wrist_girth wrist_diam age	0.8844820	0.8788193	255.442434

261	345	5	chest_diam chest_depth ankle_diam wrist_girth wrist_diam	0.8810117	0.8751789	266.000164
309	346	5	chest_diam ankle_diam wrist_diam height gender	0.8775962	0.8715960	276.391120
306	347	5	chest_diam ankle_diam wrist_girth height gender	0.8759790	0.8698996	281.311007
310	348	5	chest_diam ankle_diam age height gender	0.8731362	0.8669174	289.959918
323	349	5	chest_diam wrist_girth wrist_diam height gender	0.8688731	0.8624453	302.929500
307	350	5	chest_diam ankle_diam wrist_diam age height	0.8674665	0.8609697	307.208940
302	351	5	chest_diam ankle_diam wrist_girth wrist_diam height	0.8666132	0.8600746	309.804980
325	352	5	chest_diam wrist_diam age height gender	0.8661564	0.8595954	311.194696
304	353	5	chest_diam ankle_diam wrist_girth age height	0.8650233	0.8584068	314.641859
324	354	5	chest_diam wrist_girth age height gender	0.8631631	0.8564554	320.301165
303	355	5	chest_diam ankle_diam wrist_girth wrist_diam gender	0.8625130	0.8557735	322.278937
321	356	5	chest_diam wrist_girth wrist_diam age height	0.8611754	0.8543703	326.348341
305	357	5	chest_diam ankle_diam wrist_girth age gender	0.8607373	0.8539107	327.681233
308	358	5	chest_diam ankle_diam wrist_diam age gender	0.8597501	0.8528751	330.684580
342	359	5	chest_depth ankle_diam wrist_diam age height	0.8541318	0.8469814	347.777251
356	360	5	chest_depth wrist_girth wrist_diam age height	0.8525263	0.8452972	352.661529
360	361	5	chest_depth wrist_diam age height gender	0.8524608	0.8452285	352.860802
301	362	5	chest_diam ankle_diam wrist_girth wrist_diam age	0.8519940	0.8447388	354.281154
344	363	5	chest_depth ankle_diam wrist_diam height gender	0.8482178	0.8407775	365.769451
337	364	5	chest_depth ankle_diam wrist_girth wrist_diam height	0.8465866	0.8390664	370.732025
358	365	5	chest_depth wrist_girth wrist_diam height gender	0.8459361	0.8383840	372.711040
339	366	5	chest_depth ankle_diam wrist_girth age height	0.8421323	0.8343937	384.283363
322	367	5	chest_diam wrist_girth wrist_diam age gender	0.8404898	0.8326706	389.280609
345	368	5	chest_depth ankle_diam age height gender	0.8386524	0.8307432	394.870350
341	369	5	chest_depth ankle_diam wrist_girth height gender	0.8382176	0.8302871	396.193242
359	370	5	chest_depth wrist_girth age height gender	0.8369172	0.8289230	400.149474
336	371	5	chest_depth ankle_diam wrist_girth wrist_diam age	0.8179291	0.8090041	457.917271
343	372	5	chest_depth ankle_diam wrist_diam age gender	0.8164168	0.8074176	462.518181
338	373	5	chest_depth ankle_diam wrist_girth wrist_diam gender	0.8089835	0.7996199	485.132672
357	374	5	chest_depth wrist_girth wrist_diam age gender	0.8059385	0.7964257	494.396531
340	375	5	chest_depth ankle_diam wrist_girth age gender	0.8053631	0.7958221	496.147099
371	376	5	ankle_diam wrist_girth wrist_diam age height	0.7900842	0.7797942	542.630283
373	377	5	ankle_diam wrist_girth wrist_diam height gender	0.7900486	0.7797568	542.738752
375	378	5	ankle_diam wrist_diam age height gender	0.7865359	0.7760720	553.425286
381	379	5	wrist_girth wrist_diam age height gender	0.7783401	0.7674744	578.359553
374	380	5	ankle_diam wrist_girth age height gender	0.7749470	0.7639150	588.682468
372	381	5	ankle_diam wrist_girth wrist_diam age gender	0.7487136	0.7363956	668.492805
426	382	6	chest_diam ankle_diam waist_girth age height gender	0.9619753	0.9597164	21.683061
411	383	6	chest_diam chest_depth waist_girth age height gender	0.9616112	0.9593307	22.790771
435	384	6	chest_diam waist_girth wrist_girth age height gender	0.9606679	0.9583313	25.660737
391	385	6	chest_diam chest_depth ankle_diam waist_girth height gender	0.9589994	0.9565637	30.736825
422	386	6	chest_diam ankle_diam waist_girth wrist_girth height gender	0.9588253	0.9563793	31.266369
407	387	6	chest_diam chest_depth waist_girth wrist_girth height gender	0.9572266	0.9546856	36.130191
436	388	6	chest_diam waist_girth wrist_diam age height gender	0.9564813	0.9538961	38.397598
425	389	6	chest_diam ankle_diam waist_girth wrist_diam height gender	0.9561595	0.9535551	39.376607
410	390	6	chest_diam chest_depth waist_girth wrist_diam height gender	0.9548632	0.9521818	43.320404
434	391	6	chest_diam waist_girth wrist_girth wrist_diam height gender	0.9541490	0.9514252	45.493183
389	392	6	chest_diam chest_depth ankle_diam waist_girth age height	0.9523803	0.9495514	50.874235
462	393	6	ankle_diam waist_girth wrist_girth age height gender	0.9517339	0.9488666	52.840668
408	394	6	chest_diam chest_depth waist_girth wrist_diam age height	0.9515403	0.9486615	53.429652
405	395	6	chest_diam chest_depth waist_girth wrist_girth age height	0.9515099	0.9486293	53.522191
456	396	6	chest_depth waist_girth wrist_girth age height gender	0.9503265	0.9473756	57.122547
420	397	6	chest_diam ankle_diam waist_girth wrist_girth age height	0.9495957	0.9466014	59.345876
447	398	6	chest_depth ankle_diam waist_girth age height gender	0.9490798	0.9460549	60.915281
423	399	6	chest_diam ankle_diam waist_girth wrist_diam age height	0.9490646	0.9460387	60.961584
465	400	6	waist_girth wrist_girth wrist_diam age height gender	0.9480858	0.9450018	63.939417
432	401	6	chest_diam waist_girth wrist_girth wrist_diam age height	0.9478028	0.9447020	64.800408
457	402	6	chest_depth waist_girth wrist_diam age height gender	0.9477494	0.9446454	64.962895
463	403	6	ankle_diam waist_girth wrist_diam age height gender	0.9476775	0.9445692	65.181695
441	404	6	chest_depth ankle_diam waist_girth wrist_girth age height	0.9451672	0.9419098	72.818803
444	405	6	chest_depth ankle_diam waist_girth wrist_diam age height	0.9447120	0.9414276	74.203477
453	406	6	chest_depth waist_girth wrist_girth wrist_diam age height	0.9443006	0.9409918	75.455104
459	407	6	ankle_diam waist_girth wrist_girth wrist_diam age height	0.9432163	0.9398430	78.754083
421	408	6	chest_diam ankle_diam waist_girth wrist_girth age gender	0.9430629	0.9396805	79.220715
390	409	6	chest_diam chest_depth ankle_diam waist_girth age gender	0.9428548	0.9394601	79.853742
443	410	6	chest_depth ankle_diam waist_girth wrist_girth height gender	0.9415880	0.9381180	83.707834
461	411	6	ankle_diam waist_girth wrist_girth wrist_diam height gender	0.9409014	0.9373906	85.796619
385	412	6	chest_diam chest_depth ankle_diam waist_girth wrist_girth gender	0.9384088	0.9347499	93.379871
455	413	6	chest_depth waist_girth wrist_girth wrist_diam height gender	0.9379905	0.9343068	94.652523
446	414	6	chest_depth ankle_diam waist_girth wrist_diam height gender	0.9378127	0.9341184	95.193585
424	415	6	chest_diam ankle_diam waist_girth wrist_diam age gender	0.9374616	0.9337464	96.261725
419	416	6	chest_diam ankle_diam waist_girth wrist_girth wrist_diam gender	0.9362641	0.9324778	99.904814

406	417	6	chest_diam chest_depth waist_girth wrist_girth age gender	0.9355719	0.9317445	102.010731
387	418	6	chest_diam chest_depth ankle_diam waist_girth wrist_diam height	0.9351936	0.9313437	103.161478
384	419	6	chest_diam chest_depth ankle_diam waist_girth wrist_girth height	0.9351530	0.9313007	103.285199
388	420	6	chest_diam chest_depth ankle_diam waist_girth wrist_diam gender	0.9347001	0.9308209	104.662866
403	421	6	chest_diam chest_depth waist_girth wrist_girth wrist_diam height	0.9341312	0.9302182	106.393658
418	422	6	chest_diam ankle_diam waist_girth wrist_girth wrist_diam height	0.9338807	0.9299528	107.155878
383	423	6	chest_diam chest_depth ankle_diam waist_girth wrist_girth age	0.9323487	0.9283298	111.816647
386	424	6	chest_diam chest_depth ankle_diam waist_girth wrist_diam age	0.9314936	0.9274240	114.418024
409	425	6	chest_diam chest_depth waist_girth wrist_diam age gender	0.9301860	0.9260386	118.396425
417	426	6	chest_diam ankle_diam waist_girth wrist_girth wrist_diam age	0.9286789	0.9244420	122.981240
433	427	6	chest_diam waist_girth wrist_girth wrist_diam age gender	0.9285412	0.9242962	123.400199
402	428	6	chest_diam chest_depth waist_girth wrist_girth wrist_diam age	0.9260013	0.9216054	131.127324
404	429	6	chest_diam chest_depth waist_girth wrist_girth wrist_diam gender	0.9259644	0.9215662	131.239754
439	430	6	chest_depth ankle_diam waist_girth wrist_girth wrist_diam height	0.9252805	0.9208417	133.320432
442	431	6	chest_depth ankle_diam waist_girth wrist_girth age gender	0.9210715	0.9163827	146.125413
460	432	6	ankle_diam waist_girth wrist_girth wrist_diam age gender	0.9190622	0.9142540	152.238418
438	433	6	chest_depth ankle_diam waist_girth wrist_girth wrist_diam age	0.9162236	0.9112468	160.874394
400	434	6	chest_diam chest_depth ankle_diam wrist_diam height gender	0.9153162	0.9102855	163.634858
416	435	6	chest_diam chest_depth wrist_diam age height gender	0.9150371	0.9099898	164.483918
401	436	6	chest_diam chest_depth ankle_diam age height gender	0.9147793	0.9097167	165.268306
445	437	6	chest_depth ankle_diam waist_girth wrist_diam age gender	0.9140137	0.9089056	167.597621
382	438	6	chest_diam chest_depth ankle_diam waist_girth wrist_girth wrist_diam	0.9137838	0.9086620	168.297022
397	439	6	chest_diam chest_depth ankle_diam wrist_girth height gender	0.9136230	0.9084917	168.786143
414	440	6	chest_diam chest_depth wrist_girth wrist_diam height gender	0.9127508	0.9075677	171.439532
415	441	6	chest_diam chest_depth wrist_girth age height gender	0.9112662	0.9059948	175.956420
454	442	6	chest_depth waist_girth wrist_girth wrist_diam age gender	0.9081930	0.9027391	185.306038
440	443	6	chest_depth ankle_diam waist_girth wrist_girth wrist_diam gender	0.9050831	0.8994445	194.767124
412	444	6	chest_diam chest_depth wrist_girth wrist_diam age height	0.9044128	0.8987344	196.806456
398	445	6	chest_diam chest_depth ankle_diam wrist_diam age height	0.9040432	0.8983428	197.930947
395	446	6	chest_diam chest_depth ankle_diam wrist_girth age height	0.9026541	0.8968712	202.157067
399	447	6	chest_diam chest_depth ankle_diam wrist_diam age gender	0.9009780	0.8950955	207.256188
396	448	6	chest_diam chest_depth ankle_diam wrist_girth age gender	0.8993411	0.8933614	212.236146
394	449	6	chest_diam chest_depth ankle_diam wrist_girth wrist_diam gender	0.8985664	0.8925407	214.593078
393	450	6	chest_diam chest_depth ankle_diam wrist_girth wrist_diam height	0.8976797	0.8916013	217.290722
413	451	6	chest_diam chest_depth wrist_girth wrist_diam age gender	0.8926998	0.8863255	232.441267
392	452	6	chest_diam chest_depth ankle_diam wrist_girth wrist_diam age	0.8896570	0.8831020	241.698308
429	453	6	chest_diam ankle_diam wrist_girth wrist_diam height gender	0.8785242	0.8713078	275.567939
431	454	6	chest_diam ankle_diam wrist_diam age height gender	0.8776732	0.8704063	278.156778
430	455	6	chest_diam ankle_diam wrist_girth age height gender	0.8763271	0.8689802	282.252159
437	456	6	chest_diam wrist_girth wrist_diam age height gender	0.8689303	0.8611440	304.755403
427	457	6	chest_diam ankle_diam wrist_girth wrist_diam age height	0.8675239	0.8596540	309.034308
428	458	6	chest_diam ankle_diam wrist_girth wrist_diam age gender	0.8625216	0.8543546	324.252754
452	459	6	chest_depth ankle_diam wrist_diam age height gender	0.8543495	0.8456970	349.114934
448	460	6	chest_depth ankle_diam wrist_girth wrist_diam age height	0.8541325	0.8454671	349.775083
458	461	6	chest_depth wrist_girth wrist_diam age height gender	0.8525848	0.8438274	354.483749
450	462	6	chest_depth ankle_diam wrist_girth wrist_diam height gender	0.8483950	0.8393887	367.230435
451	463	6	chest_depth ankle_diam wrist_girth age height gender	0.8421778	0.8328022	386.145147
449	464	6	chest_depth ankle_diam wrist_girth wrist_diam age gender	0.8179957	0.8071836	459.714654
464	465	6	ankle_diam wrist_girth wrist_diam age height gender	0.7902488	0.7777883	544.129622
475	466	7	chest_diam chest_depth ankle_diam waist_girth age height gender	0.9661907	0.9638241	10.858469
490	467	7	chest_diam ankle_diam waist_girth wrist_girth age height gender	0.9649811	0.9625297	14.538722
484	468	7	chest_diam chest_depth waist_girth wrist_girth age height gender	0.9649292	0.9624742	14.696532
485	469	7	chest_diam chest_depth waist_girth wrist_diam age height gender	0.9633998	0.9608378	19.349453
491	470	7	chest_diam ankle_diam waist_girth wrist_diam age height gender	0.9624247	0.9597944	22.315947
493	471	7	chest_diam waist_girth wrist_girth wrist_diam age height gender	0.9608357	0.9580942	27.150180
471	472	7	chest_diam chest_depth ankle_diam waist_girth wrist_girth height gender	0.9606613	0.9579076	27.680759
474	473	7	chest_diam chest_depth ankle_diam waist_girth wrist_diam height gender	0.9591224	0.9562610	32.362638
489	474	7	chest_diam ankle_diam waist_girth wrist_girth wrist_diam height gender	0.9589438	0.9560699	32.905884
483	475	7	chest_diam chest_depth waist_girth wrist_girth wrist_diam height gender	0.9572765	0.9542859	37.978343
497	476	7	chest_depth ankle_diam waist_girth wrist_girth age height gender	0.9534843	0.9502283	49.515337
469	477	7	chest_diam chest_depth ankle_diam waist_girth wrist_girth age height	0.9525136	0.9491895	52.468728
472	478	7	chest_diam chest_depth ankle_diam waist_girth wrist_diam age height	0.9525029	0.9491781	52.501094
501	479	7	ankle_diam waist_girth wrist_girth wrist_diam age height gender	0.9518770	0.9485083	54.405528
481	480	7	chest_diam chest_depth waist_girth wrist_girth wrist_diam age height	0.9517143	0.9483343	54.900394
500	481	7	chest_depth waist_girth wrist_girth wrist_diam age height gender	0.9512374	0.9478240	56.351288
498	482	7	chest_depth ankle_diam waist_girth wrist_diam age height gender	0.9511312	0.9477104	56.674282
487	483	7	chest_diam ankle_diam waist_girth wrist_girth wrist_diam age height	0.9495972	0.9460690	61.341146
470	484	7	chest_diam chest_depth ankle_diam waist_girth wrist_girth age gender	0.9466340	0.9428983	70.356356
494	485	7	chest_depth ankle_diam waist_girth wrist_girth wrist_diam age height	0.9454297	0.9416098	74.020156
473	486	7	chest_diam chest_depth ankle_diam waist_girth wrist_diam age gender	0.9435183	0.9395646	79.835176
488	487	7	chest_diam ankle_diam waist_girth wrist_girth wrist_diam age gender	0.9431155	0.9391335	81.060773
496	488	7	chest_depth ankle_diam waist_girth wrist_girth wrist_diam height gender	0.9416214	0.9375348	85.606317

468	489	7	chest_diam chest_depth ankle_diam waist_girth wrist_girth wrist_diam gender	0.9385569	0.9342559	94.929437
482	490	7	chest_diam chest_depth waist_girth wrist_girth wrist_diam age gender	0.9362179	0.9317531	102.045402
467	491	7	chest_diam chest_depth ankle_diam waist_girth wrist_girth wrist_diam height	0.9352286	0.9306946	105.054981
466	492	7	chest_diam chest_depth ankle_diam waist_girth wrist_girth wrist_diam age	0.9323553	0.9276202	113.796605
495	493	7	chest_depth ankle_diam waist_girth wrist_girth wrist_diam age gender	0.9213523	0.9158469	147.271254
480	494	7	chest_diam chest_depth ankle_diam wrist_diam age height gender	0.9171323	0.9113315	160.109890
478	495	7	chest_diam chest_depth ankle_diam wrist_girth wrist_diam height gender	0.9153375	0.9094111	165.570056
486	496	7	chest_diam chest_depth wrist_girth wrist_diam age height gender	0.9150414	0.9090943	166.470838
479	497	7	chest_diam chest_depth ankle_diam wrist_girth age height gender	0.9149208	0.9089653	166.837743
476	498	7	chest_diam chest_depth ankle_diam wrist_girth wrist_diam age height	0.9051513	0.8985119	196.559666
477	499	7	chest_diam chest_depth ankle_diam wrist_girth wrist_diam age gender	0.9011156	0.8941937	208.837638
492	500	7	chest_diam ankle_diam wrist_girth wrist_diam age height gender	0.8786304	0.8701345	277.244827
499	501	7	chest_depth ankle_diam wrist_girth wrist_diam age height gender	0.8543722	0.8441782	351.045977
505	502	8	chest_diam chest_depth ankle_diam waist_girth wrist_girth age height gender	0.9677793	0.9651757	8.025419
506	503	8	chest_diam chest_depth ankle_diam waist_girth wrist_diam age height gender	0.9665896	0.9638898	11.644982
508	504	8	chest_diam chest_depth waist_girth wrist_girth wrist_diam age height gender	0.9651872	0.9623741	15.911414
509	505	8	chest_diam ankle_diam waist_girth wrist_girth wrist_diam age height gender	0.9649869	0.9621576	16.520862
504	506	8	chest_diam chest_depth ankle_diam waist_girth wrist_girth wrist_diam height gender	0.9607138	0.9575392	29.520997
510	507	8	chest_depth ankle_diam waist_girth wrist_girth wrist_diam age height gender	0.9537630	0.9500267	50.667587
502	508	8	chest_diam chest_depth ankle_diam waist_girth wrist_girth wrist_diam age height	0.9525581	0.9487244	54.333206
503	509	8	chest_diam chest_depth ankle_diam waist_girth wrist_girth wrist_diam age gender	0.9466354	0.9423231	72.352051
507	510	8	chest_diam chest_depth ankle_diam wrist_girth wrist_diam age height gender	0.9172127	0.9105229	161.865037
511	511	9	chest_diam chest_depth ankle_diam waist_girth wrist_girth wrist_diam age height gender	0.9677877	0.9648294	10.000000

```
plot(bd.all)
```

```
## Warning: It is deprecated to specify `guide = FALSE` to remove a guide. Please
## use `guide = "none"` instead.
```

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## use `guide = "none"` instead.
```

```
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## use `guide = "none"` instead.
```

```
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## use `guide = "none"` instead.
```

```
## Warning: It is deprecated to specify `guide = FALSE` to remove a guide. Please
## use `guide = "none"` instead.
```

```
## Warning: It is deprecated to specify `guide = FALSE` to remove a guide. Please
```



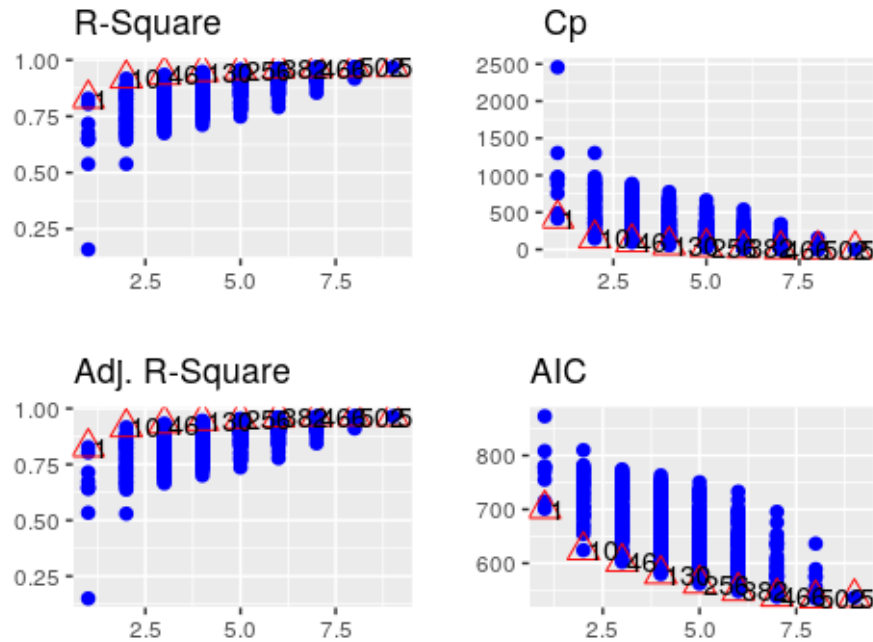
```
## use `guide = "none"` instead.

## Warning: It is deprecated to specify `guide = FALSE` to remove a guide. Please
## use `guide = "none"` instead.

## Warning: It is deprecated to specify `guide = FALSE` to remove a guide. Please
## use `guide = "none"` instead.

## Warning: It is deprecated to specify `guide = FALSE` to remove a guide. Please
## use `guide = "none"` instead.

## Warning: It is deprecated to specify `guide = FALSE` to remove a guide. Please
## use `guide = "none"` instead.
```



#check models with 5 variables

```
body_5 <- subset(bd.all,n==5)
summary(body_5)
##   mindex      n predictors    rsquare
## Min. :256.0 Min. :5 Length:126   Min. :0.7487
## 1st Qu.:287.2 1st Qu.:5 Class :character 1st Qu.:0.8678
## Median :318.5 Median :5 Mode :character Median :0.9092
## Mean :318.5 Mean :5      Mean :0.8972
## 3rd Qu.:349.8 3rd Qu.:5      3rd Qu.:0.9334
## Max. :381.0 Max. :5      Max. :0.9560
##   adjr   predrsq    cp    aic
## Min. :0.7364 Min. :0.7125 Min. :37.88 Min. :562.2
## 1st Qu.:0.8613 1st Qu.:0.8523 1st Qu.:106.58 1st Qu.:606.9
## Median :0.9047 Median :0.8974 Median :180.38 Median :640.4
## Mean :0.8921 Mean :0.8843 Mean :216.81 Mean :644.4
## 3rd Qu.:0.9302 3rd Qu.:0.9254 3rd Qu.:306.14 3rd Qu.:681.0
## Max. :0.9538 Max. :0.9505 Max. :668.49 Max. :750.3
##   sbic    sbc    msepfpe
## Min. :253.3 Min. :580.9 Min. :1072 Min. :10.47
## 1st Qu.:294.4 1st Qu.:625.7 1st Qu.:1622 1st Qu.:15.85
## Median :325.9 Median :659.2 Median :2213 Median :21.62
## Mean :330.1 Mean :663.2 Mean :2505 Mean :24.47
## 3rd Qu.:364.6 3rd Qu.:699.7 3rd Qu.:3220 3rd Qu.:31.46
## Max. :432.1 Max. :769.1 Max. :6122 Max. :59.81
##   apc    hsp
## Min. :0.04918 Min. :0.09825
## 1st Qu.:0.07442 1st Qu.:0.14867
## Median :0.10153 Median :0.20283
## Mean :0.11492 Mean :0.22957
## 3rd Qu.:0.14773 3rd Qu.:0.29513
## Max. :0.28085 Max. :0.56105
```

#check models with 6 variables

```
body_6 <- subset(bd.all,n==6)
summary(body_6)
##   mindex      n predictors    rsquare
## Min. :382.0 Min. :6 Length:84   Min. :0.7902
## 1st Qu.:402.8 1st Qu.:6 Class:character 1st Qu.:0.9043
## Median:423.5 Median:6 Mode :character Median:0.9319
## Mean :423.5 Mean :6      Mean :0.9204
## 3rd Qu.:444.2 3rd Qu.:6      3rd Qu.:0.9477
## Max. :465.0 Max. :6      Max. :0.9620
##   adjr      predrsq      cp      aic
## Min. :0.7778 Min. :0.7553 Min. :21.68 Min. :548.4
## 1st Qu.:0.8986 1st Qu.:0.8905 1st Qu.: 65.13 1st Qu.:582.8
## Median:0.9279 Median:0.9235 Median:113.12 Median:611.3
## Mean :0.9156 Mean :0.9085 Mean :148.30 Mean :619.2
## 3rd Qu.:0.9446 3rd Qu.:0.9393 3rd Qu.:197.09 3rd Qu.:648.0
## Max. :0.9597 Max. :0.9564 Max. :544.13 Max. :732.8
##   sbic      sbc      msepfpe
## Min. :241.0 Min. :569.8 Min. :935.7 Min. :9.221
## 1st Qu.:271.6 1st Qu.:604.3 1st Qu.:1287.1 1st Qu.:12.684
## Median:297.6 Median:632.7 Median:1675.2 Median:16.509
## Mean :305.5 Mean :640.7 Mean :1959.8 Mean :19.313
## 3rd Qu.:332.0 3rd Qu.:669.5 3rd Qu.:2354.4 3rd Qu.:23.202
## Max. :413.3 Max. :754.3 Max. :5161.4 Max. :50.864
##   apc      hsp
## Min. :0.04330 Min. :0.0866
## 1st Qu.:0.05955 1st Qu.:0.1191
## Median:0.07752 Median:0.1550
## Mean :0.09068 Mean :0.1814
## 3rd Qu.:0.10894 3rd Qu.:0.2179
## Max. :0.23883 Max. :0.4777
```

#check models with 7 variables

```
body_7 <- subset(bd.all,n==7)
summary(body_7)
##   mindex      n predictors    rsquare
## Min. :466.0 Min. :7 Length:36   Min. :0.8544
## 1st Qu.:474.8 1st Qu.:7 Class:character 1st Qu.:0.9296
## Median:483.5 Median:7 Mode :character Median:0.9481
## Mean :483.5 Mean :7      Mean :0.9394
## 3rd Qu.:492.2 3rd Qu.:7      3rd Qu.:0.9577
## Max. :501.0 Max. :7      Max. :0.9662
##   adjr      predrsq      cp      aic
## Min. :0.8442 Min. :0.8269 Min. :10.86 Min. :537.7
## 1st Qu.:0.9247 1st Qu.:0.9187 1st Qu.: 36.71 1st Qu.:561.9
## Median:0.9445 Median:0.9398 Median: 65.85 Median:583.9
## Mean :0.9352 Mean :0.9288 Mean : 92.35 Mean :593.1
## 3rd Qu.:0.9547 3rd Qu.:0.9499 3rd Qu.:122.17 3rd Qu.:616.7
## Max. :0.9638 Max. :0.9601 Max. :351.05 Max. :695.4
##   sbic      sbc      msepfpe
## Min. :232.0 Min. :561.8 Min. :840.4 Min. :8.353
## 1st Qu.:252.8 1st Qu.:586.0 1st Qu.:1051.6 1st Qu.:10.452
## Median:272.2 Median:608.1 Median:1289.6 Median:12.818
## Mean :280.9 Mean :617.2 Mean :1506.2 Mean :14.970
## 3rd Qu.:301.8 3rd Qu.:640.8 3rd Qu.:1749.7 3rd Qu.:17.391
## Max. :375.7 Max. :719.6 Max. :3619.7 Max. :35.978
##   apc      hsp
## Min. :0.03922 Min. :0.07855
## 1st Qu.:0.04908 1st Qu.:0.09829
## Median:0.06019 Median:0.12055
## Mean :0.07029 Mean :0.14079
## 3rd Qu.:0.08166 3rd Qu.:0.16356
## Max. :0.16893 Max. :0.33835
```

#check models with 8 variables

```
body_8 <- subset(bd.all,n==8)
summary(body_8)
```

```

##      minindex      n predictors      rsquare      adjr
## Min. :.502 Min. :8 Length:9      Min. :0.9172 Min. :0.9105
## 1st Qu.:.504 1st Qu.:8 Class :character 1st Qu.:0.9526 1st Qu.:0.9487
## Median :.506 Median :8 Mode :character Median :0.9607 Median :0.9575
## Mean :.506 Mean :8      Mean :0.9550 Mean :0.9514
## 3rd Qu.:.508 3rd Qu.:8      3rd Qu.:0.9652 3rd Qu.:0.9624
## Max. :.510 Max. :8      Max. :0.9678 Max. :0.9652
## predrsq      cp      aic      sbic
## Min. :0.8994 Min. : 8.025 Min. :534.5 Min. :229.8
## 1st Qu.:0.9441 1st Qu.: 15.911 1st Qu.:542.9 1st Qu.:236.7
## Median :0.9525 Median : 29.521 Median :555.9 Median :247.7
## Mean :0.9460 Mean : 46.760 Mean :565.6 Mean :256.4
## 3rd Qu.:0.9580 3rd Qu.: 54.333 3rd Qu.:576.3 3rd Qu.:265.1
## Max. :0.9612 Max. :161.865 Max. :636.4 Max. :319.0
## sbc      msepfpe      apc
## Min. :.5613 Min. : 809.0 Min. : 8.110 Min. :0.03808
## 1st Qu.:.5697 1st Qu.: 874.1 1st Qu.: 8.762 1st Qu.:0.04114
## Median :.5827 Median : 986.5 Median : 9.888 Median :0.04643
## Mean :.5924 Mean :1128.7 Mean :11.315 Mean :0.05313
## 3rd Qu.:.6031 3rd Qu.:1191.2 3rd Qu.:11.941 3rd Qu.:0.05607
## Max. :.6632 Max. :2078.7 Max. :20.838 Max. :0.09784
## hsp
## Min. :0.07639
## 1st Qu.:0.08253
## Median :0.09314
## Mean :0.10657
## 3rd Qu.:0.11248
## Max. :0.19627

```

The best model predicting weight using adjusted R^2 value as a selection criteria, is the model using the eight predictors of chest_diam, chest_depth, ankle_diam, waist_girth, wrist_girth, age, height, and gender (adjusted $R^2=0.9651757$). However, the question specifically asks about the best models using 5, 6, and 7 predictors, which have lower adjusted R^2 values of 0.9538377, 0.9597164, and 0.9638241, respectively. All of the adjusted R^2 values of these models (5, 6, 7, and 8 predictor models) are close in terms of adjusted R^2 , and close to the models derived from forward selection and backward elimination (both also with 8 predictors) that had adjusted R^2 values of 0.9648 and 0.9652, respectively.

Question 3.

```
city = read.csv("hw3_city_temps.csv", header=T)
```

```
#fit linear regression model
```

```
city.lm = lm(High_F ~ Latitude, data=city)
```

```
summary(city.lm)
```

```
##
```

```
## Call:
```

```
## lm(formula = High_F ~ Latitude, data = city)
```

```
##
```

```
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max  
## -6.975    -4.153    -2.571     1.021    24.073
```

```
##
```

```
## Coefficients:
```

```
##           Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 133.3425    7.2663  18.35 < 2e-16 ***  
## Latitude   -2.2772    0.1932 -11.79 6.53e-16 ***
```

```
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
```

```
## Residual standard error: 6.773 on 49 degrees of freedom
```

```
## Multiple R-squared:  0.7393, Adjusted R-squared:  0.7339
```

```
## F-statistic: 138.9 on 1 and 49 DF, p-value: 6.526e-16
```

```
#RMSE
```

```
rss1 = c(crossprod(city.lm$residuals))
```

```
mse1 = rss1 / length(city.lm$residuals)
```

```
rmse1 = sqrt(mse1)
```

```
cat("RMSE: ", rmse1)
```

```
##RMSE: 6.638825
```

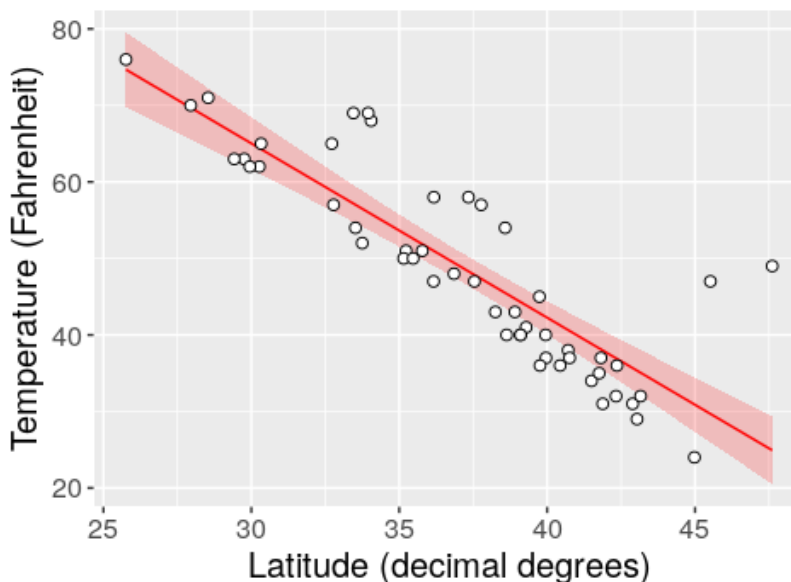
```
#scatter plot of High_F vs Latitude with linear model
```

```
ggplot(city, aes(Latitude, High_F)) + geom_smooth(method="lm", color='red', size=0.5, fill='red', alpha=0.2) + geom_point(aes(Latitude, High_F), shape=21, size=2, fill='white') + labs(x = "Latitude (decimal degrees)", y = "Temperature (Fahrenheit)") + theme(text = element_text(size = 15), plot.title=element_text(hjust=0.5)) + ggtitle("Average High January Temperature vs. Latitude")
```

```
## Warning: Duplicated aesthetics after name standardisation: colour
```

```
## `geom_smooth()` using formula 'y ~ x'
```

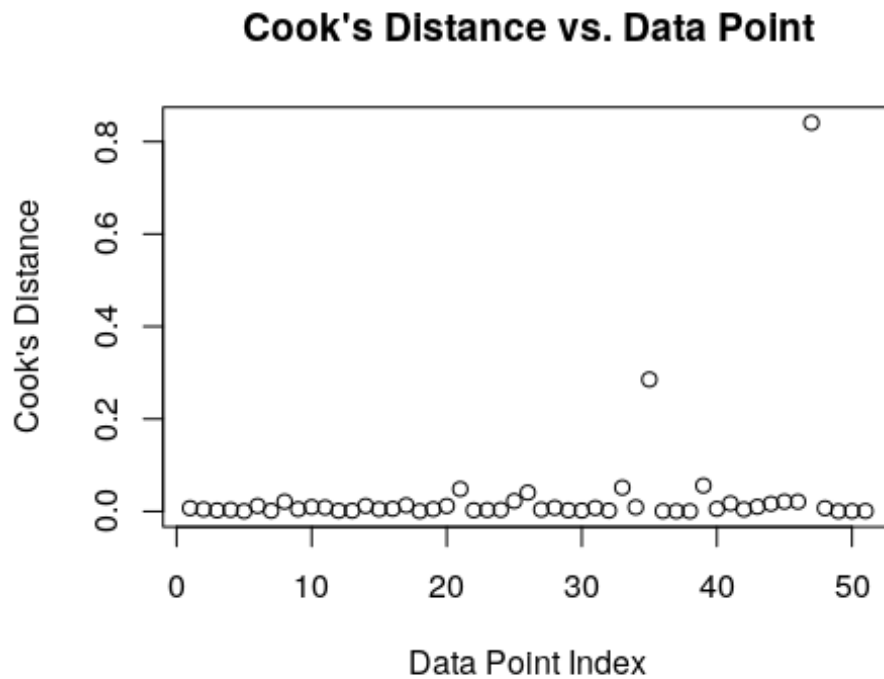
Average High January Temperature vs. Latitude



```
#Cook's distance to detect influential observations
```

```
cooks = cooks.distance(city.lm)
```

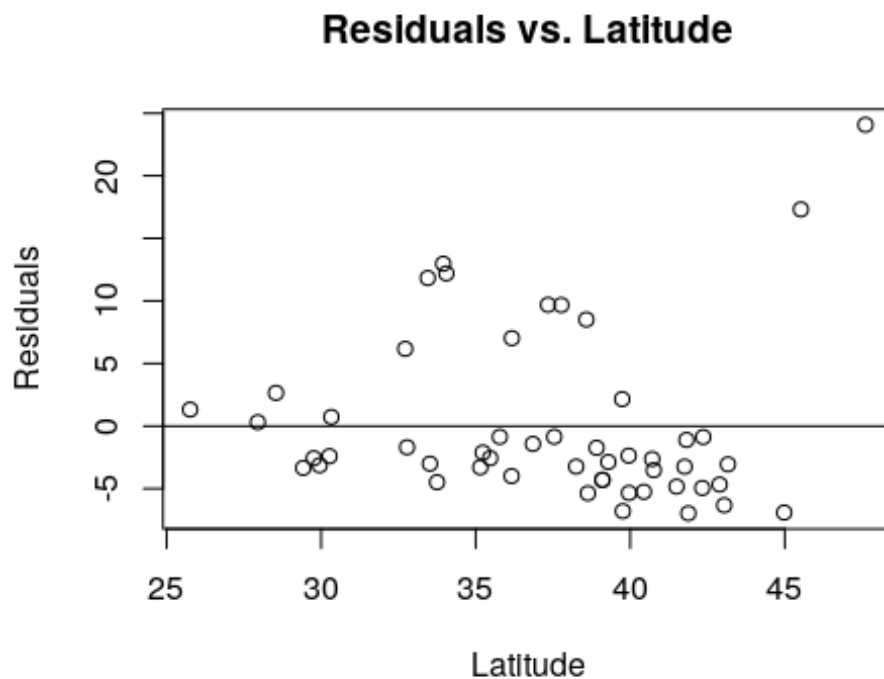
```
plot(cooks, ylab="Cook's Distance", xlab="Data Point Index", main="Cook's Distance vs. Data Point")
```



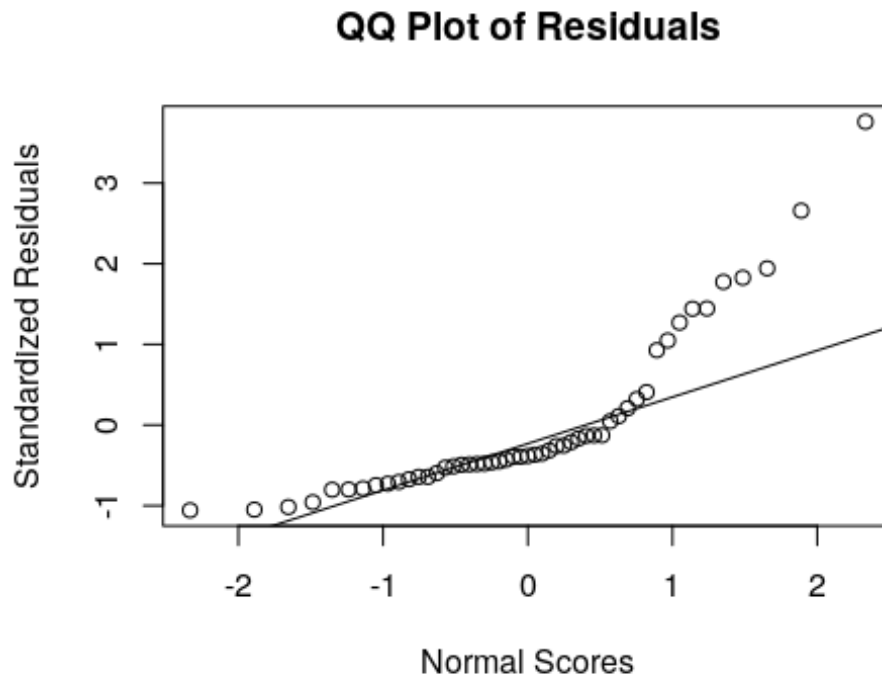
```
#residuals
```

```
city.res = resid(city.lm)
```

```
plot(city$Latitude, city.res,  
      ylab="Residuals", xlab="Latitude",  
      main="Residuals vs. Latitude")  
abline(0,0)
```



```
#QQ plot
city.stres = rstandard(city.lm)
qqnorm(city.stres,
  ylab="Standardized Residuals",
  xlab = "Normal Scores",
  main = "QQ Plot of Residuals")
qqline(city.stres)
```



3A. The linear regression model for predicting the highest average January temperature as a response of latitude is given by the general single linear regression equation:

$$y_i = \beta_0 + \beta_1 x_{1i} + e_i$$

y_i = response variable; average high January temperature of city in degrees Fahrenheit (High_F) for the i th observation

β_0 = y intercept; the value of the response variable when the predictor variable is 0

β_1 = regression coefficient for predictor variable Latitude

x_{1i} = predictor variable at i th observation; latitude of city in decimal degrees (Latitude) at i th observation

e_i = residual error; difference between observed value at i th observation and expected value (model value)

3B. The fitted linear regression model of average high January temperature as a response of latitude is given by the equation:

$$High_F = 133.3425 - 2.2772(Latitude)$$

$High_F$ = response variable at i th observation; average highest January temperature of city in Fahrenheit
 133.3425 = y-intercept; degrees Fahrenheit of average high January temperature of city at 0 degrees latitude, as predicted by regression model

-2.2772 = regression coefficient for predictor variable Latitude of regression model

$Latitude$ = latitude of city in decimal degrees at i th observation

The fitted regression shows a negative association between average high January temperature (High_F) and latitude (Latitude), where temperature decreases 2.2772 degrees Fahrenheit for every degree of latitude increase above/below the equator (Latitude=0 degrees). The model also shows that at the equator (Latitude=0 degrees), the predicted mean temperature would be 133 degrees Fahrenheit; however, this seems unrealistic and could be

explained by the dataset only consisting of selected cities in the United States and not close to the equator. The calculated coefficients of the y-intercept and slope are significant, as shown by their high t values (and low P values) of 18.35 ($< 2e-16$) and -11.79 ($6.53e-16$), respectively.

3C. The four assumptions for a least squares regression analysis are (1) mean linearity, where the average value of errors is 0 regardless of values of any predictors of the response, (2) homoscedasticity, where variance is equally distributed around 0 on residual plot, (3) independence, where errors are uncorrelated, and (4) error normality, where errors are normally distributed. Assumptions 1, 2, and 4 are not met according to the summary of the linear model, “Residuals vs Latitude” plot, and “QQ Plot of Residuals” plot, found above. The mean linearity deviates negatively from zero, as can be seen by the median of -2.571, the Q1 -4.153, and the Q3 of 1.021. Examination of the “Residuals vs. Latitude” plot shows that most of the data points lie below zero. Assumption 2 of homoscedasticity is also not met. The “Residuals vs Latitude” plot above, shows highly positive values in the middle between 30 and 40 degrees Latitude, and very highly positive data points above 45 degrees Latitude. However, negative residuals are approximately evenly distributed. Assumption 4 of error normality is also not satisfied. The median of -2.571, the Q1 -4.153, and the Q3 of 1.021 suggest a positively skewed dataset, the “Residuals vs Latitude” plot shows a positively skewed dataset, and the “QQ Plot of Residuals” clearly does not produce a straight line that would be suggestive of a normal distribution. Finally, assumption 3 does appear to be satisfied. Although the high January temperature does appear to respond to Latitude above the equator, the associated errors are not affected and therefore independent. Overall, the assumptions are not met and the data needs to be examined in more detail before moving forward.

Question 4.

4A. These two points have both an unusual y and unusual x, and can be classified as both outliers (unusual y) and influential points (unusual x). The y values of the two points are both well above where data would be predicted to occur at those latitudes. Additionally, the x values are beyond the rest of the dataset, giving these two points the most extreme x values (two most northern cities in the data set). We should also look at the Cook's Distance of each data point (plot above in question 3), which measures the change of parameter estimates if that specific data point (x_i) is removed. For these two points we see that Cook's D is ~ 0.3 and 0.8 for Portland, OR and Seattle, WA, respectively, and are well above the remaining datapoints that average around ~ 0.05 . Both points change the parameter estimates by a significant amount when removed.

4B.

```
#modified city_temps data without Seattle, WA and Portland, OR
city_2 = city[-c(35,47),]
```

```
#fit new linear regression model
```

```
city_2.lm = lm(High_F ~ Latitude, data = city_2)
summary(city_2.lm)
##
## Call:
## lm(formula = High_F ~ Latitude, data = city_2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.4109  -3.1086  -1.8758   0.2318  12.6632
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 146.8260    5.7478  25.55 <2e-16 ***
## Latitude   -2.6654    0.1545 -17.25 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.001 on 47 degrees of freedom
## Multiple R-squared:  0.8636, Adjusted R-squared:  0.8607
## F-statistic: 297.5 on 1 and 47 DF, p-value: < 2.2e-16
```

```
#new RMSE
```

```
rss2 = c(crossprod(city_2.lm$residuals))
mse2 = rss2 / length(city_2.lm$residuals)
rmse2 = sqrt(mse2)
cat("RMSE (new model): ", rmse2)
```

```
##RMSE (new model): 4.898205
```

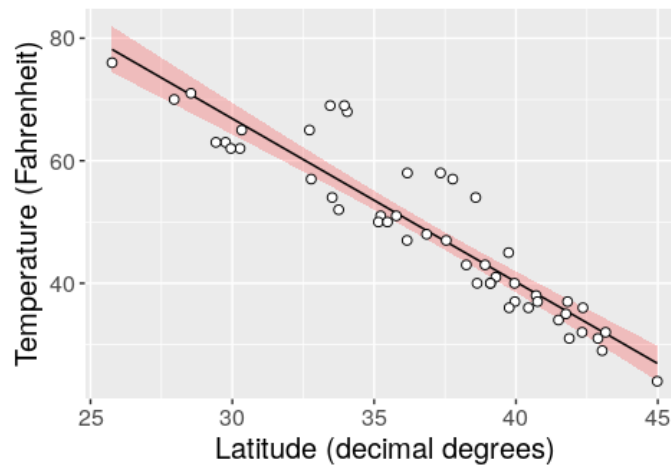
```
#scatter plot of High_F vs Latitude with linear model
```

```
ggplot(city_2, aes(High_F, Latitude)) + geom_smooth(method="lm", col=1, color='red', size=0.5, fill='red', alpha=0.2) +
geom_point(aes(High_F, Latitude), shape=21, size=2, fill='white') + labs(x = "Latitude (decimal degrees)", y = "Temperature (Fahrenheit)") +
theme(text = element_text(size = 15), plot.title=element_text(hjust=0.5), plot.subtitle=element_text(hjust = 0.5, face="italic", size=10)) +
ggtitle("Average High January Temperature vs. Latitude", subtitle=("(excluding Portland, OR and Seattle, WA)"))
```

```
## Warning: Duplicated aesthetics after name standardisation: colour
## `geom_smooth()` using formula 'y ~ x'
```

Average High January Temperature vs. Latitude

(excluding Portland, OR and Seattle, WA)



After refitting the linear regression to a modified dataset that excludes Portland, OR and Seattle, WA, we see a much better fit of the model, which can be seen by the comparison of several values:

	Original Model	New model (excluding Portland and Seattle)
F value	138.9 on 1 and 49 DF, p-value: 6.526e-16	297.5 on 1 and 47 DF, p-value: < 2.2e-16
Root MSE	6.638825	4.898205
R²	0.7393	0.8636
Adjusted R²	0.7339	0.8607
t value of predictor	-11.79	-17.25
P value of predictor	6.53e-16	<2e-16

The F value of the old model increase from 138.9 to 297.5 in the new model, and the associated P values decrease from 6.526e-16 to < 2.2e-16, respectively. The R² value of the old model increases from 0.7393 to 0.8636 in the new model. The adjusted R² value of the old model increases from 0.7339 to 0.8607 in the new model. The t value of the Latitude predictor variable increases from -11.79 in the old model to -17.25 in the new model, and the associated P value decreases from 6.53e-16 to <2e-16 in the new model. The root MSE value of the old model decreases from 6.638825 to 4.898205 in the new model.

All of these changes are expected with modifying a dataset to remove outliers and influential points, which result in a more accurate and precise model: (1) the F value of the overall model should increase, signaling a stronger significance of the model (and the associated P value decreases); (2) the R² value increases, which signals that the model accounts for more variation; (3) the adjusted R² value increases, which signals a better fit compared to the old model; (4) the t value of the predictor parameter estimate increases, which shows that the new regression is a better fit to the dataset (and the associated P value decreases); (5) and the RMSE decreases, which shows that the standard deviation of the residuals decreases and that the new model is a better fit to the observed data points.

Question 5.

#add indicator based on first letter of city name

#create new indicator variable

```
earlyind1 = c(substr(city$City,0, 1) < "M")
```

#create new dataset with new indicator variable earlyind1

```
city_3 = data.frame(city, earlyind = earlyind1)
```

#fit linear regression model

```
city_3.lm = lm(High_F~Latitude + earlyind, data = city_3)
```

```
summary(city_3.lm)
```

```
##
```

```
## Call:
```

```
## lm(formula = High_F ~ Latitude + earlyind, data = city_3)
```

```
##
```

```
## Residuals:
```

```
##   Min     1Q   Median     3Q      Max   
## -8.606 -4.223 -2.202   1.158  22.356
```

```
##
```

```
## Coefficients:
```

```
##              Estimate      Std. Error    t value      Pr(>|t|)      
## (Intercept)   134.5624         7.0777     19.012    < 2e-16 ***   
## Latitude      -2.2667         0.1876    -12.085    3.61e-16 ***   
## earlyindTRUE  -3.7319         1.8591     -2.007     0.0504 .
```

```
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
```

```
## Residual standard error: 6.573 on 48 degrees of freedom
```

```
## Multiple R-squared:  0.7594, Adjusted R-squared:  0.7494
```

```
## F-statistic: 75.77 on 2 and 48 DF, p-value: 1.409e-15
```

#f test for overall model

```
fcv5 = qf(p=0.05, df1=2, df2=48, lower.tail=F)
```

```
cat("F0.05,2,48 critical value for MLR: ", fcv5)
```

```
##F0.05,2,48 critical value for MLR: 3.190727
```

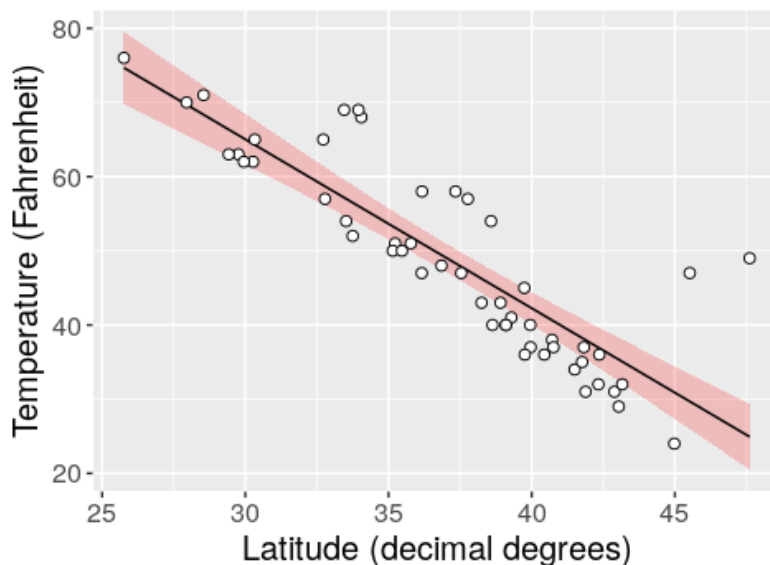
#scatter plot of High_F vs Latitude with linear model

```
ggplot(city_3, aes(High_F, Latitude)) + geom_smooth(method="lm", col=1, color='red', size=0.5, fill='red', alpha=0.2) +   
geom_point(aes(High_F, Latitude), shape=21, size=2, fill='white') + labs(x = "Latitude (decimal degrees)", y = "Temperature (Fahrenheit)") +   
theme(text = element_text(size = 15), plot.title=element_text(hjust=0.5), plot.subtitle=element_text(hjust = 0.5, face="italic", size=10)) +   
ggtitle("Average High January Temperature vs. Latitude", subtitle=("exluding Portland, OR and Seattle, WA"))
```

```
## Warning: Duplicated aesthetics after name standardisation: colour
```

```
## `geom_smooth()` using formula 'y ~ x'
```

Average High January Temperature vs. Latitude



5A. To test the significance of the overall fit of the regression model, we will use a right-tailed F test with a null hypothesis (H_0) of $B_1=B_2=0$, an alternative hypothesis (H_A) of $B_k \neq 0$ for some k (at least one predictor not equal to 0). We are not given a significance level, but I will assume a significance level of $\alpha=0.05$. If the F value of the model is beyond the F critical value, we will reject the null hypothesis. Otherwise we will fail to reject the null hypothesis.

Here see that the F value of the model is 75.77 and the $F_{0.05,2,48}$ critical value is 3.190727. The F value of the model is well beyond the critical value, and we reject the null hypothesis. We can conclude that at least one predictor is not equal to zero and that the overall fit of the MLR model relating average high January temperatures (response) to Latitude and first letter of the city's name (predictors) is significant.

The R^2 value for this MLR is 0.7594, which indicates that over 75% of the variance of the average high January temperature is explained by this model. For reference, the original model has an R^2 value of 0.7393 and an adjusted R^2 value of 0.7339, and this new MLR model has an adjusted R^2 of 0.7494.

5B. Again, we are not given a significance level criterion for assessing variable significance, but I will assume a significance level of $\alpha=0.05$. Within this context, the only significant variable is Latitude, which has a P value of $3.61e-16$ that is well below the significance level of 0.05 assumed here. This implies that Latitude, while keeping the other predictor constant, significantly changes the mean response of average high January temperature. More specifically, we can be 95% confident that the average high January temperature decreases by -2.2667 degrees Fahrenheit for each degree that Latitude increases above the equator (or decreases below the equator if using extreme extrapolation).

On the other hand, the other predictor, `earlyindTRUE`, has a P value of 0.0504, higher than our assumed significance level 0.05. This implies that the beginning letter of each city does not significantly change the mean response of average high January temperature, while keeping Latitude constant. If we used a larger significance level, say $\alpha=0.1$, then this parameter estimate would be significant and we could be 90% confident that first letters of city names (first half of the alphabet vs. second half of alphabet), do affect the predicted average high January temperature.

5C. Statistically, the beginning letter of city names could be considered useful for predicting average high January temperatures, IF a reasonably high confidence level were used for the assessment. However, this makes absolutely no sense, as the physical effects of climate are in no way related to arbitrary city names.

If the city name indicator variable were used and did show significance with your chose level of significance for the study, it would be to an underlying, confounding variable. In this example, we see that that both groups have similar mean latitudes, where A to M is 37.4 degrees and N to Z is 37.1 degrees. However, we can also see that cities located near oceans (which greatly affects seasonal temperatures) is unevenly distributed, with the A to M group having five cities near an ocean, and the N to Z group having 13 cities near the ocean. Other examples could include very large sample sizes and/or low sample variance, both of which, could result in statistical significance, but no real practical significance.

To reiterate, this makes zero practical sense, but may mistakenly make statistical sense in some cases.