Part 4

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```
fat <- read.csv("~/Documents/[STAT420]Project1/Bodyfat.csv")

#Backwards
modelALL = lm(bodyfat ~ ., data = fat)
backwardsAIC = step(modelALL, direction = "backward") #Picks model with predictors Density Age and Ches
```

```
## Start:  AIC=136.71
## bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen +
##     Hip + Thigh + Knee + Ankle + Biceps + Forearm + Wrist
##
##           Df Sum of Sq    RSS    AIC
## - Wrist    1       0.0  384.9 134.71
## - Knee     1       0.0  384.9 134.71
## - Height   1       0.1  385.0 134.79
## - Thigh    1       0.2  385.1 134.87
## - Neck     1       0.3  385.1 134.89
## - Hip      1       0.3  385.2 134.91
## - Forearm  1       0.5  385.4 135.05
## - Abdomen  1       0.6  385.4 135.07
## - Weight   1       0.6  385.5 135.13
## - Chest    1       1.4  386.2 135.59
## - Biceps   1       1.9  386.8 135.95
## - Ankle    1       2.8  387.6 136.50
## - Age      1       2.8  387.6 136.52
## <none>                  384.9 136.71
## - Density  1    4026.6 4411.4 749.36
##
## Step:  AIC=134.71
## bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen +
##     Hip + Thigh + Knee + Ankle + Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Knee     1       0.0  384.9 132.71
## - Height   1       0.1  385.0 132.79
## - Thigh    1       0.2  385.1 132.87
## - Neck     1       0.3  385.1 132.89
## - Hip      1       0.3  385.2 132.92
## - Abdomen  1       0.6  385.4 133.07
## - Forearm  1       0.6  385.4 133.08
## - Weight   1       0.7  385.5 133.14
## - Chest    1       1.3  386.2 133.59
## - Biceps   1       1.9  386.8 133.95
```

```
## - Ankle    1       2.9  387.7 134.59
## <none>                  384.9 134.71
## - Age      1       3.2  388.1 134.82
## - Density  1    4196.7 4581.6 756.89
##
## Step:  AIC=132.71
## bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen +
##     Hip + Thigh + Ankle + Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Height   1       0.1  385.0 130.80
## - Neck     1       0.3  385.1 130.89
## - Thigh    1       0.3  385.2 130.90
## - Hip      1       0.3  385.2 130.92
## - Forearm  1       0.6  385.4 131.08
## - Abdomen  1       0.6  385.4 131.08
## - Weight   1       0.7  385.5 131.16
## - Chest    1       1.4  386.2 131.61
## - Biceps   1       1.9  386.8 131.95
## - Ankle    1       3.1  387.9 132.70
## <none>                  384.9 132.71
## - Age      1       3.5  388.3 132.97
## - Density  1    4197.2 4582.1 754.92
##
## Step:  AIC=130.8
## bodyfat ~ Density + Age + Weight + Neck + Chest + Abdomen + Hip +
##     Thigh + Ankle + Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Thigh    1       0.2  385.2 128.95
## - Neck     1       0.3  385.3 128.97
## - Hip      1       0.5  385.5 129.10
## - Weight   1       0.5  385.5 129.16
## - Forearm  1       0.6  385.5 129.16
## - Abdomen  1       0.6  385.6 129.19
## - Chest    1       1.7  386.7 129.89
## - Biceps   1       1.9  386.8 130.01
## - Ankle    1       3.0  388.0 130.77
## <none>                  385.0 130.80
## - Age      1       3.6  388.6 131.14
## - Density  1    4217.5 4602.5 754.04
##
## Step:  AIC=128.95
## bodyfat ~ Density + Age + Weight + Neck + Chest + Abdomen + Hip +
##     Ankle + Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Hip      1       0.3  385.5 127.13
## - Neck     1       0.3  385.5 127.15
## - Weight   1       0.5  385.7 127.28
## - Forearm  1       0.5  385.8 127.31
## - Abdomen  1       0.6  385.8 127.33
## - Chest    1       1.9  387.1 128.19
## - Biceps   1       2.4  387.6 128.49
```

```
## <none>                  385.2 128.95
## - Ankle    1       3.1  388.3 128.96
## - Age      1       4.9  390.1 130.13
## - Density  1    4299.1 4684.4 756.48
##
## Step:  AIC=127.13
## bodyfat ~ Density + Age + Weight + Neck + Chest + Abdomen + Ankle +
##     Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Neck     1       0.4  385.9 125.41
## - Forearm  1       0.5  386.0 125.44
## - Abdomen  1       1.0  386.5 125.77
## - Weight   1       1.6  387.1 126.18
## - Chest    1       1.7  387.2 126.22
## - Biceps   1       2.3  387.8 126.61
## <none>                  385.5 127.13
## - Ankle    1       3.1  388.6 127.16
## - Age      1       4.6  390.1 128.13
## - Density  1    4302.3 4687.8 754.67
##
## Step:  AIC=125.41
## bodyfat ~ Density + Age + Weight + Chest + Abdomen + Ankle +
##     Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Forearm  1       0.3  386.3 123.63
## - Abdomen  1       0.9  386.8 124.00
## - Weight   1       1.3  387.2 124.25
## - Chest    1       1.6  387.5 124.43
## - Biceps   1       2.6  388.6 125.12
## - Ankle    1       3.0  388.9 125.37
## <none>                  385.9 125.41
## - Age      1       4.2  390.2 126.15
## - Density  1    4455.2 4841.1 760.78
##
## Step:  AIC=123.63
## bodyfat ~ Density + Age + Weight + Chest + Abdomen + Ankle +
##     Biceps
##
##           Df Sum of Sq    RSS    AIC
## - Abdomen  1       0.8  387.0 122.12
## - Weight   1       1.5  387.8 122.60
## - Chest    1       1.8  388.1 122.82
## - Biceps   1       2.3  388.6 123.12
## - Ankle    1       3.0  389.2 123.55
## <none>                  386.3 123.63
## - Age      1       4.1  390.4 124.31
## - Density  1    4488.2 4874.4 760.51
##
## Step:  AIC=122.12
## bodyfat ~ Density + Age + Weight + Chest + Ankle + Biceps
##
##           Df Sum of Sq    RSS    AIC
```

```
## - Biceps   1       2.9  390.0 122.03
## <none>                  387.0 122.12
## - Chest    1       3.3  390.3 122.26
## - Ankle    1       3.6  390.6 122.43
## - Weight   1       4.8  391.8 123.21
## - Age      1       5.9  392.9 123.92
## - Density  1    7905.3 8292.3 892.40
##
## Step:  AIC=122.03
## bodyfat ~ Density + Age + Weight + Chest + Ankle
##
##           Df Sum of Sq    RSS    AIC
## - Weight   1       2.7  392.6 121.74
## - Chest    1       2.9  392.9 121.93
## <none>                  390.0 122.03
## - Ankle    1       3.5  393.5 122.29
## - Age      1       6.6  396.6 124.28
## - Density  1    7902.4 8292.4 890.40
##
## Step:  AIC=121.74
## bodyfat ~ Density + Age + Chest + Ankle
##
##           Df Sum of Sq    RSS    AIC
## - Ankle    1       1.7  394.3 120.84
## <none>                  392.6 121.74
## - Age      1       4.6  397.3 122.70
## - Chest    1      27.5  420.1 136.81
## - Density  1    7959.6 8352.2 890.22
##
## Step:  AIC=120.84
## bodyfat ~ Density + Age + Chest
##
##           Df Sum of Sq    RSS    AIC
## <none>                  394.3 120.84
## - Age      1       6.1  400.4 122.71
## - Chest    1      26.9  421.3 135.49
## - Density  1    7997.4 8391.7 889.40
```

```
N = length(resid(modelALL))
backwardsBIC = step(modelALL, direction = "backward", k = log(N)) #Picks Density and Chest #BIC= 133.3
```

```
## Start:  AIC=189.65
## bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen +
##     Hip + Thigh + Knee + Ankle + Biceps + Forearm + Wrist
##
##           Df Sum of Sq    RSS    AIC
## - Wrist    1       0.0  384.9 184.12
## - Knee     1       0.0  384.9 184.12
## - Height   1       0.1  385.0 184.20
## - Thigh    1       0.2  385.1 184.28
## - Neck     1       0.3  385.1 184.30
## - Hip      1       0.3  385.2 184.33
## - Forearm  1       0.5  385.4 184.46
## - Abdomen  1       0.6  385.4 184.48
## - Weight   1       0.6  385.5 184.54
```

```
## - Chest    1       1.4  386.2 185.00
## - Biceps   1       1.9  386.8 185.36
## - Ankle    1       2.8  387.6 185.92
## - Age      1       2.8  387.6 185.93
## <none>                  384.9 189.65
## - Density  1    4026.6 4411.4 798.77
##
## Step:  AIC=184.12
## bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen +
##     Hip + Thigh + Knee + Ankle + Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Knee     1       0.0  384.9 178.60
## - Height   1       0.1  385.0 178.67
## - Thigh    1       0.2  385.1 178.75
## - Neck     1       0.3  385.1 178.77
## - Hip      1       0.3  385.2 178.80
## - Abdomen  1       0.6  385.4 178.95
## - Forearm  1       0.6  385.4 178.96
## - Weight   1       0.7  385.5 179.03
## - Chest    1       1.3  386.2 179.47
## - Biceps   1       1.9  386.8 179.83
## - Ankle    1       2.9  387.7 180.48
## - Age      1       3.2  388.1 180.71
## <none>                  384.9 184.12
## - Density  1    4196.7 4581.6 802.78
##
## Step:  AIC=178.6
## bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen +
##     Hip + Thigh + Ankle + Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Height   1       0.1  385.0 173.15
## - Neck     1       0.3  385.1 173.24
## - Thigh    1       0.3  385.2 173.26
## - Hip      1       0.3  385.2 173.27
## - Forearm  1       0.6  385.4 173.43
## - Abdomen  1       0.6  385.4 173.43
## - Weight   1       0.7  385.5 173.51
## - Chest    1       1.4  386.2 173.97
## - Biceps   1       1.9  386.8 174.30
## - Ankle    1       3.1  387.9 175.06
## - Age      1       3.5  388.3 175.32
## <none>                  384.9 178.60
## - Density  1    4197.2 4582.1 797.27
##
## Step:  AIC=173.15
## bodyfat ~ Density + Age + Weight + Neck + Chest + Abdomen + Hip +
##     Thigh + Ankle + Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Thigh    1       0.2  385.2 167.77
## - Neck     1       0.3  385.3 167.79
## - Hip      1       0.5  385.5 167.92
```

```
## - Weight   1       0.5  385.5 167.98
## - Forearm  1       0.6  385.5 167.98
## - Abdomen  1       0.6  385.6 168.02
## - Chest    1       1.7  386.7 168.71
## - Biceps   1       1.9  386.8 168.83
## - Ankle    1       3.0  388.0 169.60
## - Age      1       3.6  388.6 169.97
## <none>                  385.0 173.15
## - Density  1    4217.5 4602.5 792.86
##
## Step:  AIC=167.77
## bodyfat ~ Density + Age + Weight + Neck + Chest + Abdomen + Hip +
##     Ankle + Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Hip      1       0.3  385.5 162.42
## - Neck     1       0.3  385.5 162.45
## - Weight   1       0.5  385.7 162.58
## - Forearm  1       0.5  385.8 162.60
## - Abdomen  1       0.6  385.8 162.62
## - Chest    1       1.9  387.1 163.48
## - Biceps   1       2.4  387.6 163.78
## - Ankle    1       3.1  388.3 164.25
## - Age      1       4.9  390.1 165.42
## <none>                  385.2 167.77
## - Density  1    4299.1 4684.4 791.78
##
## Step:  AIC=162.42
## bodyfat ~ Density + Age + Weight + Neck + Chest + Abdomen + Ankle +
##     Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Neck     1       0.4  385.9 157.18
## - Forearm  1       0.5  386.0 157.21
## - Abdomen  1       1.0  386.5 157.53
## - Weight   1       1.6  387.1 157.95
## - Chest    1       1.7  387.2 157.98
## - Biceps   1       2.3  387.8 158.38
## - Ankle    1       3.1  388.6 158.93
## - Age      1       4.6  390.1 159.89
## <none>                  385.5 162.42
## - Density  1    4302.3 4687.8 786.43
##
## Step:  AIC=157.18
## bodyfat ~ Density + Age + Weight + Chest + Abdomen + Ankle +
##     Biceps + Forearm
##
##           Df Sum of Sq    RSS    AIC
## - Forearm  1       0.3  386.3 151.86
## - Abdomen  1       0.9  386.8 152.24
## - Weight   1       1.3  387.2 152.48
## - Chest    1       1.6  387.5 152.66
## - Biceps   1       2.6  388.6 153.36
## - Ankle    1       3.0  388.9 153.61
```

```
## - Age      1       4.2  390.2 154.39
## <none>                  385.9 157.18
## - Density  1    4455.2 4841.1 789.02
##
## Step:  AIC=151.86
## bodyfat ~ Density + Age + Weight + Chest + Abdomen + Ankle +
##     Biceps
##
##           Df Sum of Sq    RSS    AIC
## - Abdomen  1       0.8  387.0 146.82
## - Weight   1       1.5  387.8 147.30
## - Chest    1       1.8  388.1 147.52
## - Biceps   1       2.3  388.6 147.83
## - Ankle    1       3.0  389.2 148.25
## - Age      1       4.1  390.4 149.02
## <none>                  386.3 151.86
## - Density  1    4488.2 4874.4 785.21
##
## Step:  AIC=146.82
## bodyfat ~ Density + Age + Weight + Chest + Ankle + Biceps
##
##           Df Sum of Sq    RSS    AIC
## - Biceps   1       2.9  390.0 143.21
## - Chest    1       3.3  390.3 143.44
## - Ankle    1       3.6  390.6 143.61
## - Weight   1       4.8  391.8 144.39
## - Age      1       5.9  392.9 145.10
## <none>                  387.0 146.82
## - Density  1    7905.3 8292.3 913.58
##
## Step:  AIC=143.21
## bodyfat ~ Density + Age + Weight + Chest + Ankle
##
##           Df Sum of Sq    RSS    AIC
## - Weight   1       2.7  392.6 139.39
## - Chest    1       2.9  392.9 139.57
## - Ankle    1       3.5  393.5 139.94
## - Age      1       6.6  396.6 141.92
## <none>                  390.0 143.21
## - Density  1    7902.4 8292.4 908.05
##
## Step:  AIC=139.39
## bodyfat ~ Density + Age + Chest + Ankle
##
##           Df Sum of Sq    RSS    AIC
## - Ankle    1       1.7  394.3 134.96
## - Age      1       4.6  397.3 136.82
## <none>                  392.6 139.39
## - Chest    1      27.5  420.1 150.92
## - Density  1    7959.6 8352.2 904.33
##
## Step:  AIC=134.96
## bodyfat ~ Density + Age + Chest
##
```

```
##           Df Sum of Sq    RSS    AIC
## - Age      1       6.1  400.4 133.30
## <none>                  394.3 134.96
## - Chest    1      26.9  421.3 146.08
## - Density  1    7997.4 8391.7 899.99
##
## Step:  AIC=133.3
## bodyfat ~ Density + Chest
##
##           Df Sum of Sq    RSS    AIC
## <none>                  400.4 133.30
## - Chest    1      26.5  426.9 143.91
## - Density  1    8500.2 8900.7 909.30
```

```
#Forward
modelstart = lm(bodyfat ~ 1, data = fat)
forwardAIC = step(modelstart, scope = bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdome
```

```
## Start:  AIC=1071.75
## bodyfat ~ 1
##
##           Df Sum of Sq     RSS     AIC
## + Density  1   17152.1   426.9  136.85
## + Abdomen  1   11631.5  5947.5  800.65
## + Chest    1    8678.3  8900.7  902.24
## + Hip      1    6871.2 10707.8  948.82
## + Weight   1    6593.0 10986.0  955.29
## + Thigh    1    5505.0 12073.9  979.08
## + Knee     1    4548.4 13030.6  998.30
## + Biceps   1    4277.3 13301.7 1003.49
## + Neck     1    4230.9 13348.1 1004.36
## + Forearm  1    2295.8 15283.2 1038.48
## + Age      1    1493.3 16085.7 1051.38
## + Ankle    1    1243.5 16335.5 1055.26
## + Height   1     140.8 17438.2 1071.72
## <none>                 17579.0 1071.75
##
## Step:  AIC=136.85
## bodyfat ~ Density
##
##           Df Sum of Sq    RSS    AIC
## + Abdomen  1   28.5567 398.37 121.40
## + Chest    1   26.4765 400.45 122.71
## + Weight   1   17.8177 409.10 128.10
## + Hip      1   15.1976 411.72 129.71
## + Neck     1   12.4035 414.52 131.42
## + Knee     1    9.0122 417.91 133.47
## + Age      1    5.6436 421.28 135.49
## + Thigh    1    4.4625 422.46 136.20
## + Forearm  1    3.9512 422.97 136.50
## + Biceps   1    3.3820 423.54 136.84
## <none>                 426.92 136.85
## + Height   1    0.9175 426.00 138.31
## + Ankle    1    0.3522 426.57 138.64
##
```

```
## Step:  AIC=121.4
## bodyfat ~ Density + Abdomen
##
##           Df Sum of Sq    RSS    AIC
## + Age      1    5.2736 393.09 120.04
## + Ankle    1    3.2258 395.14 121.35
## <none>                  398.37 121.40
## + Thigh    1    3.1472 395.22 121.40
## + Biceps   1    2.0070 396.36 122.13
## + Chest    1    1.4196 396.95 122.50
## + Hip      1    0.5715 397.79 123.04
## + Weight   1    0.4411 397.92 123.12
## + Knee     1    0.4231 397.94 123.13
## + Height   1    0.2979 398.07 123.21
## + Neck     1    0.1494 398.22 123.31
## + Forearm  1    0.0179 398.35 123.39
##
## Step:  AIC=120.04
## bodyfat ~ Density + Abdomen + Age
##
##           Df Sum of Sq    RSS    AIC
## <none>                  393.09 120.04
## + Chest    1   1.75995 391.33 120.91
## + Ankle    1   1.75690 391.33 120.91
## + Biceps   1   0.70381 392.39 121.59
## + Thigh    1   0.26225 392.83 121.88
## + Hip      1   0.24640 392.85 121.89
## + Weight   1   0.21339 392.88 121.91
## + Forearm  1   0.15934 392.93 121.94
## + Neck     1   0.08049 393.01 121.99
## + Knee     1   0.03561 393.06 122.02
## + Height   1   0.03136 393.06 122.02
```

```
forwardBIC = step(modelstart, scope = bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen
```

```
## Start:  AIC=1075.28
## bodyfat ~ 1
##
##           Df Sum of Sq     RSS     AIC
## + Density  1   17152.1   426.9  143.91
## + Abdomen  1   11631.5  5947.5  807.70
## + Chest    1    8678.3  8900.7  909.30
## + Hip      1    6871.2 10707.8  955.88
## + Weight   1    6593.0 10986.0  962.35
## + Thigh    1    5505.0 12073.9  986.14
## + Knee     1    4548.4 13030.6 1005.36
## + Biceps   1    4277.3 13301.7 1010.55
## + Neck     1    4230.9 13348.1 1011.42
## + Forearm  1    2295.8 15283.2 1045.54
## + Age      1    1493.3 16085.7 1058.44
## + Ankle    1    1243.5 16335.5 1062.32
## <none>                 17579.0 1075.28
## + Height   1     140.8 17438.2 1078.78
##
## Step:  AIC=143.91
```

```
## bodyfat ~ Density
##
##           Df Sum of Sq    RSS    AIC
## + Abdomen  1   28.5567 398.37 131.99
## + Chest    1   26.4765 400.45 133.30
## + Weight   1   17.8177 409.10 138.69
## + Hip      1   15.1976 411.72 140.30
## + Neck     1   12.4035 414.52 142.01
## <none>                 426.92 143.91
## + Knee     1    9.0122 417.91 144.06
## + Age      1    5.6436 421.28 146.08
## + Thigh    1    4.4625 422.46 146.79
## + Forearm  1    3.9512 422.97 147.09
## + Biceps   1    3.3820 423.54 147.43
## + Height   1    0.9175 426.00 148.89
## + Ankle    1    0.3522 426.57 149.23
##
## Step:  AIC=131.99
## bodyfat ~ Density + Abdomen
##
##           Df Sum of Sq    RSS    AIC
## <none>                 398.37 131.99
## + Age      1    5.2736 393.09 134.16
## + Ankle    1    3.2258 395.14 135.47
## + Thigh    1    3.1472 395.22 135.52
## + Biceps   1    2.0070 396.36 136.25
## + Chest    1    1.4196 396.95 136.62
## + Hip      1    0.5715 397.79 137.16
## + Weight   1    0.4411 397.92 137.24
## + Knee     1    0.4231 397.94 137.25
## + Height   1    0.2979 398.07 137.33
## + Neck     1    0.1494 398.22 137.42
## + Forearm  1    0.0179 398.35 137.51
```

```
#Stepwise
stepAIC = step(modelstart, scope = bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen +
```

```
## Start:  AIC=1071.75
## bodyfat ~ 1
##
##           Df Sum of Sq     RSS     AIC
## + Density  1   17152.1   426.9  136.85
## + Abdomen  1   11631.5  5947.5  800.65
## + Chest    1    8678.3  8900.7  902.24
## + Hip      1    6871.2 10707.8  948.82
## + Weight   1    6593.0 10986.0  955.29
## + Thigh    1    5505.0 12073.9  979.08
## + Knee     1    4548.4 13030.6  998.30
## + Biceps   1    4277.3 13301.7 1003.49
## + Neck     1    4230.9 13348.1 1004.36
## + Forearm  1    2295.8 15283.2 1038.48
## + Age      1    1493.3 16085.7 1051.38
## + Ankle    1    1243.5 16335.5 1055.26
## + Height   1     140.8 17438.2 1071.72
## <none>                 17579.0 1071.75
```

```
##
## Step:  AIC=136.85
## bodyfat ~ Density
##
##           Df Sum of Sq     RSS     AIC
## + Abdomen  1      28.6   398.4  121.40
## + Chest    1      26.5   400.4  122.71
## + Weight   1      17.8   409.1  128.10
## + Hip      1      15.2   411.7  129.71
## + Neck     1      12.4   414.5  131.42
## + Knee     1       9.0   417.9  133.47
## + Age      1       5.6   421.3  135.49
## + Thigh    1       4.5   422.5  136.20
## + Forearm  1       4.0   423.0  136.50
## + Biceps   1       3.4   423.5  136.84
## <none>                   426.9  136.85
## + Height   1       0.9   426.0  138.31
## + Ankle    1       0.4   426.6  138.64
## - Density  1   17152.1 17579.0 1071.75
##
## Step:  AIC=121.4
## bodyfat ~ Density + Abdomen
##
##           Df Sum of Sq    RSS    AIC
## + Age      1       5.3  393.1 120.04
## + Ankle    1       3.2  395.1 121.35
## <none>                  398.4 121.40
## + Thigh    1       3.1  395.2 121.40
## + Biceps   1       2.0  396.4 122.13
## + Chest    1       1.4  396.9 122.50
## + Hip      1       0.6  397.8 123.04
## + Weight   1       0.4  397.9 123.12
## + Knee     1       0.4  397.9 123.13
## + Height   1       0.3  398.1 123.21
## + Neck     1       0.1  398.2 123.31
## + Forearm  1       0.0  398.3 123.39
## - Abdomen  1      28.6  426.9 136.85
## - Density  1    5549.1 5947.5 800.65
##
## Step:  AIC=120.04
## bodyfat ~ Density + Abdomen + Age
##
##           Df Sum of Sq    RSS    AIC
## <none>                  393.1 120.04
## + Chest    1       1.8  391.3 120.91
## + Ankle    1       1.8  391.3 120.91
## - Age      1       5.3  398.4 121.40
## + Biceps   1       0.7  392.4 121.59
## + Thigh    1       0.3  392.8 121.87
## + Hip      1       0.2  392.8 121.88
## + Weight   1       0.2  392.9 121.91
## + Forearm  1       0.2  392.9 121.94
## + Neck     1       0.1  393.0 121.99
## + Knee     1       0.0  393.1 122.02
```

```
## + Height   1       0.0  393.1 122.02
## - Abdomen  1      28.2  421.3 135.49
## - Density  1    5353.4 5746.5 793.98
```

```
stepBIC = step(modelstart, scope = bodyfat ~ Density + Age + Weight + Height + Neck + Chest + Abdomen +
```

```
## Start:  AIC=1075.28
## bodyfat ~ 1
##
##           Df Sum of Sq     RSS     AIC
## + Density  1   17152.1   426.9  143.91
## + Abdomen  1   11631.5  5947.5  807.70
## + Chest    1    8678.3  8900.7  909.30
## + Hip      1    6871.2 10707.8  955.88
## + Weight   1    6593.0 10986.0  962.35
## + Thigh    1    5505.0 12073.9  986.14
## + Knee     1    4548.4 13030.6 1005.36
## + Biceps   1    4277.3 13301.7 1010.55
## + Neck     1    4230.9 13348.1 1011.42
## + Forearm  1    2295.8 15283.2 1045.54
## + Age      1    1493.3 16085.7 1058.44
## + Ankle    1    1243.5 16335.5 1062.32
## <none>                 17579.0 1075.28
## + Height   1     140.8 17438.2 1078.78
##
## Step:  AIC=143.91
## bodyfat ~ Density
##
##           Df Sum of Sq     RSS     AIC
## + Abdomen  1      28.6   398.4  131.99
## + Chest    1      26.5   400.4  133.30
## + Weight   1      17.8   409.1  138.69
## + Hip      1      15.2   411.7  140.30
## + Neck     1      12.4   414.5  142.01
## <none>                   426.9  143.91
## + Knee     1       9.0   417.9  144.06
## + Age      1       5.6   421.3  146.08
## + Thigh    1       4.5   422.5  146.79
## + Forearm  1       4.0   423.0  147.09
## + Biceps   1       3.4   423.5  147.43
## + Height   1       0.9   426.0  148.89
## + Ankle    1       0.4   426.6  149.23
## - Density  1   17152.1 17579.0 1075.28
##
## Step:  AIC=131.99
## bodyfat ~ Density + Abdomen
##
##           Df Sum of Sq    RSS    AIC
## <none>                  398.4 131.99
## + Age      1       5.3  393.1 134.16
## + Ankle    1       3.2  395.1 135.47
## + Thigh    1       3.1  395.2 135.52
## + Biceps   1       2.0  396.4 136.25
## + Chest    1       1.4  396.9 136.62
## + Hip      1       0.6  397.8 137.16
```

```
## + Weight   1       0.4  397.9 137.24
## + Knee     1       0.4  397.9 137.25
## + Height   1       0.3  398.1 137.33
## + Neck     1       0.1  398.2 137.42
## + Forearm  1       0.0  398.3 137.51
## - Abdomen  1      28.6  426.9 143.91
## - Density  1    5549.1 5947.5 807.70
```

```
#Exhaustive
library(leaps)
all_fat_mod = summary(regsubsets(bodyfat ~ ., data = fat))
p = length(coef(modelALL))
n = length(resid(modelALL))
fat_mod_aic = n * log(all_fat_mod$rss / n) + 2 * (2:p)
```

```
## Warning in n * log(all_fat_mod$rss/n) + 2 * (2:p): longer object length is not a
## multiple of shorter object length
```

```
best_fat_ind = which.min(fat_mod_aic)
all_fat_mod$which[best_fat_ind,]
```

```
## (Intercept)     Density         Age      Weight      Height        Neck
##        TRUE        TRUE        TRUE       FALSE       FALSE       FALSE
##       Chest     Abdomen         Hip       Thigh        Knee       Ankle
##       FALSE        TRUE       FALSE       FALSE       FALSE       FALSE
##      Biceps     Forearm       Wrist
##       FALSE       FALSE       FALSE
```

```
fat_mod_best_aic = lm(bodyfat ~ Density + Age + Abdomen, data = fat) #AIC = 120.0427

fat_mod_bic = n * log(all_fat_mod$rss / n) + log(n) * (2:p)
```

```
## Warning in n * log(all_fat_mod$rss/n) + log(n) * (2:p): longer object length is
## not a multiple of shorter object length
```

```
best_fat_bic = which.min(fat_mod_bic)
all_fat_mod$which[best_fat_bic,] #Density, Abdomen
```

```
## (Intercept)     Density         Age      Weight      Height        Neck
##        TRUE        TRUE       FALSE       FALSE       FALSE       FALSE
##       Chest     Abdomen         Hip       Thigh        Knee       Ankle
##       FALSE        TRUE       FALSE       FALSE       FALSE       FALSE
##      Biceps     Forearm       Wrist
##       FALSE       FALSE       FALSE
```

```
fat_mod_best_Bic = lm(bodyfat ~ Density + Abdomen, data = fat)
extractAIC(fat_mod_best_Bic, k = log(n)) #BIC = 131.9893
```

```
## [1]   3.0000 131.9893
```

```
#models to consider
Model_DAC = lm(bodyfat ~ Density + Age + Chest, data = fat) #AIC Selection
Model_DC = lm(bodyfat ~ Density + Chest, data = fat) #BIC selection
Model_DAA = lm(bodyfat ~ Density + Age + Abdomen, data = fat) #AIC Selection
Model_DA = lm(bodyfat ~ Density + Abdomen, data = fat) #BIC Selection
summary(Model_DAA)
```

```
##
## Call:
```

```
## lm(formula = bodyfat ~ Density + Age + Abdomen, data = fat)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.3394 -0.3463 -0.0945  0.2131 15.6006
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  4.453e+02  8.393e+00  53.060  < 2e-16 ***
## Density     -4.088e+02  7.034e+00 -58.116  < 2e-16 ***
## Age          1.197e-02  6.565e-03   1.824   0.0694 .
## Abdomen      5.168e-02  1.226e-02   4.217 3.47e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.259 on 248 degrees of freedom
## Multiple R-squared:  0.9776, Adjusted R-squared:  0.9774
## F-statistic:  3614 on 3 and 248 DF,  p-value: < 2.2e-16
```

```
summary(Model_DA)
```

```
##
## Call:
## lm(formula = bodyfat ~ Density + Abdomen, data = fat)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.3831 -0.3299 -0.0698  0.1923 15.7848
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  447.98155    8.30227  53.959  < 2e-16 ***
## Density     -410.81441    6.97550 -58.894  < 2e-16 ***
## Abdomen        0.05201    0.01231   4.225 3.36e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.265 on 249 degrees of freedom
## Multiple R-squared:  0.9773, Adjusted R-squared:  0.9772
## F-statistic:  5369 on 2 and 249 DF,  p-value: < 2.2e-16
```

```
#BIC - picks smaller models
extractAIC(Model_DAC, k = log(n)) #134.9566 last #AIC Selection
```

```
## [1]   4.0000 134.9566
```

```
extractAIC(Model_DC, k = log(n)) #133.3018 second #BIC Selection
```

```
## [1]   3.0000 133.3018
```

```
extractAIC(Model_DAA, k = log(n)) #134.1604 third #AIC Selection
```

```
## [1]   4.0000 134.1604
```

```
extractAIC(Model_DA, k = log(n)) #131.9893 best #BIC Selection
```

```
## [1]   3.0000 131.9893
```

```r
#AIC - picks larger models
extractAIC(Model_DAC) #120.8389 second #AIC Selection
```

```
## [1]   4.0000 120.8389
```

```r
extractAIC(Model_DC) #122.7135 last #BIC Selection
```

```
## [1]   3.0000 122.7135
```

```r
extractAIC(Model_DAA) #120.0427 best #AIC Selection
```

```
## [1]   4.0000 120.0427
```

```r
extractAIC(Model_DA) #121.401 third #BIC Selection
```

```
## [1]   3.000 121.401
```

```r
#RMSE
RMSE = function(test)
{sqrt((summary(test)$sigma^2)*test$df.residual/length(test$fitted.values))}

RMSE(Model_DAC) #1.250929
```

```
## [1] 1.250929
```

```r
RMSE(Model_DAA) #1.248955
```

```
## [1] 1.248955
```

```r
RMSE(Model_DA) #1.257305
```

```
## [1] 1.257305
```

```r
RMSE(Model_DC) #1.260583
```

```
## [1] 1.260583
```

```r
#anova
anova(Model_DA,Model_DAA) #not significant at 5 percent - significant at 7
```

```
## Analysis of Variance Table
##
## Model 1: bodyfat ~ Density + Abdomen
## Model 2: bodyfat ~ Density + Age + Abdomen
##   Res.Df    RSS Df Sum of Sq      F  Pr(>F)
## 1    249 398.37
## 2    248 393.09  1    5.2736 3.3271 0.06935 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#Normality Assumption
shapiro.test(resid(Model_DAA))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  resid(Model_DAA)
## W = 0.37137, p-value < 2.2e-16
```

```r
shapiro.test(resid(Model_DA))
```

```
##
```

```
##  Shapiro-Wilk normality test
##
## data:  resid(Model_DA)
## W = 0.35526, p-value < 2.2e-16
```

```
#Constant Variance Assumption
library(lmtest)
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
bptest(Model_DAA)
```

```
##
##  studentized Breusch-Pagan test
##
## data:  Model_DAA
## BP = 20.521, df = 3, p-value = 0.0001324
```

```
bptest(Model_DA)
```

```
##
##  studentized Breusch-Pagan test
##
## data:  Model_DA
## BP = 19.052, df = 2, p-value = 7.294e-05
```

Model_DAA RSE = 1.259 RMSE = 1.248955 R^2 = .9776 Adjusted R^2 = .9774

Model_DAC RSE = 1.261 RMSE = 1.250929 R^2 = .9776 Adjusted R^2 = .9773

Model_DC RSE = 1.268 RMSE = 1.260583 R^2 = .9772 Adjusted R^2 = .9770

Model_DA RSE = 1.265 RMSE = 1.257305 R^2 = .9773 Adjusted R^2 = .9772

Given the intent of backward, forward, stepwise, and exhaustive selection procedures seek to find models with the smallest respective AIC and BIC values, we will omit the higher AIC and BIC models.

This leaves us with `Model_DAA` (AIC) and `Model_DA`(BIC) to consider. In terms of testing, both models don't meet the Normality and Constant Variance assumption making them inadequate in being explanatory. In terms of anova testing, there is not a significant difference between models at a .05 significance level but there is a significant difference at .10. In terms of T tests for individual predictors of a model, the predictor Age in `Model_DAA` would reject the null (proving linearity) at a .10 significance but accepts the null at .05. Based off the rather dynamic nature of test results from change of significance, we will base our final decision on measures of error and variance of each model.

The best model to predict is `Model_DAA`. It has less error associated with it due to lower RSE and RMSE values It also has higher R^2 and adjusted R^2 values than `Model_DA`, meaning 97.76% of variance observed in the explanatory variable of selected model is described by the model.