STAT 526 HW 4

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20 March 2023

```
library("MASS")
library("lmtest")
data(minn38)
minn38
```

```
##     hs phs fol sex   f
## 1    L   C  F1   M  87
## 2    L   C  F2   M  72
## 3    L   C  F3   M  52
## 4    L   C  F4   M  88
## 5    L   C  F5   M  32
## 6    L   C  F6   M  14
## 7    L   C  F7   M  20
## 8    L   N  F1   M   3
## 9    L   N  F2   M   6
## 10   L   N  F3   M  17
## 11   L   N  F4   M   9
## 12   L   N  F5   M   1
## 13   L   N  F6   M   2
## 14   L   N  F7   M   3
## 15   L   E  F1   M  17
## 16   L   E  F2   M  18
## 17   L   E  F3   M  14
## 18   L   E  F4   M  14
## 19   L   E  F5   M  12
## 20   L   E  F6   M   5
## 21   L   E  F7   M   4
## 22   L   O  F1   M 105
## 23   L   O  F2   M 209
## 24   L   O  F3   M 541
## 25   L   O  F4   M 328
## 26   L   O  F5   M 124
## 27   L   O  F6   M 148
## 28   L   O  F7   M 109
## 29   M   C  F1   M 216
## 30   M   C  F2   M 159
## 31   M   C  F3   M 119
## 32   M   C  F4   M 158
## 33   M   C  F5   M  43
## 34   M   C  F6   M  24
## 35   M   C  F7   M  41
## 36   M   N  F1   M   4
```

```
## 37   M   N  F2   M  14
## 38   M   N  F3   M  13
## 39   M   N  F4   M  15
## 40   M   N  F5   M   5
## 41   M   N  F6   M   6
## 42   M   N  F7   M   5
## 43   M   E  F1   M  14
## 44   M   E  F2   M  28
## 45   M   E  F3   M  44
## 46   M   E  F4   M  36
## 47   M   E  F5   M   7
## 48   M   E  F6   M  15
## 49   M   E  F7   M  13
## 50   M   O  F1   M 118
## 51   M   O  F2   M 227
## 52   M   O  F3   M 578
## 53   M   O  F4   M 304
## 54   M   O  F5   M 119
## 55   M   O  F6   M 131
## 56   M   O  F7   M  88
## 57   U   C  F1   M 256
## 58   U   C  F2   M 176
## 59   U   C  F3   M 119
## 60   U   C  F4   M 144
## 61   U   C  F5   M  42
## 62   U   C  F6   M  24
## 63   U   C  F7   M  32
## 64   U   N  F1   M   2
## 65   U   N  F2   M   8
## 66   U   N  F3   M  10
## 67   U   N  F4   M  12
## 68   U   N  F5   M   2
## 69   U   N  F6   M   2
## 70   U   N  F7   M   2
## 71   U   E  F1   M  10
## 72   U   E  F2   M  22
## 73   U   E  F3   M  33
## 74   U   E  F4   M  20
## 75   U   E  F5   M   7
## 76   U   E  F6   M   4
## 77   U   E  F7   M   4
## 78   U   O  F1   M  53
## 79   U   O  F2   M  95
## 80   U   O  F3   M 257
## 81   U   O  F4   M 115
## 82   U   O  F5   M  56
## 83   U   O  F6   M  61
## 84   U   O  F7   M  41
## 85   L   C  F1   F  53
## 86   L   C  F2   F  36
## 87   L   C  F3   F  52
## 88   L   C  F4   F  48
## 89   L   C  F5   F  12
## 90   L   C  F6   F   9
```

```
## 91   L   C  F7   F   3
## 92   L   N  F1   F   7
## 93   L   N  F2   F  16
## 94   L   N  F3   F  28
## 95   L   N  F4   F  18
## 96   L   N  F5   F   5
## 97   L   N  F6   F   1
## 98   L   N  F7   F   1
## 99   L   E  F1   F  13
## 100  L   E  F2   F  11
## 101  L   E  F3   F  49
## 102  L   E  F4   F  29
## 103  L   E  F5   F  10
## 104  L   E  F6   F  15
## 105  L   E  F7   F   6
## 106  L   O  F1   F  76
## 107  L   O  F2   F 111
## 108  L   O  F3   F 521
## 109  L   O  F4   F 191
## 110  L   O  F5   F 101
## 111  L   O  F6   F 130
## 112  L   O  F7   F  88
## 113  M   C  F1   F 163
## 114  M   C  F2   F 116
## 115  M   C  F3   F 162
## 116  M   C  F4   F 130
## 117  M   C  F5   F  35
## 118  M   C  F6   F  19
## 119  M   C  F7   F  25
## 120  M   N  F1   F  30
## 121  M   N  F2   F  41
## 122  M   N  F3   F  64
## 123  M   N  F4   F  47
## 124  M   N  F5   F  11
## 125  M   N  F6   F  13
## 126  M   N  F7   F   9
## 127  M   E  F1   F  28
## 128  M   E  F2   F  53
## 129  M   E  F3   F 129
## 130  M   E  F4   F  62
## 131  M   E  F5   F  37
## 132  M   E  F6   F  22
## 133  M   E  F7   F  15
## 134  M   O  F1   F 118
## 135  M   O  F2   F 214
## 136  M   O  F3   F 708
## 137  M   O  F4   F 305
## 138  M   O  F5   F 152
## 139  M   O  F6   F 174
## 140  M   O  F7   F 158
## 141  U   C  F1   F 309
## 142  U   C  F2   F 225
## 143  U   C  F3   F 243
## 144  U   C  F4   F 237
```

```
## 145  U   C  F5   F  72
## 146  U   C  F6   F  42
## 147  U   C  F7   F  36
## 148  U   N  F1   F  17
## 149  U   N  F2   F  49
## 150  U   N  F3   F  79
## 151  U   N  F4   F  57
## 152  U   N  F5   F  20
## 153  U   N  F6   F  10
## 154  U   N  F7   F  14
## 155  U   E  F1   F  38
## 156  U   E  F2   F  68
## 157  U   E  F3   F 284
## 158  U   E  F4   F  63
## 159  U   E  F5   F  21
## 160  U   E  F6   F  19
## 161  U   E  F7   F  19
## 162  U   O  F1   F  89
## 163  U   O  F2   F 210
## 164  U   O  F3   F 448
## 165  U   O  F4   F 219
## 166  U   O  F5   F  95
## 167  U   O  F6   F 105
## 168  U   O  F7   F  93
```

Problem 1

```
options(contrasts = c("contr.treatment", "contr.treatment"))
m0 <- glm(f ~ hs * fol * sex + phs, family = poisson, minn38)

# stepwise
step(m0, list(lower = ~ ., upper = ~.^2))
```

```
## Start:  AIC=4011.05
## f ~ hs * fol * sex + phs
##
##           Df Deviance    AIC
## + fol:phs 18   1545.1 2582.0
## + hs:phs   6   1895.8 2908.8
## + sex:phs  3   2593.5 3600.4
## <none>         3010.1 4011.0
##
## Step:  AIC=2582.02
## f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:fol:sex
##
##           Df Deviance    AIC
## + hs:phs   6   557.34 1606.3
## + sex:phs  3  1141.00 2183.9
## <none>        1545.11 2582.0
## - fol:phs 18  3010.14 4011.0
```

```
##
## Step:  AIC=1606.25
## f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:phs + hs:fol:sex
##
##              Df Deviance    AIC
## + sex:phs     3   201.63 1256.5
## + hs:fol:phs 36   469.36 1590.3
## <none>            557.34 1606.2
## - hs:phs      6  1545.11 2582.0
## - fol:phs    18  1895.85 2908.8
##
## Step:  AIC=1256.54
## f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:phs + sex:phs + hs:fol:sex
##
##               Df Deviance    AIC
## + fol:sex:phs 18   136.35 1227.3
## + hs:fol:phs  36   113.11 1240.0
## <none>             201.63 1256.5
## + hs:sex:phs   6   194.13 1261.0
## - sex:phs      3   557.34 1606.2
## - hs:phs       6  1141.00 2183.9
## - fol:phs     18  1501.90 2520.8
##
## Step:  AIC=1227.26
## f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:phs + sex:phs + hs:fol:sex + fol:sex:phs
##
##               Df Deviance    AIC
## + hs:fol:phs  36    52.88 1215.8
## <none>             136.35 1227.3
## + hs:sex:phs   6   129.09 1232.0
## - fol:sex:phs 18   201.63 1256.5
## - hs:phs       6  1080.49 2159.4
##
## Step:  AIC=1215.79
## f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs
##
##               Df Deviance    AIC
## <none>             52.881 1215.8
## + hs:sex:phs   6   47.745 1222.7
## - hs:fol:phs  36  136.355 1227.3
## - fol:sex:phs 18  113.107 1240.0


##
## Call:  glm(formula = f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex +
##     fol:phs + hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs,
##     family = poisson, data = minn38)
##
## Coefficients:
##     (Intercept)              hsM              hsU            folF2
##        3.889272         1.211402         1.853707        -0.460595
```

```
##           folF3           folF4           folF5           folF6
##        0.080511       -0.030620       -1.172333       -1.645572
##           folF7            sexM            phsE            phsN
##       -2.267240        0.622958       -1.078729       -1.811398
##           phsO       hsM:folF2       hsU:folF2       hsM:folF3
##        0.435104        0.090066        0.168021       -0.104720
##       hsU:folF3       hsM:folF4       hsU:folF4       hsM:folF5
##       -0.327058       -0.184789       -0.251611       -0.307397
##       hsU:folF5       hsM:folF6       hsU:folF6       hsM:folF7
##       -0.373545       -0.409568       -0.419825        0.384782
##       hsU:folF7        hsM:sexM        hsU:sexM      folF2:sexM
##        0.049243       -0.353610       -0.832516        0.294302
##      folF3:sexM      folF4:sexM      folF5:sexM      folF6:sexM
##       -0.660386        0.002507        0.022771       -0.258659
##      folF7:sexM      folF2:phsE      folF3:phsE      folF4:phsE
##        0.641856        0.276607        0.983510        0.386979
##      folF5:phsE      folF6:phsE      folF7:phsE      folF2:phsN
##        0.952982        1.354902        0.982857        1.047627
##      folF3:phsN      folF4:phsN      folF5:phsN      folF6:phsN
##        1.360336        0.812449        0.528800        0.168821
##      folF7:phsN      folF2:phsO      folF3:phsO      folF4:phsO
##        0.879820        0.880905        1.839521        0.991519
##      folF5:phsO      folF6:phsO      folF7:phsO        hsM:phsE
##        1.405234        2.198839        2.401175       -0.732384
##        hsU:phsE        hsM:phsN        hsU:phsN        hsM:phsO
##       -1.093310        0.074188       -1.091134       -0.755416
##        hsU:phsO       sexM:phsE       sexM:phsN       sexM:phsO
##       -1.696954       -0.839660       -2.001439       -0.288796
##  hsM:folF2:sexM  hsU:folF2:sexM  hsM:folF3:sexM  hsU:folF3:sexM
##       -0.208125       -0.410305        0.108654        0.145719
##  hsM:folF4:sexM  hsU:folF4:sexM  hsM:folF5:sexM  hsU:folF5:sexM
##       -0.109352       -0.271961       -0.208626       -0.149440
##  hsM:folF6:sexM  hsU:folF6:sexM  hsM:folF7:sexM  hsU:folF7:sexM
##        0.033853        0.065869       -0.415445       -0.429541
## folF2:sexM:phsE folF3:sexM:phsE folF4:sexM:phsE folF5:sexM:phsE
##        0.015426       -0.300264        0.005643       -0.239200
## folF6:sexM:phsE folF7:sexM:phsE folF2:sexM:phsN folF3:sexM:phsN
##       -0.019923       -0.265002        0.451808        0.941292
## folF4:sexM:phsN folF5:sexM:phsN folF6:sexM:phsN folF7:sexM:phsN
##        0.772147        0.510890        1.197994        0.742004
## folF2:sexM:phsO folF3:sexM:phsO folF4:sexM:phsO folF5:sexM:phsO
##       -0.050000        0.386038        0.151339       -0.049167
## folF6:sexM:phsO folF7:sexM:phsO  hsM:folF2:phsE  hsU:folF2:phsE
##        0.035103       -0.727880        0.712805        0.669707
##  hsM:folF3:phsE  hsU:folF3:phsE  hsM:folF4:phsE  hsU:folF4:phsE
##        0.688386        1.306874        0.711108        0.504921
##  hsM:folF5:phsE  hsU:folF5:phsE  hsM:folF6:phsE  hsU:folF6:phsE
##        0.706867        0.136710        0.655134        0.025766
##  hsM:folF7:phsE  hsU:folF7:phsE  hsM:folF2:phsN  hsU:folF2:phsN
##        0.507903        0.512835       -0.297879        0.304902
##  hsM:folF3:phsN  hsU:folF3:phsN  hsM:folF4:phsN  hsU:folF4:phsN
##       -0.587837        0.379191       -0.129104        0.696934
##  hsM:folF5:phsN  hsU:folF5:phsN  hsM:folF6:phsN  hsU:folF6:phsN
##        0.141029        1.118451        1.083269        1.279091
```

```
##  hsM:folF7:phsN   hsU:folF7:phsN   hsM:folF2:phsO   hsU:folF2:phsO
##       -0.104273         1.019873         0.096761         0.235698
##  hsM:folF3:phsO   hsU:folF3:phsO   hsM:folF4:phsO   hsU:folF4:phsO
##       -0.041237         0.056085         0.149598         0.189042
##  hsM:folF5:phsO   hsU:folF5:phsO   hsM:folF6:phsO   hsU:folF6:phsO
##        0.322268         0.264971         0.202221         0.079430
##  hsM:folF7:phsO   hsU:folF7:phsO
##       -0.259978        -0.076004
##
## Degrees of Freedom: 167 Total (i.e. Null);  42 Residual
## Null Deviance:       18660
## Residual Deviance: 52.88     AIC: 1216
```

```
# best model on AIC
m1 <- glm(formula = f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex +
    fol:phs + hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs,
    family = poisson, data = minn38)

# nearby models
## no term is worth being dropped
drop1(m1)
```

```
## Single term deletions
##
## Model:
## f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs
##             Df Deviance    AIC
## <none>           52.881 1215.8
## hs:fol:sex  12   78.051 1217.0
## fol:sex:phs 18  113.107 1240.0
## hs:fol:phs  36  136.355 1227.3
```

```
## didnt see phs:hs:sex term so add it to the model
## seems like AIC increases a little yet, its size is not large and Deviance decreases in the new model
add1(m1, ~. + phs:hs:sex)
```

```
## Single term additions
##
## Model:
## f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs
##            Df Deviance    AIC
## <none>          52.881 1215.8
## hs:sex:phs  6   47.745 1222.7
```

```
m1_add <- glm(formula = f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex +
    fol:phs + hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs + phs:hs:sex,
    family = poisson, data = minn38)

# they fit the data equally well, in terms of the model, either method will work
# complex model is not significantly more accurate under an alpha equal to .05
lrtest(m1, m1_add)
```

```
## Likelihood ratio test
##
## Model 1: f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs
## Model 2: f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex + fol:phs +
##     hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs +
##     phs:hs:sex
##   #Df  LogLik Df  Chisq Pr(>Chisq)
## 1 126 -481.90
## 2 132 -479.33  6 5.1359     0.5265
```

```
# summary
summary(m1_add)
```

```
##
## Call:
## glm(formula = f ~ hs + fol + sex + phs + hs:fol + hs:sex + fol:sex +
##     fol:phs + hs:phs + sex:phs + hs:fol:sex + fol:sex:phs + hs:fol:phs +
##     phs:hs:sex, family = poisson, data = minn38)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -1.73196  -0.40811  -0.00349   0.36057   1.11605
##
## Coefficients:
##                  Estimate Std. Error z value Pr(>|z|)
## (Intercept)      3.901606   0.122431  31.868  < 2e-16 ***
## hsM              1.196039   0.136627   8.754  < 2e-16 ***
## hsU              1.841019   0.131362  14.015  < 2e-16 ***
## folF2           -0.451815   0.175717  -2.571 0.010133 *
## folF3            0.082348   0.160103   0.514 0.607012
## folF4           -0.025290   0.161152  -0.157 0.875298
## folF5           -1.171061   0.224490  -5.217 1.82e-07 ***
## folF6           -1.646832   0.270292  -6.093 1.11e-09 ***
## folF7           -2.257813   0.296928  -7.604 2.87e-14 ***
## sexM             0.603945   0.137003   4.408 1.04e-05 ***
## phsE            -1.094461   0.236239  -4.633 3.61e-06 ***
## phsN            -1.873355   0.349718  -5.357 8.47e-08 ***
## phsO             0.420602   0.142234   2.957 0.003105 **
## hsM:folF2        0.079966   0.191682   0.417 0.676546
## hsU:folF2        0.158879   0.186439   0.852 0.394116
## hsM:folF3       -0.109418   0.177215  -0.617 0.536953
## hsU:folF3       -0.327784   0.172713  -1.898 0.057715 .
## hsM:folF4       -0.192845   0.178067  -1.083 0.278810
## hsU:folF4       -0.256951   0.173650  -1.480 0.138951
## hsM:folF5       -0.313352   0.249123  -1.258 0.208456
## hsU:folF5       -0.373264   0.242171  -1.541 0.123237
## hsM:folF6       -0.415184   0.302252  -1.374 0.169555
## hsU:folF6       -0.415633   0.290483  -1.431 0.152479
## hsM:folF7        0.371483   0.306934   1.210 0.226162
## hsU:folF7        0.041947   0.311509   0.135 0.892881
## hsM:sexM        -0.329261   0.150442  -2.189 0.028624 *
## hsU:sexM        -0.812714   0.149664  -5.430 5.63e-08 ***
## folF2:sexM       0.283636   0.176926   1.603 0.108905
```

```
## folF3:sexM      -0.670471   0.161654  -4.148 3.36e-05 ***
## folF4:sexM      -0.005725   0.165825  -0.035 0.972460
## folF5:sexM       0.020970   0.220451   0.095 0.924218
## folF6:sexM      -0.258487   0.249458  -1.036 0.300112
## folF7:sexM       0.632879   0.258217   2.451 0.014248 *
## folF2:phsE       0.274458   0.323464   0.848 0.396161
## folF3:phsE       0.981718   0.281195   3.491 0.000481 ***
## folF4:phsE       0.393314   0.297168   1.324 0.185656
## folF5:phsE       0.963828   0.369622   2.608 0.009118 **
## folF6:phsE       1.368037   0.406154   3.368 0.000756 ***
## folF7:phsE       0.985361   0.485431   2.030 0.042370 *
## folF2:phsN       1.006998   0.431553   2.333 0.019625 *
## folF3:phsN       1.350821   0.393690   3.431 0.000601 ***
## folF4:phsN       0.772159   0.416025   1.856 0.063448 .
## folF5:phsN       0.497893   0.581154   0.857 0.391594
## folF6:phsN       0.110043   0.734488   0.150 0.880905
## folF7:phsN       0.784692   0.695329   1.129 0.259101
## folF2:phsO       0.877949   0.186200   4.715 2.42e-06 ***
## folF3:phsO       1.842342   0.172557  10.677  < 2e-16 ***
## folF4:phsO       0.990250   0.173726   5.700 1.20e-08 ***
## folF5:phsO       1.406084   0.234696   5.991 2.08e-09 ***
## folF6:phsO       2.202104   0.278503   7.907 2.64e-15 ***
## folF7:phsO       2.395093   0.297795   8.043 8.78e-16 ***
## hsM:phsE        -0.752651   0.277322  -2.714 0.006648 **
## hsU:phsE        -1.047205   0.270958  -3.865 0.000111 ***
## hsM:phsN         0.145405   0.385813   0.377 0.706263
## hsU:phsN        -1.016857   0.415240  -2.449 0.014332 *
## hsM:phsO        -0.726679   0.157251  -4.621 3.82e-06 ***
## hsU:phsO        -1.695538   0.162859 -10.411  < 2e-16 ***
## sexM:phsE       -0.813045   0.250333  -3.248 0.001163 **
## sexM:phsN       -1.757052   0.417201  -4.212 2.54e-05 ***
## sexM:phsO       -0.266066   0.139822  -1.903 0.057054 .
## hsM:folF2:sexM  -0.195411   0.181516  -1.077 0.281681
## hsU:folF2:sexM  -0.398724   0.187058  -2.132 0.033044 *
## hsM:folF3:sexM   0.127050   0.159336   0.797 0.425236
## hsU:folF3:sexM   0.152694   0.167306   0.913 0.361420
## hsM:folF4:sexM  -0.095836   0.169431  -0.566 0.571643
## hsU:folF4:sexM  -0.263569   0.177615  -1.484 0.137825
## hsM:folF5:sexM  -0.197406   0.208838  -0.945 0.344528
## hsU:folF5:sexM  -0.151309   0.224776  -0.673 0.500849
## hsM:folF6:sexM   0.047631   0.207117   0.230 0.818114
## hsU:folF6:sexM   0.058458   0.228272   0.256 0.797880
## hsM:folF7:sexM  -0.400723   0.224926  -1.782 0.074819 .
## hsU:folF7:sexM  -0.424906   0.248824  -1.708 0.087700 .
## folF2:sexM:phsE  0.012300   0.269011   0.046 0.963531
## folF3:sexM:phsE -0.283621   0.249724  -1.136 0.256066
## folF4:sexM:phsE -0.012273   0.264951  -0.046 0.963055
## folF5:sexM:phsE -0.267319   0.341978  -0.782 0.434400
## folF6:sexM:phsE -0.050246   0.369965  -0.136 0.891970
## folF7:sexM:phsE -0.279488   0.384580  -0.727 0.467388
## folF2:sexM:phsN  0.455942   0.437506   1.042 0.297348
## folF3:sexM:phsN  0.937653   0.419262   2.236 0.025323 *
## folF4:sexM:phsN  0.777914   0.425658   1.828 0.067616 .
## folF5:sexM:phsN  0.529847   0.561563   0.944 0.345414
```

```
## folF6:sexM:phsN  1.231503   0.562130   2.191 0.028468 *
## folF7:sexM:phsN  0.779505   0.563206   1.384 0.166343
## folF2:sexM:phsO -0.048764   0.148947  -0.327 0.743370
## folF3:sexM:phsO  0.387566   0.140035   2.768 0.005646 **
## folF4:sexM:phsO  0.152797   0.144120   1.060 0.289048
## folF5:sexM:phsO -0.051002   0.194330  -0.262 0.792974
## folF6:sexM:phsO  0.031523   0.225598   0.140 0.888872
## folF7:sexM:phsO -0.724715   0.223548  -3.242 0.001187 **
## hsM:folF2:phsE   0.714200   0.358677   1.991 0.046458 *
## hsU:folF2:phsE   0.670489   0.356374   1.881 0.059914 .
## hsM:folF3:phsE   0.705559   0.322947   2.185 0.028907 *
## hsU:folF3:phsE   1.291314   0.314754   4.103 4.09e-05 ***
## hsM:folF4:phsE   0.714494   0.335750   2.128 0.033332 *
## hsU:folF4:phsE   0.496436   0.337282   1.472 0.141056
## hsM:folF5:phsE   0.715833   0.417351   1.715 0.086312 .
## hsU:folF5:phsE   0.122383   0.430289   0.284 0.776088
## hsM:folF6:phsE   0.660015   0.461526   1.430 0.152697
## hsU:folF6:phsE   0.012576   0.472509   0.027 0.978766
## hsM:folF7:phsE   0.513492   0.516903   0.993 0.320514
## hsU:folF7:phsE   0.511277   0.530402   0.964 0.335075
## hsM:folF2:phsN  -0.253902   0.473834  -0.536 0.592065
## hsU:folF2:phsN   0.349464   0.500253   0.699 0.484818
## hsM:folF3:phsN  -0.574035   0.438809  -1.308 0.190816
## hsU:folF3:phsN   0.393960   0.464266   0.849 0.396123
## hsM:folF4:phsN  -0.084436   0.458851  -0.184 0.854001
## hsU:folF4:phsN   0.743096   0.484675   1.533 0.125230
## hsM:folF5:phsN   0.173092   0.644624   0.269 0.788302
## hsU:folF5:phsN   1.150766   0.651806   1.766 0.077479 .
## hsM:folF6:phsN   1.141012   0.776046   1.470 0.141483
## hsU:folF6:phsN   1.345582   0.810612   1.660 0.096923 .
## hsM:folF7:phsN  -0.011836   0.735491  -0.016 0.987160
## hsU:folF7:phsN   1.121221   0.754634   1.486 0.137337
## hsM:folF2:phsO   0.099605   0.195864   0.509 0.611076
## hsU:folF2:phsO   0.239617   0.203440   1.178 0.238866
## hsM:folF3:phsO  -0.046558   0.186719  -0.249 0.803093
## hsU:folF3:phsO   0.053768   0.192905   0.279 0.780453
## hsM:folF4:phsO   0.150466   0.185089   0.813 0.416252
## hsU:folF4:phsO   0.190707   0.194080   0.983 0.325795
## hsM:folF5:phsO   0.321497   0.253116   1.270 0.204028
## hsU:folF5:phsO   0.265894   0.257892   1.031 0.302527
## hsM:folF6:phsO   0.200158   0.306070   0.654 0.513136
## hsU:folF6:phsO   0.078284   0.303281   0.258 0.796311
## hsM:folF7:phsO  -0.256090   0.301127  -0.850 0.395081
## hsU:folF7:phsO  -0.067777   0.315174  -0.215 0.829730
## hsM:sexM:phsE    0.072587   0.202778   0.358 0.720372
## hsU:sexM:phsE   -0.148461   0.209475  -0.709 0.478493
## hsM:sexM:phsN   -0.291921   0.267852  -1.090 0.275774
## hsU:sexM:phsN   -0.373501   0.283842  -1.316 0.188216
## hsM:sexM:phsO   -0.050830   0.119692  -0.425 0.671077
## hsU:sexM:phsO    0.011657   0.121685   0.096 0.923683
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
```

```
##
##     Null deviance: 18660.923  on 167  degrees of freedom
## Residual deviance:    47.745  on  36  degrees of freedom
## AIC: 1222.7
##
## Number of Fisher Scoring iterations: 4
```

Problem 2

```
options(contrasts = c("contr.treatment", "contr.treatment"))
m2 <- glm(f ~ fol * sex + phs + hs, family = poisson, minn38)

# stepwise
step(m2, list(lower = ~ ., upper = ~.^2))
```

```
## Start:  AIC=4587.13
## f ~ fol * sex + phs + hs
##
##           Df Deviance    AIC
## + fol:phs 18   2173.2 3158.1
## + phs:hs   6   2523.9 3484.8
## + sex:hs   2   3216.9 4169.8
## + sex:phs  3   3221.6 4176.5
## + fol:hs  12   3480.1 4453.0
## <none>         3638.2 4587.1
##
## Step:  AIC=3158.1
## f ~ fol + sex + phs + hs + fol:sex + fol:phs
##
##           Df Deviance    AIC
## + phs:hs   6   1058.9 2055.8
## + sex:hs   2   1751.9 2740.8
## + sex:phs  3   1769.1 2760.0
## + fol:hs  12   2015.1 3024.0
## <none>         2173.2 3158.1
## - fol:phs 18   3638.2 4587.1
##
## Step:  AIC=2055.81
## f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs
##
##           Df Deviance    AIC
## + sex:hs   2   613.21 1614.1
## + sex:phs  3   654.79 1657.7
## + fol:hs  12  1027.29 2048.2
## <none>        1058.90 2055.8
## - phs:hs   6  2173.19 3158.1
## - fol:phs 18  2523.93 3484.8
##
## Step:  AIC=1614.12
## f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs + sex:hs
##
```

```
##           Df Deviance    AIC
## + sex:phs  3   256.18 1263.1
## + fol:hs  12   575.23 1600.1
## <none>         613.21 1614.1
## - sex:hs   2  1058.90 2055.8
## - phs:hs   6  1751.91 2740.8
## - fol:phs 18  2102.65 3067.6
##
## Step:  AIC=1263.09
## f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs + sex:hs +
##     sex:phs
##
##               Df Deviance    AIC
## + fol:sex:phs 18   195.68 1238.6
## + fol:hs      12   220.04 1251.0
## <none>             256.18 1263.1
## - sex:phs      3   613.21 1614.1
## - sex:hs       2   654.79 1657.7
## - phs:hs       6  1347.79 2342.7
## - fol:phs     18  1708.70 2679.6
##
## Step:  AIC=1238.59
## f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs + sex:hs +
##     sex:phs + fol:sex:phs
##
##               Df Deviance    AIC
## + fol:hs      12   160.17 1227.1
## <none>             195.68 1238.6
## - fol:sex:phs 18   256.18 1263.1
## - sex:hs       2   594.29 1633.2
## - phs:hs       6  1287.29 2318.2
##
## Step:  AIC=1227.08
## f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs + sex:hs +
##     sex:phs + fol:hs + fol:sex:phs
##
##               Df Deviance    AIC
## <none>             160.17 1227.1
## + fol:sex:hs  12   136.35 1227.3
## - fol:hs      12   195.68 1238.6
## - fol:sex:phs 18   220.04 1251.0
## - sex:hs       2   562.68 1625.6
## - phs:hs       6  1098.38 2153.3


##
## Call:  glm(formula = f ~ fol + sex + phs + hs + fol:sex + fol:phs +
##     phs:hs + sex:hs + sex:phs + fol:hs + fol:sex:phs, family = poisson,
##     data = minn38)
##
## Coefficients:
##     (Intercept)           folF2           folF3           folF4
##        3.931911       -0.414771       -0.024426       -0.063793
##           folF5           folF6           folF7            sexM
##       -1.285959       -1.752629       -1.976800        0.682549
```

```
##            phsE            phsN            phsO            hsM
##       -1.645579       -1.918549        0.362089        1.177388
##             hsU      folF2:sexM      folF3:sexM      folF4:sexM
##        1.799621        0.027082       -0.534022       -0.153965
##      folF5:sexM      folF6:sexM      folF7:sexM      folF2:phsE
##       -0.112393       -0.229101        0.279159        0.849654
##      folF3:phsE      folF4:phsE      folF5:phsE      folF6:phsE
##        1.898641        0.891288        1.321690        1.653291
##      folF7:phsE      folF2:phsN      folF3:phsN      folF4:phsN
##        1.410666        1.014308        1.281205        1.031186
##      folF5:phsN      folF6:phsN      folF7:phsN      folF2:phsO
##        1.057763        1.174821        1.270574        0.991509
##      folF3:phsO      folF4:phsO      folF5:phsO      folF6:phsO
##        1.888429        1.110927        1.633436        2.304406
##      folF7:phsO         phsE:hsM        phsN:hsM        phsO:hsM
##        2.231692       -0.129501       -0.138840       -0.689903
##        phsE:hsU        phsN:hsU        phsO:hsU         sexM:hsM
##       -0.369829       -0.579974       -1.588715       -0.403021
##        sexM:hsU       sexM:phsE       sexM:phsN       sexM:phsO
##       -0.937114       -0.768770       -1.937218       -0.300782
##       folF2:hsM       folF3:hsM       folF4:hsM       folF5:hsM
##        0.056297       -0.094087       -0.117373       -0.143441
##       folF6:hsM       folF7:hsM       folF2:hsU       folF3:hsU
##       -0.184653       -0.025986        0.110970       -0.145754
##       folF4:hsU       folF5:hsU       folF6:hsU       folF7:hsU
##       -0.233902       -0.267183       -0.359789       -0.211101
## folF2:sexM:phsE folF3:sexM:phsE folF4:sexM:phsE folF5:sexM:phsE
##       -0.020490       -0.452388       -0.008943       -0.227359
## folF6:sexM:phsE folF7:sexM:phsE folF2:sexM:phsN folF3:sexM:phsN
##       -0.009098       -0.299419        0.447376        0.855453
## folF4:sexM:phsN folF5:sexM:phsN folF6:sexM:phsN folF7:sexM:phsN
##        0.695322        0.366282        1.099371        0.606493
## folF2:sexM:phsO folF3:sexM:phsO folF4:sexM:phsO folF5:sexM:phsO
##        0.005017        0.342162        0.192511       -0.048973
## folF6:sexM:phsO folF7:sexM:phsO
##        0.023031       -0.634411
##
## Degrees of Freedom: 167 Total (i.e. Null);  90 Residual
## Null Deviance:       18660
## Residual Deviance: 160.2     AIC: 1227
```

```
# best model on AIC
m3 <- glm(formula = f ~ fol + sex + phs + hs + fol:sex + fol:phs +
    phs:hs + sex:hs + sex:phs + fol:hs + fol:sex:phs, family = poisson,
    data = minn38)

# nearby models
## hs:fol term and fol:sex:phs term can be dropped since AIC increases a little
drop1(m3)
```

```
## Single term deletions
##
## Model:
## f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs + sex:hs +
```

```
##     sex:phs + fol:hs + fol:sex:phs
##             Df Deviance    AIC
## <none>           160.17 1227.1
## phs:hs       6  1098.38 2153.3
## sex:hs       2   562.68 1625.6
## fol:hs      12   195.68 1238.6
## fol:sex:phs 18   220.04 1251.0
```

```
## seems like AIC and deviance decrease with fol:phs:hs term and sex:phs:hs also does not hurt the model
add1(m3, ~. + sex:hs:phs + fol:hs:phs)
```

```
## Single term additions
##
## Model:
## f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs + sex:hs +
##     sex:phs + fol:hs + fol:sex:phs
##            Df Deviance    AIC
## <none>          160.174 1227.1
## sex:phs:hs  6  152.387 1231.3
## fol:phs:hs 36   78.051 1217.0
```

```
m3_add <- glm(formula = f ~ fol + sex + phs + hs + fol:sex + fol:phs +
    phs:hs + sex:hs + sex:phs + fol:hs + fol:sex:phs + sex:hs:phs + fol:hs:phs, family = poisson,
    data = minn38)

# the new model fits differently
# the complex model fits better.
# Thus, we know that we should definitely use the complex model as it increases the accuracy of our model
lrtest(m3, m3_add)
```

```
## Likelihood ratio test
##
## Model 1: f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs + sex:hs +
##     sex:phs + fol:hs + fol:sex:phs
## Model 2: f ~ fol + sex + phs + hs + fol:sex + fol:phs + phs:hs + sex:hs +
##     sex:phs + fol:hs + fol:sex:phs + sex:hs:phs + fol:hs:phs
##   #Df  LogLik Df  Chisq Pr(>Chisq)
## 1  78 -535.54
## 2 120 -491.68 42 87.726  4.545e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# summary
summary(m3_add)
```

```
##
## Call:
## glm(formula = f ~ fol + sex + phs + hs + fol:sex + fol:phs +
##     phs:hs + sex:hs + sex:phs + fol:hs + fol:sex:phs + sex:hs:phs +
##     fol:hs:phs, family = poisson, data = minn38)
##
## Deviance Residuals:
```

```
##      Min        1Q    Median        3Q       Max
## -2.14698  -0.44113   0.00233   0.39172   1.61111
##
## Coefficients:
##                  Estimate Std. Error z value Pr(>|z|)
## (Intercept)      3.844060   0.108919  35.293  < 2e-16 ***
## folF2           -0.263180   0.142963  -1.841 0.065636 .
## folF3            0.038076   0.142351   0.267 0.789101
## folF4            0.081725   0.135068   0.605 0.545134
## folF5           -1.075478   0.196793  -5.465 4.63e-08 ***
## folF6           -1.665469   0.253557  -6.568 5.09e-11 ***
## folF7           -1.989386   0.257858  -7.715 1.21e-14 ***
## sexM             0.691602   0.103113   6.707 1.98e-11 ***
## phsE            -1.062221   0.237100  -4.480 7.46e-06 ***
## phsN            -1.827746   0.349194  -5.234 1.66e-07 ***
## phsO             0.459002   0.142565   3.220 0.001284 **
## hsM              1.236838   0.118854  10.406  < 2e-16 ***
## hsU              1.915998   0.113526  16.877  < 2e-16 ***
## folF2:sexM       0.005501   0.095246   0.058 0.953943
## folF3:sexM      -0.557855   0.098175  -5.682 1.33e-08 ***
## folF4:sexM      -0.171129   0.094688  -1.807 0.070717 .
## folF5:sexM      -0.125697   0.146183  -0.860 0.389865
## folF6:sexM      -0.219337   0.187813  -1.168 0.242869
## folF7:sexM       0.263752   0.175959   1.499 0.133888
## folF2:phsE       0.198026   0.319265   0.620 0.535089
## folF3:phsE       1.003648   0.281057   3.571 0.000356 ***
## folF4:phsE       0.340025   0.295010   1.153 0.249079
## folF5:phsE       0.924458   0.365182   2.531 0.011358 *
## folF6:phsE       1.379158   0.406809   3.390 0.000698 ***
## folF7:phsE       0.879051   0.473990   1.855 0.063656 .
## folF2:phsN       0.887949   0.425127   2.089 0.036738 *
## folF3:phsN       1.360888   0.392686   3.466 0.000529 ***
## folF4:phsN       0.704110   0.412164   1.708 0.087576 .
## folF5:phsN       0.439774   0.576242   0.763 0.445359
## folF6:phsN       0.090352   0.736773   0.123 0.902398
## folF7:phsN       0.677990   0.680997   0.996 0.319452
## folF2:phsO       0.807293   0.181829   4.440 9.00e-06 ***
## folF3:phsO       1.843867   0.172368  10.697  < 2e-16 ***
## folF4:phsO       0.944456   0.171142   5.519 3.42e-08 ***
## folF5:phsO       1.379005   0.230739   5.976 2.28e-09 ***
## folF6:phsO       2.207521   0.278614   7.923 2.31e-15 ***
## folF7:phsO       2.268601   0.285555   7.945 1.95e-15 ***
## phsE:hsM        -0.768999   0.277564  -2.771 0.005597 **
## phsN:hsM         0.116048   0.384438   0.302 0.762756
## phsO:hsM        -0.749638   0.157366  -4.764 1.90e-06 ***
## phsE:hsU        -1.085049   0.271248  -4.000 6.33e-05 ***
## phsN:hsU        -1.073882   0.414078  -2.593 0.009502 **
## phsO:hsU        -1.733336   0.163189 -10.622  < 2e-16 ***
## sexM:hsM        -0.387631   0.102147  -3.795 0.000148 ***
## sexM:hsU        -0.939711   0.098517  -9.539  < 2e-16 ***
## sexM:phsE       -0.845062   0.249652  -3.385 0.000712 ***
## sexM:phsN       -1.795872   0.416142  -4.316 1.59e-05 ***
## sexM:phsO       -0.321143   0.137925  -2.328 0.019892 *
## folF2:hsM       -0.060754   0.150837  -0.403 0.687110
```

```
## folF3:hsM       -0.054860   0.152421  -0.360 0.718905
## folF4:hsM       -0.261435   0.143883  -1.817 0.069218 .
## folF5:hsM       -0.434963   0.213366  -2.039 0.041493 *
## folF6:hsM       -0.390588   0.277239  -1.409 0.158880
## folF7:hsM        0.081375   0.262050   0.311 0.756156
## folF2:hsU       -0.082099   0.145386  -0.565 0.572281
## folF3:hsU       -0.275745   0.148247  -1.860 0.062880 .
## folF4:hsU       -0.404323   0.139235  -2.904 0.003686 **
## folF5:hsU       -0.471991   0.203853  -2.315 0.020594 *
## folF6:hsU       -0.391426   0.263537  -1.485 0.137470
## folF7:hsU       -0.252163   0.261946  -0.963 0.335721
## folF2:sexM:phsE  0.060995   0.267064   0.228 0.819343
## folF3:sexM:phsE -0.265420   0.249532  -1.064 0.287477
## folF4:sexM:phsE  0.032221   0.263387   0.122 0.902634
## folF5:sexM:phsE -0.257966   0.339273  -0.760 0.447045
## folF6:sexM:phsE -0.059436   0.368288  -0.161 0.871790
## folF7:sexM:phsE -0.238535   0.381277  -0.626 0.531564
## folF2:sexM:phsN  0.533570   0.435315   1.226 0.220308
## folF3:sexM:phsN  0.926127   0.419112   2.210 0.027123 *
## folF4:sexM:phsN  0.826525   0.424508   1.947 0.051533 .
## folF5:sexM:phsN  0.553775   0.560467   0.988 0.323123
## folF6:sexM:phsN  1.250819   0.561626   2.227 0.025938 *
## folF7:sexM:phsN  0.816835   0.559884   1.459 0.144583
## folF2:sexM:phsO  0.037583   0.142434   0.264 0.791886
## folF3:sexM:phsO  0.359513   0.135477   2.654 0.007962 **
## folF4:sexM:phsO  0.216729   0.138322   1.567 0.117152
## folF5:sexM:phsO -0.024175   0.187378  -0.129 0.897343
## folF6:sexM:phsO  0.020263   0.219468   0.092 0.926437
## folF7:sexM:phsO -0.618713   0.213670  -2.896 0.003784 **
## sexM:phsE:hsM    0.077533   0.200269   0.387 0.698649
## sexM:phsN:hsM   -0.278977   0.265778  -1.050 0.293873
## sexM:phsO:hsM   -0.022374   0.114425  -0.196 0.844974
## sexM:phsE:hsU   -0.128038   0.206635  -0.620 0.535498
## sexM:phsN:hsU   -0.366011   0.281472  -1.300 0.193483
## sexM:phsO:hsU    0.058691   0.116038   0.506 0.613004
## folF2:phsE:hsM   0.756484   0.356506   2.122 0.033843 *
## folF3:phsE:hsM   0.672907   0.321269   2.095 0.036213 *
## folF4:phsE:hsM   0.738359   0.334166   2.210 0.027136 *
## folF5:phsE:hsM   0.763796   0.414195   1.844 0.065176 .
## folF6:phsE:hsM   0.648801   0.460094   1.410 0.158495
## folF7:phsE:hsM   0.613681   0.512043   1.198 0.230724
## folF2:phsN:hsM  -0.181892   0.467658  -0.389 0.697320
## folF3:phsN:hsM  -0.589400   0.435869  -1.352 0.176298
## folF4:phsN:hsM  -0.049957   0.454315  -0.110 0.912441
## folF5:phsN:hsM   0.242060   0.639211   0.379 0.704921
## folF6:phsN:hsM   1.150659   0.774997   1.485 0.137616
## folF7:phsN:hsM   0.093460   0.726662   0.129 0.897662
## folF2:phsO:hsM   0.120506   0.194993   0.618 0.536573
## folF3:phsO:hsM  -0.039313   0.186576  -0.211 0.833114
## folF4:phsO:hsM   0.160632   0.184765   0.869 0.384637
## folF5:phsO:hsM   0.340376   0.252127   1.350 0.177011
## folF6:phsO:hsM   0.197648   0.306007   0.646 0.518349
## folF7:phsO:hsM  -0.160744   0.296219  -0.543 0.587369
## folF2:phsE:hsU   0.760325   0.352686   2.156 0.031098 *
```

```
## folF3:phsE:hsU   1.258407   0.313470   4.014 5.96e-05 ***
## folF4:phsE:hsU   0.560191   0.334773   1.673 0.094259 .
## folF5:phsE:hsU   0.159343   0.426007   0.374 0.708375
## folF6:phsE:hsU  -0.000973   0.471284  -0.002 0.998353
## folF7:phsE:hsU   0.620992   0.522107   1.189 0.234283
## folF2:phsN:hsU   0.498732   0.493508   1.011 0.312215
## folF3:phsN:hsU   0.384943   0.461919   0.833 0.404644
## folF4:phsN:hsU   0.834619   0.480015   1.739 0.082081 .
## folF5:phsN:hsU   1.211206   0.646443   1.874 0.060979 .
## folF6:phsN:hsU   1.368315   0.810694   1.688 0.091444 .
## folF7:phsN:hsU   1.242935   0.743693   1.671 0.094662 .
## folF2:phsO:hsU   0.286093   0.201581   1.419 0.155828
## folF3:phsO:hsU   0.066035   0.193188   0.342 0.732487
## folF4:phsO:hsU   0.216109   0.193265   1.118 0.263481
## folF5:phsO:hsU   0.283531   0.256582   1.105 0.269148
## folF6:phsO:hsU   0.075639   0.303724   0.249 0.803332
## folF7:phsO:hsU   0.033822   0.307268   0.110 0.912352
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 18660.923  on 167  degrees of freedom
## Residual deviance:    72.448  on  48  degrees of freedom
## AIC: 1223.4
##
## Number of Fisher Scoring iterations: 4
```