class_08_project

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Let's begin by getting the data for this project using the `read.csv()` function and set the correct first row using `row.names = x`.

```
wisc.df <- read.csv("WisconsinCancer.csv", row.names = 1)
head(wisc.df)
```

```
         diagnosis radius_mean texture_mean perimeter_mean area_mean
842302           M       17.99        10.38         122.80    1001.0
842517           M       20.57        17.77         132.90    1326.0
84300903         M       19.69        21.25         130.00    1203.0
84348301         M       11.42        20.38          77.58     386.1
84358402         M       20.29        14.34         135.10    1297.0
843786           M       12.45        15.70          82.57     477.1
         smoothness_mean compactness_mean concavity_mean concave.points_mean
842302           0.11840          0.27760         0.3001             0.14710
842517           0.08474          0.07864         0.0869             0.07017
84300903         0.10960          0.15990         0.1974             0.12790
84348301         0.14250          0.28390         0.2414             0.10520
84358402         0.10030          0.13280         0.1980             0.10430
843786           0.12780          0.17000         0.1578             0.08089
         symmetry_mean fractal_dimension_mean radius_se texture_se perimeter_se
842302          0.2419                0.07871    1.0950     0.9053        8.589
842517          0.1812                0.05667    0.5435     0.7339        3.398
84300903        0.2069                0.05999    0.7456     0.7869        4.585
84348301        0.2597                0.09744    0.4956     1.1560        3.445
84358402        0.1809                0.05883    0.7572     0.7813        5.438
843786          0.2087                0.07613    0.3345     0.8902        2.217
         area_se smoothness_se compactness_se concavity_se concave.points_se
842302    153.40      0.006399        0.04904      0.05373           0.01587
842517     74.08      0.005225        0.01308      0.01860           0.01340
84300903   94.03      0.006150        0.04006      0.03832           0.02058
```

```
84348301   27.23      0.009110        0.07458      0.05661           0.01867
84358402   94.44      0.011490        0.02461      0.05688           0.01885
843786     27.19      0.007510        0.03345      0.03672           0.01137
         symmetry_se fractal_dimension_se radius_worst texture_worst
842302       0.03003             0.006193        25.38         17.33
842517       0.01389             0.003532        24.99         23.41
84300903     0.02250             0.004571        23.57         25.53
84348301     0.05963             0.009208        14.91         26.50
84358402     0.01756             0.005115        22.54         16.67
843786       0.02165             0.005082        15.47         23.75
         perimeter_worst area_worst smoothness_worst compactness_worst
842302            184.60     2019.0           0.1622            0.6656
842517            158.80     1956.0           0.1238            0.1866
84300903          152.50     1709.0           0.1444            0.4245
84348301           98.87      567.7           0.2098            0.8663
84358402          152.20     1575.0           0.1374            0.2050
843786            103.40      741.6           0.1791            0.5249
         concavity_worst concave.points_worst symmetry_worst
842302            0.7119               0.2654         0.4601
842517            0.2416               0.1860         0.2750
84300903          0.4504               0.2430         0.3613
84348301          0.6869               0.2575         0.6638
84358402          0.4000               0.1625         0.2364
843786            0.5355               0.1741         0.3985
         fractal_dimension_worst
842302                   0.11890
842517                   0.08902
84300903                 0.08758
84348301                 0.17300
84358402                 0.07678
843786                   0.12440
```

Notice that this data includes the answers to the question we're trying to find, so we need to create a df that doesn't include the first column

```r
wisc.data <- wisc.df[,-1]
head(wisc.data)
```

```
         radius_mean texture_mean perimeter_mean area_mean smoothness_mean
842302         17.99        10.38         122.80    1001.0         0.11840
842517         20.57        17.77         132.90    1326.0         0.08474
84300903       19.69        21.25         130.00    1203.0         0.10960
```

```
84348301       11.42        20.38          77.58     386.1         0.14250
84358402       20.29        14.34         135.10    1297.0         0.10030
843786         12.45        15.70          82.57     477.1         0.12780
         compactness_mean concavity_mean concave.points_mean symmetry_mean
842302            0.27760         0.3001             0.14710        0.2419
842517            0.07864         0.0869             0.07017        0.1812
84300903          0.15990         0.1974             0.12790        0.2069
84348301          0.28390         0.2414             0.10520        0.2597
84358402          0.13280         0.1980             0.10430        0.1809
843786            0.17000         0.1578             0.08089        0.2087
         fractal_dimension_mean radius_se texture_se perimeter_se area_se
842302                  0.07871    1.0950     0.9053        8.589  153.40
842517                  0.05667    0.5435     0.7339        3.398   74.08
84300903                0.05999    0.7456     0.7869        4.585   94.03
84348301                0.09744    0.4956     1.1560        3.445   27.23
84358402                0.05883    0.7572     0.7813        5.438   94.44
843786                  0.07613    0.3345     0.8902        2.217   27.19
         smoothness_se compactness_se concavity_se concave.points_se
842302        0.006399        0.04904      0.05373           0.01587
842517        0.005225        0.01308      0.01860           0.01340
84300903      0.006150        0.04006      0.03832           0.02058
84348301      0.009110        0.07458      0.05661           0.01867
84358402      0.011490        0.02461      0.05688           0.01885
843786        0.007510        0.03345      0.03672           0.01137
         symmetry_se fractal_dimension_se radius_worst texture_worst
842302       0.03003             0.006193        25.38         17.33
842517       0.01389             0.003532        24.99         23.41
84300903     0.02250             0.004571        23.57         25.53
84348301     0.05963             0.009208        14.91         26.50
84358402     0.01756             0.005115        22.54         16.67
843786       0.02165             0.005082        15.47         23.75
         perimeter_worst area_worst smoothness_worst compactness_worst
842302            184.60     2019.0           0.1622            0.6656
842517            158.80     1956.0           0.1238            0.1866
84300903          152.50     1709.0           0.1444            0.4245
84348301           98.87      567.7           0.2098            0.8663
84358402          152.20     1575.0           0.1374            0.2050
843786            103.40      741.6           0.1791            0.5249
         concavity_worst concave.points_worst symmetry_worst
842302            0.7119               0.2654         0.4601
842517            0.2416               0.1860         0.2750
84300903          0.4504               0.2430         0.3613
84348301          0.6869               0.2575         0.6638
```

```
84358402          0.4000               0.1625         0.2364
843786            0.5355               0.1741         0.3985
         fractal_dimension_worst
842302                   0.11890
842517                   0.08902
84300903                 0.08758
84348301                 0.17300
84358402                 0.07678
843786                   0.12440
```

We still want to be able to know if we get the answer correct, so we can save the diagnosis information as a vector that can be called later, and call it diagnosis.

```
diagnosis <- as.factor(wisc.df$diagnosis)
diagnosis
```

```
  [1] M M M M M M M M M M M M M M M M M M M B B B M M M M M M M M M M M M M M M
 [38] B M M M M M M M M B M B B B B B M M B M M B B B B M B M M B B B B M B M M
 [75] B M B M M B B B M M B M M M B B B M B B M M B B B M M B B B B M B B M B B
[112] B B B B B B M M M B M M B B B M M B M B M M B M M B B M B B M B B B B M B
[149] B B B B B B B B M B B B B M M B M B B M M B B M M B B B B M B B M M M B M
[186] B M B B B M B B M M B M M M M B M M M B M B M B B M B M M M M B B M M B B
[223] B M B B B B B M M B B M B B M M B M B B B B M B B B B B M B M M M M M M M
[260] M M M M M M M B B B B B B M B M B B M B B M B M M B B B B B B B B B B B B
[297] B M B B M B M B B B B B B B B B B B B B B M B B B M B M B B B B M M M B B
[334] B B M B M B M B B B M B B B B B B B M M M B B B B B B B B B B B M M B M M
[371] M B M M B B B B B M B B B B B M B B B M B B M M B B B B B B M B B B B B B
[408] B M B B B B B M B B M B B B B B B B B B B B B M B M M B M B B B B B M B B
[445] M B M B B M B M B B B B B B B B M M B B B B B B M B B B B B B B B B B M B
[482] B B B B B B M B M B B M B B B B B M M B M B M B B B B B M B B M B M B M M
[519] B B B M B B B B B B B B B B B M B M M B B B B B B B B B B B B B B B B B B
[556] B B B B B B B M M M M M M B
Levels: B M
```

Q1. How many observations are in this dataset?

```
#We can use the `nrow` function to call how many rows there are in the set.
nrow(wisc.data)
```

```
[1] 569
```

Using `nrow`, we can show that there are 569 people's data stored in the set.

> Q2. How many of the observations have a malignant diagnosis?

```
table(wisc.df$diagnosis)
```

```

  B   M 
357 212 
```

Using the `table()` function, we can see that there are 357 benign tumours and 212 malignant tumours.

> Q3. How many variables/features in the data are suffixed with _mean?

```
mean_columns <- grep("_mean$", names(wisc.df), value = TRUE)
num_mean_columns <- length(mean_columns)
print(num_mean_columns)
```

```
[1] 10
```

Using the `grep` function, we are able to specify the pattern we're looking for, which in this case is "_mean", and the df we're looking for the pattern in. Then we can use the length function to see that there are 10 columns that end with the word "_mean"

Next we're going to perform a PCA, but before we do we should find out whether or not we need to scale the data by checking the means and standard deviations.

```
colMeans(wisc.data)
```

```
            radius_mean            texture_mean          perimeter_mean 
           1.412729e+01            1.928965e+01            9.196903e+01 
              area_mean         smoothness_mean        compactness_mean 
           6.548891e+02            9.636028e-02            1.043410e-01 
         concavity_mean     concave.points_mean           symmetry_mean 
           8.879932e-02            4.891915e-02            1.811619e-01 
 fractal_dimension_mean               radius_se              texture_se 
           6.279761e-02            4.051721e-01            1.216853e+00 
           perimeter_se                 area_se           smoothness_se 
           2.866059e+00            4.033708e+01            7.040979e-03 
         compactness_se            concavity_se       concave.points_se 
           2.547814e-02            3.189372e-02            1.179614e-02 
            symmetry_se    fractal_dimension_se            radius_worst 
           2.054230e-02            3.794904e-03            1.626919e+01 
          texture_worst         perimeter_worst              area_worst 
           2.567722e+01            1.072612e+02            8.805831e+02 
       smoothness_worst       compactness_worst         concavity_worst 
           1.323686e-01            2.542650e-01            2.721885e-01 
   concave.points_worst          symmetry_worst fractal_dimension_worst 
           1.146062e-01            2.900756e-01            8.394582e-02 
```

```r
apply(wisc.data,2,sd)
```

```
            radius_mean            texture_mean          perimeter_mean 
           3.524049e+00            4.301036e+00            2.429898e+01 
              area_mean         smoothness_mean        compactness_mean 
           3.519141e+02            1.406413e-02            5.281276e-02 
         concavity_mean     concave.points_mean           symmetry_mean 
           7.971981e-02            3.880284e-02            2.741428e-02 
 fractal_dimension_mean               radius_se              texture_se 
           7.060363e-03            2.773127e-01            5.516484e-01 
           perimeter_se                 area_se           smoothness_se 
           2.021855e+00            4.549101e+01            3.002518e-03 
         compactness_se            concavity_se       concave.points_se 
           1.790818e-02            3.018606e-02            6.170285e-03 
            symmetry_se    fractal_dimension_se            radius_worst 
           8.266372e-03            2.646071e-03            4.833242e+00 
          texture_worst         perimeter_worst              area_worst 
           6.146258e+00            3.360254e+01            5.693570e+02 
       smoothness_worst       compactness_worst         concavity_worst 
           2.283243e-02            1.573365e-01            2.086243e-01 
   concave.points_worst          symmetry_worst fractal_dimension_worst 
           6.573234e-02            6.186747e-02            1.806127e-02 
```

Now we can execute a PCA by:

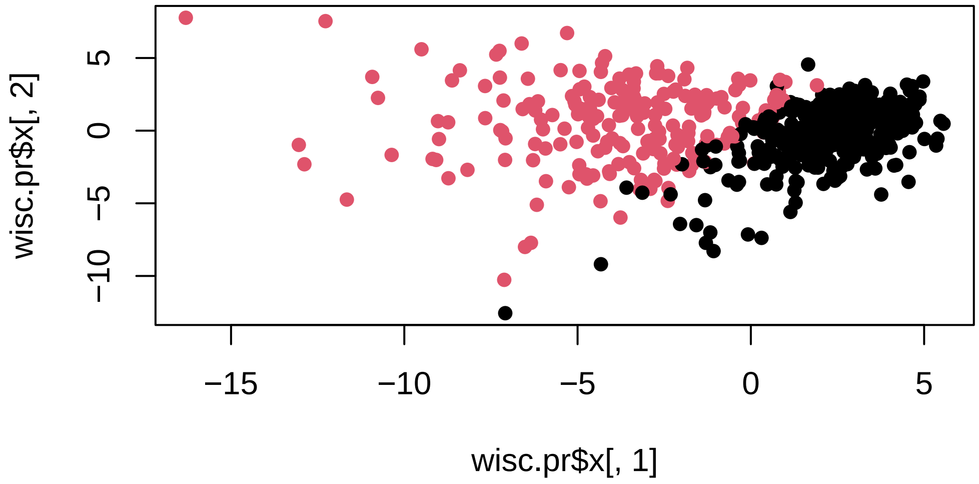
```r
wisc.pr <- prcomp(wisc.data, scale. = TRUE) #we want to scale the data because every colum
summary(wisc.pr)
```

```
Importance of components:
```

```
                          PC1    PC2     PC3     PC4     PC5     PC6     PC7
Standard deviation     3.6444 2.3857 1.67867 1.40735 1.28403 1.09880 0.82172
Proportion of Variance 0.4427 0.1897 0.09393 0.06602 0.05496 0.04025 0.02251
Cumulative Proportion  0.4427 0.6324 0.72636 0.79239 0.84734 0.88759 0.91010
                           PC8    PC9    PC10   PC11    PC12    PC13    PC14
Standard deviation     0.69037 0.6457 0.59219 0.5421 0.51104 0.49128 0.39624
Proportion of Variance 0.01589 0.0139 0.01169 0.0098 0.00871 0.00805 0.00523
Cumulative Proportion  0.92598 0.9399 0.95157 0.9614 0.97007 0.97812 0.98335
                          PC15    PC16    PC17    PC18    PC19    PC20   PC21
Standard deviation     0.30681 0.28260 0.24372 0.22939 0.22244 0.17652 0.1731
Proportion of Variance 0.00314 0.00266 0.00198 0.00175 0.00165 0.00104 0.0010
Cumulative Proportion  0.98649 0.98915 0.99113 0.99288 0.99453 0.99557 0.9966
                          PC22    PC23   PC24    PC25    PC26    PC27    PC28
Standard deviation     0.16565 0.15602 0.1344 0.12442 0.09043 0.08307 0.03987
Proportion of Variance 0.00091 0.00081 0.0006 0.00052 0.00027 0.00023 0.00005
Cumulative Proportion  0.99749 0.99830 0.9989 0.99942 0.99969 0.99992 0.99997
                          PC29    PC30
Standard deviation     0.02736 0.01153
Proportion of Variance 0.00002 0.00000
Cumulative Proportion  1.00000 1.00000
```

We can take a look at the results with

```
plot(wisc.pr$x[,1], wisc.pr$x[,2], col=diagnosis, pch=16)
```



> Q4. From your results, what proportion of the original variance is captured by the first principal components (PC1)?

Using the table, we can see that 44.27% of the variance is captured by the first principal component.

> Q5. How many principal components (PCs) are required to describe at least 70% of the original variance in the data?

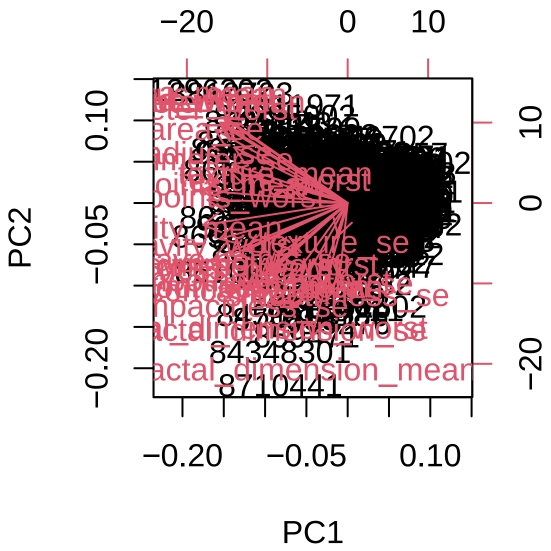
From the table, we can see that PC1-PC3 describes 70% of the original variance.

> Q6. How many principal components (PCs) are required to describe at least 90% of the original variance in the data?

From the able, we can see that PC1-PC7 descibes 90% of the original variance.

We can also create a biplot to visualise the PC data.

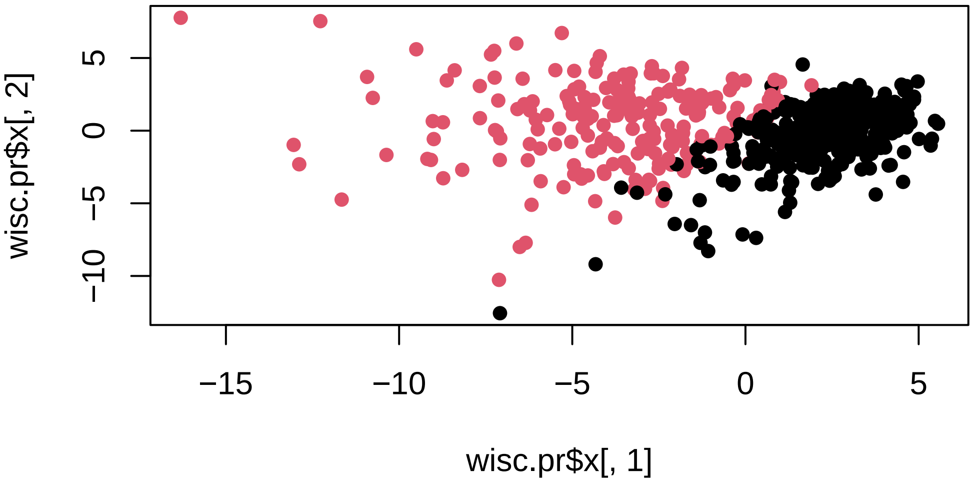
```r
biplot(wisc.pr)
```



> Q7. What stands out to you about this plot? Is it easy or difficult to understand? Why?

It's immediately obvious that this plot as it is is almost impossible to interpret. Generating a scatterplot makes it much easier to see.

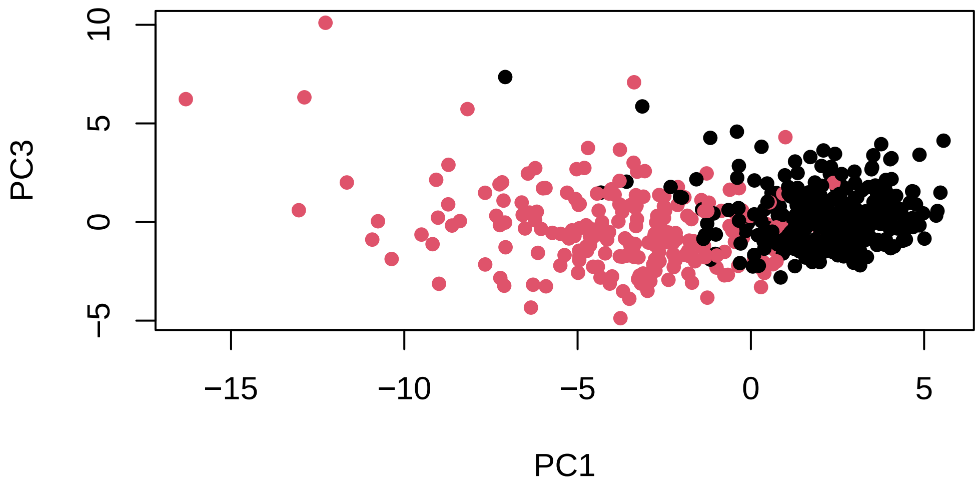
```
plot(wisc.pr$x[,1], wisc.pr$x[,2], col=diagnosis, pch=16)
```



> Q8.Generate a similar plot for principal components 1 and 3. What do you notice about these plots?

We can generate a plot for components 1 and 3 by:

```
plot(wisc.pr$x[, 1 ], wisc.pr$x[,3], col = diagnosis, pch=16,
     xlab = "PC1", ylab = "PC3")
```



We can see that the first plot has a cleaner "line" (it's imaginary) between the two groups.

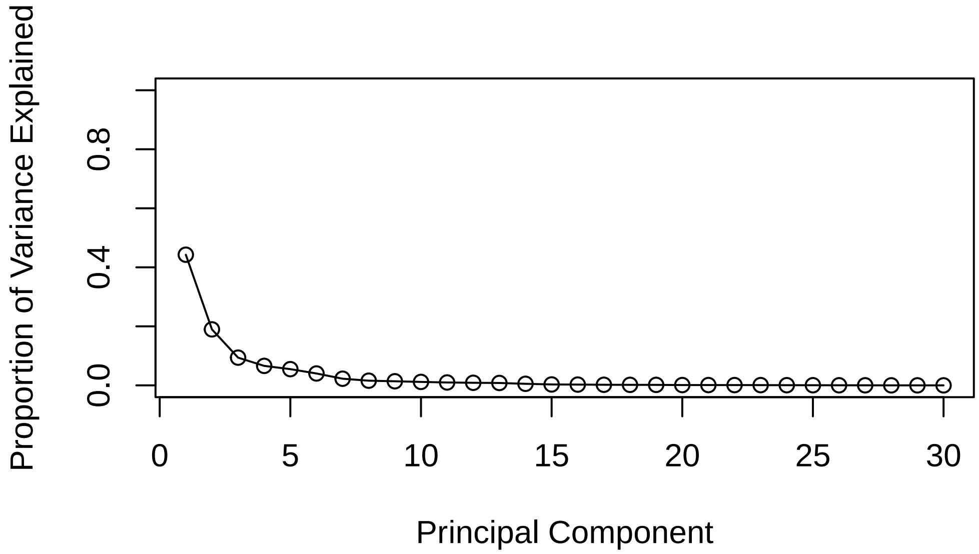
#Variance

```
pr.var <- wisc.pr$sdev^2
head(pr.var)
```

```
[1] 13.281608  5.691355  2.817949  1.980640  1.648731  1.207357
```

We can calculate variance explained by each principal component with some math, and then plot it out.

```
pve <- pr.var / sum(pr.var)
plot(pve, xlab = "Principal Component",
     ylab = "Proportion of Variance Explained",
     ylim = c(0, 1), type = "o")
```



Q9. For the first principal component, what is the component of the loading vector (i.e. wisc.pr$rotation[,1]) for the feature concave.points_mean?

```
wisc.pr$rotation
```

```
                                PC1          PC2          PC3          PC4
radius_mean             -0.21890244  0.233857132 -0.008531243  0.041408962
texture_mean            -0.10372458  0.059706088  0.064549903 -0.603050001
perimeter_mean          -0.22753729  0.215181361 -0.009314220  0.041983099
area_mean               -0.22099499  0.231076711  0.028699526  0.053433795
smoothness_mean         -0.14258969 -0.186113023 -0.104291904  0.159382765
compactness_mean        -0.23928535 -0.151891610 -0.074091571  0.031794581
concavity_mean          -0.25840048 -0.060165363  0.002733838  0.019122753
concave.points_mean     -0.26085376  0.034767500 -0.025563541  0.065335944
symmetry_mean           -0.13816696 -0.190348770 -0.040239936  0.067124984
fractal_dimension_mean  -0.06436335 -0.366575471 -0.022574090  0.048586765
radius_se               -0.20597878  0.105552152  0.268481387  0.097941242
texture_se              -0.01742803 -0.089979682  0.374633665 -0.359855528
perimeter_se            -0.21132592  0.089457234  0.266645367  0.088992415
area_se                 -0.20286964  0.152292628  0.216006528  0.108205039
smoothness_se           -0.01453145 -0.204430453  0.308838979  0.044664180
compactness_se          -0.17039345 -0.232715896  0.154779718 -0.027469363
```

```
concavity_se            -0.15358979 -0.197207283  0.176463743  0.001316880
concave.points_se       -0.18341740 -0.130321560  0.224657567  0.074067335
symmetry_se             -0.04249842 -0.183848000  0.288584292  0.044073351
fractal_dimension_se    -0.10256832 -0.280092027  0.211503764  0.015304750
radius_worst            -0.22799663  0.219866379 -0.047506990  0.015417240
texture_worst           -0.10446933  0.045467298 -0.042297823 -0.632807885
perimeter_worst         -0.23663968  0.199878428 -0.048546508  0.013802794
area_worst              -0.22487053  0.219351858 -0.011902318  0.025894749
smoothness_worst        -0.12795256 -0.172304352 -0.259797613  0.017652216
compactness_worst       -0.21009588 -0.143593173 -0.236075625 -0.091328415
concavity_worst         -0.22876753 -0.097964114 -0.173057335 -0.073951180
concave.points_worst    -0.25088597  0.008257235 -0.170344076  0.006006996
symmetry_worst          -0.12290456 -0.141883349 -0.271312642 -0.036250695
fractal_dimension_worst -0.13178394 -0.275339469 -0.232791313 -0.077053470
                                 PC5           PC6           PC7          PC8
radius_mean             -0.037786354  0.0187407904 -0.1240883403  0.007452296
texture_mean             0.049468850 -0.0321788366  0.0113995382 -0.130674825
perimeter_mean          -0.037374663  0.0173084449 -0.1144770573  0.018687258
area_mean               -0.010331251 -0.0018877480 -0.0516534275 -0.034673604
smoothness_mean          0.365088528 -0.2863744966 -0.1406689928  0.288974575
compactness_mean        -0.011703971 -0.0141309489  0.0309184960  0.151396350
concavity_mean          -0.086375412 -0.0093441809 -0.1075204434  0.072827285
concave.points_mean      0.043861025 -0.0520499505 -0.1504822142  0.152322414
symmetry_mean            0.305941428  0.3564584607 -0.0938911345  0.231530989
fractal_dimension_mean   0.044424360 -0.1194306679  0.2957600240  0.177121441
radius_se                0.154456496 -0.0256032561  0.3124900373 -0.022539967
texture_se               0.191650506 -0.0287473145 -0.0907553556  0.475413139
perimeter_se             0.120990220  0.0018107150  0.3146403902  0.011896690
area_se                  0.127574432 -0.0428639079  0.3466790028 -0.085805135
smoothness_se            0.232065676 -0.3429173935 -0.2440240556 -0.573410232
compactness_se          -0.279968156  0.0691975186  0.0234635340 -0.117460157
concavity_se            -0.353982091  0.0563432386 -0.2088237897 -0.060566501
concave.points_se       -0.195548089 -0.0312244482 -0.3696459369  0.108319309
symmetry_se              0.252868765  0.4902456426 -0.0803822539 -0.220149279
fractal_dimension_se    -0.263297438 -0.0531952674  0.1913949726 -0.011168188
radius_worst             0.004406592 -0.0002906849 -0.0097099360 -0.042619416
texture_worst            0.092883400 -0.0500080613  0.0098707439 -0.036251636
perimeter_worst         -0.007454151  0.0085009872 -0.0004457267 -0.030558534
area_worst               0.027390903 -0.0251643821  0.0678316595 -0.079394246
smoothness_worst         0.324435445 -0.3692553703 -0.1088308865 -0.205852191
compactness_worst       -0.121804107  0.0477057929  0.1404729381 -0.084019659
concavity_worst         -0.188518727  0.0283792555 -0.0604880561 -0.072467871
concave.points_worst    -0.043332069 -0.0308734498 -0.1679666187  0.036170795
```

```
symmetry_worst           0.244558663  0.4989267845 -0.0184906298 -0.228225053
fractal_dimension_worst -0.094423351 -0.0802235245  0.3746576261 -0.048360667
                                 PC9         PC10        PC11         PC12
radius_mean             -0.223109764  0.095486443 -0.04147149  0.051067457
texture_mean             0.112699390  0.240934066  0.30224340  0.254896423
perimeter_mean          -0.223739213  0.086385615 -0.01678264  0.038926106
area_mean               -0.195586014  0.074956489 -0.11016964  0.065437508
smoothness_mean          0.006424722 -0.069292681  0.13702184  0.316727211
compactness_mean        -0.167841425  0.012936200  0.30800963 -0.104017044
concavity_mean           0.040591006 -0.135602298 -0.12419024  0.065653480
concave.points_mean     -0.111971106  0.008054528  0.07244603  0.042589267
symmetry_mean            0.256040084  0.572069479 -0.16305408 -0.288865504
fractal_dimension_mean  -0.123740789  0.081103207  0.03804827  0.236358988
radius_se                0.249985002 -0.049547594  0.02535702 -0.016687915
texture_se              -0.246645397 -0.289142742 -0.34494446 -0.306160423
perimeter_se             0.227154024 -0.114508236  0.16731877 -0.101446828
area_se                  0.229160015 -0.091927889 -0.05161946 -0.017679218
smoothness_se           -0.141924890  0.160884609 -0.08420621 -0.294710053
compactness_se          -0.145322810  0.043504866  0.20688568 -0.263456509
concavity_se             0.358107079 -0.141276243 -0.34951794  0.251146975
concave.points_se        0.272519886  0.086240847  0.34237591 -0.006458751
symmetry_se             -0.304077200 -0.316529830  0.18784404  0.320571348
fractal_dimension_se    -0.213722716  0.367541918 -0.25062479  0.276165974
radius_worst            -0.112141463  0.077361643 -0.10506733  0.039679665
texture_worst            0.103341204  0.029550941 -0.01315727  0.079797450
perimeter_worst         -0.109614364  0.050508334 -0.05107628 -0.008987738
area_worst              -0.080732461  0.069921152 -0.18459894  0.048088657
smoothness_worst         0.112315904 -0.128304659 -0.14389035  0.056514866
compactness_worst       -0.100677822 -0.172133632  0.19742047 -0.371662503
concavity_worst          0.161908621 -0.311638520 -0.18501676 -0.087034532
concave.points_worst     0.060488462 -0.076648291  0.11777205 -0.068125354
symmetry_worst           0.064637806 -0.029563075 -0.15756025  0.044033503
fractal_dimension_worst -0.134174175  0.012609579 -0.11828355 -0.034731693
                               PC13         PC14         PC15        PC16
radius_mean              0.01196721  0.059506135 -0.051118775 -0.15058388
texture_mean             0.20346133 -0.021560100 -0.107922421 -0.15784196
perimeter_mean           0.04410950  0.048513812 -0.039902936 -0.11445396
area_mean                0.06737574  0.010830829  0.013966907 -0.13244803
smoothness_mean          0.04557360  0.445064860 -0.118143364 -0.20461325
compactness_mean         0.22928130  0.008101057  0.230899962  0.17017837
concavity_mean           0.38709081 -0.189358699 -0.128283732  0.26947021
concave.points_mean      0.13213810 -0.244794768 -0.217099194  0.38046410
symmetry_mean            0.18993367  0.030738856 -0.073961707 -0.16466159
```

```
fractal_dimension_mean   0.10623908 -0.377078865  0.517975705 -0.04079279
radius_se               -0.06819523  0.010347413 -0.110050711  0.05890572
texture_se              -0.16822238 -0.010849347  0.032752721 -0.03450040
perimeter_se            -0.03784399 -0.045523718 -0.008268089  0.02651665
area_se                  0.05606493  0.083570718 -0.046024366  0.04115323
smoothness_se            0.15044143 -0.201152530  0.018559465 -0.05803906
compactness_se           0.01004017  0.491755932  0.168209315  0.18983090
concavity_se             0.15878319  0.134586924  0.250471408 -0.12542065
concave.points_se       -0.49402674 -0.199666719  0.062079344 -0.19881035
symmetry_se              0.01033274 -0.046864383 -0.113383199 -0.15771150
fractal_dimension_se    -0.24045832  0.145652466 -0.353232211  0.26855388
radius_worst            -0.13789053  0.023101281  0.166567074 -0.08156057
texture_worst           -0.08014543  0.053430792  0.101115399  0.18555785
perimeter_worst         -0.09696571  0.012219382  0.182755198 -0.05485705
area_worst              -0.10116061 -0.006685465  0.314993600 -0.09065339
smoothness_worst        -0.20513034  0.162235443  0.046125866  0.14555166
compactness_worst        0.01227931  0.166470250 -0.049956014 -0.15373486
concavity_worst          0.21798433 -0.066798931 -0.204835886 -0.21502195
concave.points_worst    -0.25438749 -0.276418891 -0.169499607  0.17814174
symmetry_worst          -0.25653491  0.005355574  0.139888394  0.25789401
fractal_dimension_worst -0.17281424 -0.212104110 -0.256173195 -0.40555649
                                PC17          PC18        PC19         PC20
radius_mean              0.202924255  0.1467123385  0.22538466 -0.049698664
texture_mean            -0.038706119 -0.0411029851  0.02978864 -0.244134993
perimeter_mean           0.194821310  0.1583174548  0.23959528 -0.017665012
area_mean                0.255705763  0.2661681046 -0.02732219 -0.090143762
smoothness_mean          0.167929914 -0.3522268017 -0.16456584  0.017100960
compactness_mean        -0.020307708  0.0077941384  0.28422236  0.488686329
concavity_mean          -0.001598353 -0.0269681105  0.00226636 -0.033387086
concave.points_mean      0.034509509 -0.0828277367 -0.15497236 -0.235407606
symmetry_mean           -0.191737848  0.1733977905 -0.05881116  0.026069156
fractal_dimension_mean   0.050225246  0.0878673570 -0.05815705 -0.175637222
radius_se               -0.139396866 -0.2362165319  0.17588331 -0.090800503
texture_se               0.043963016 -0.0098586620  0.03600985 -0.071659988
perimeter_se            -0.024635639 -0.0259288003  0.36570154 -0.177250625
area_se                  0.334418173  0.3049069032 -0.41657231  0.274201148
smoothness_se            0.139595006 -0.2312599432 -0.01326009  0.090061477
compactness_se          -0.008246477  0.1004742346 -0.24244818 -0.461098220
concavity_se             0.084616716 -0.0001954852  0.12638102  0.066946174
concave.points_se        0.108132263  0.0460549116 -0.01216430  0.068868294
symmetry_se             -0.274059129  0.1870147640 -0.08903929  0.107385289
fractal_dimension_se    -0.122733398 -0.0598230982  0.08660084  0.222345297
radius_worst            -0.240049982 -0.2161013526  0.01366130 -0.005626909
```

```
texture_worst            0.069365185  0.0583984505 -0.07586693  0.300599798
perimeter_worst         -0.234164147 -0.1885435919  0.09081325  0.011003858
area_worst              -0.273399584 -0.1420648558 -0.41004720  0.060047387
smoothness_worst        -0.278030197  0.5015516751  0.23451384 -0.129723903
compactness_worst       -0.004037123 -0.0735745143  0.02020070  0.229280589
concavity_worst         -0.191313419 -0.1039079796 -0.04578612 -0.046482792
concave.points_worst    -0.075485316  0.0758138963 -0.26022962  0.033022340
symmetry_worst           0.430658116 -0.2787138431  0.11725053 -0.116759236
fractal_dimension_worst  0.159394300  0.0235647497 -0.01149448 -0.104991974
                                 PC21        PC22          PC23        PC24
radius_mean             -0.0685700057 -0.07292890 -0.0985526942 -0.18257944
texture_mean             0.4483694667 -0.09480063 -0.0005549975  0.09878679
perimeter_mean          -0.0697690429 -0.07516048 -0.0402447050 -0.11664888
area_mean               -0.0184432785 -0.09756578  0.0077772734  0.06984834
smoothness_mean         -0.1194917473 -0.06382295 -0.0206657211  0.06869742
compactness_mean         0.1926213963  0.09807756  0.0523603957 -0.10413552
concavity_mean           0.0055717533  0.18521200  0.3248703785  0.04474106
concave.points_mean     -0.0094238187  0.31185243 -0.0514087968  0.08402770
symmetry_mean           -0.0869384844  0.01840673 -0.0512005770  0.01933947
fractal_dimension_mean  -0.0762718362 -0.28786888 -0.0846898562 -0.13326055
radius_se                0.0863867747  0.15027468 -0.2641253170 -0.55870157
texture_se               0.2170719674 -0.04845693 -0.0008738805  0.02426730
perimeter_se            -0.3049501584 -0.15935280  0.0900742110  0.51675039
area_se                  0.1925877857 -0.06423262  0.0982150746 -0.02246072
smoothness_se           -0.0720987261 -0.05054490 -0.0598177179  0.01563119
compactness_se          -0.1403865724  0.04528769  0.0091038710 -0.12177779
concavity_se             0.0630479298  0.20521269 -0.3875423290  0.18820504
concave.points_se        0.0343753236  0.07254538  0.3517550738 -0.10966898
symmetry_se             -0.0976995265  0.08465443 -0.0423628949  0.00322620
fractal_dimension_se     0.0628432814 -0.24470508  0.0857810992  0.07519442
radius_worst             0.0072938995  0.09629821 -0.0556767923 -0.15683037
texture_worst           -0.5944401434  0.11111202 -0.0089228997 -0.11848460
perimeter_worst         -0.0920235990 -0.01722163  0.0633448296  0.23711317
area_worst               0.1467901315  0.09695982  0.1908896250  0.14406303
smoothness_worst         0.1648492374  0.06825409  0.0936901494 -0.01099014
compactness_worst        0.1813748671 -0.02967641 -0.1479209247  0.18674995
concavity_worst         -0.1321005945 -0.46042619  0.2864331353 -0.28885257
concave.points_worst     0.0008860815 -0.29984056 -0.5675277966  0.10734024
symmetry_worst           0.1627085487 -0.09714484  0.1213434508 -0.01438181
fractal_dimension_worst -0.0923439434  0.46947115  0.0076253382  0.03782545
                               PC25         PC26         PC27          PC28
radius_mean             -0.01922650 -0.129476396 -0.131526670  2.111940e-01
texture_mean             0.08474593 -0.024556664 -0.017357309 -6.581146e-05
```

```
perimeter_mean           0.02701541 -0.125255946 -0.115415423  8.433827e-02
area_mean               -0.21004078  0.362727403  0.466612477 -2.725083e-01
smoothness_mean          0.02895489 -0.037003686  0.069689923  1.479269e-03
compactness_mean         0.39662323  0.262808474  0.097748705 -5.462767e-03
concavity_mean          -0.09697732 -0.548876170  0.364808397  4.553864e-02
concave.points_mean     -0.18645160  0.387643377 -0.454699351 -8.883097e-03
symmetry_mean           -0.02458369 -0.016044038 -0.015164835  1.433026e-03
fractal_dimension_mean  -0.20722186 -0.097404839 -0.101244946 -6.311687e-03
radius_se               -0.17493043  0.049977080  0.212982901 -1.922239e-01
texture_se               0.05698648 -0.011237242 -0.010092889 -5.622611e-03
perimeter_se             0.07292764  0.103653282  0.041691553  2.631919e-01
area_se                  0.13185041 -0.155304589 -0.313358657 -4.206811e-02
smoothness_se            0.03121070 -0.007717557 -0.009052154  9.792963e-03
compactness_se           0.17316455 -0.049727632  0.046536088 -1.539555e-02
concavity_se             0.01593998  0.091454968 -0.084224797  5.820978e-03
concave.points_se       -0.12954655 -0.017941919 -0.011165509 -2.900930e-02
symmetry_se             -0.01951493 -0.017267849 -0.019975983 -7.636526e-03
fractal_dimension_se    -0.08417120  0.035488974 -0.012036564  1.975646e-02
radius_worst             0.07070972 -0.197054744 -0.178666740  4.126396e-01
texture_worst           -0.11818972  0.036469433  0.021410694 -3.902509e-04
perimeter_worst          0.11803403 -0.244103670 -0.241031046 -7.286809e-01
area_worst              -0.03828995  0.231359525  0.237162466  2.389603e-01
smoothness_worst        -0.04796476  0.012602464 -0.040853568 -1.535248e-03
compactness_worst       -0.62438494 -0.100463424 -0.070505414  4.869182e-02
concavity_worst          0.11577034  0.266853781 -0.142905801 -1.764090e-02
concave.points_worst     0.26319634 -0.133574507  0.230901389  2.247567e-02
symmetry_worst           0.04529962  0.028184296  0.022790444  4.920481e-03
fractal_dimension_worst  0.28013348  0.004520482  0.059985998 -2.356214e-02
                                 PC29          PC30
radius_mean              2.114605e-01  0.7024140910
texture_mean            -1.053393e-02  0.0002736610
perimeter_mean           3.838261e-01 -0.6898969685
area_mean               -4.227949e-01 -0.0329473482
smoothness_mean         -3.434667e-03 -0.0048474577
compactness_mean        -4.101677e-02  0.0446741863
concavity_mean          -1.001479e-02  0.0251386661
concave.points_mean     -4.206949e-03 -0.0010772653
symmetry_mean           -7.569862e-03 -0.0012803794
fractal_dimension_mean   7.301433e-03 -0.0047556848
radius_se                1.184421e-01 -0.0087110937
texture_se              -8.776279e-03 -0.0010710392
perimeter_se            -6.100219e-03  0.0137293906
area_se                 -8.592591e-02  0.0011053260
```

```
smoothness_se            1.776386e-03 -0.0016082109
compactness_se           3.158134e-03  0.0019156224
concavity_se             1.607852e-02 -0.0089265265
concave.points_se       -2.393779e-02 -0.0021601973
symmetry_se             -5.223292e-03  0.0003293898
fractal_dimension_se    -8.341912e-03  0.0017989568
radius_worst            -6.357249e-01 -0.1356430561
texture_worst            1.723549e-02  0.0010205360
perimeter_worst          2.292180e-02  0.0797438536
area_worst               4.449359e-01  0.0397422838
smoothness_worst         7.385492e-03  0.0045832773
compactness_worst        3.566904e-06 -0.0128415624
concavity_worst         -1.267572e-02  0.0004021392
concave.points_worst     3.524045e-02 -0.0022884418
symmetry_worst           1.340423e-02  0.0003954435
fractal_dimension_worst  1.147766e-02  0.0018942925
```

```
wisc.pr$rotation[,1]["concave.points_mean"]
```

```
concave.points_mean 
         -0.2608538 
```

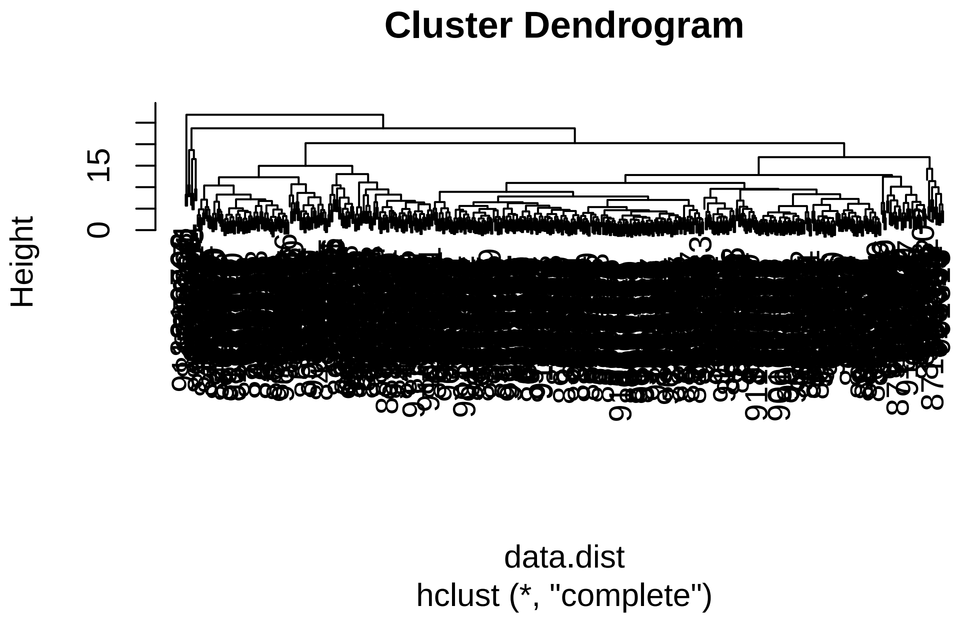
-0.2608538

> Q10. What is the minimum number of principal components required to explain 80% of the variance of the data?

PC1-PC5

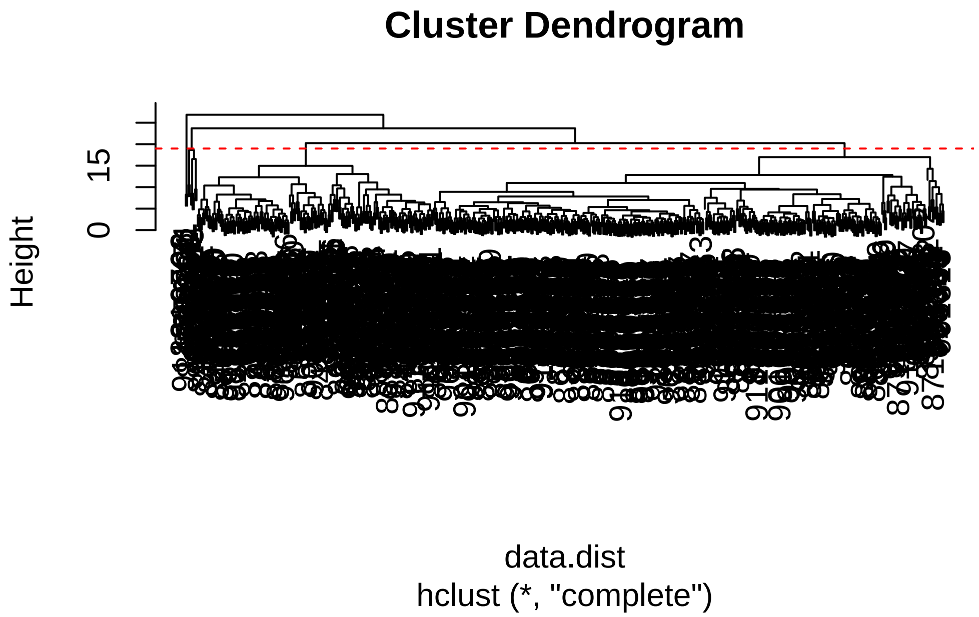
#Hierarchical Clustering

```
data.scaled <- scale(wisc.data) #scaling data
data.dist <- dist(data.scaled)
wisc.hclust <- hclust(data.dist)
plot(wisc.hclust)
```



Q11. Using the plot() and abline() functions, what is the height at which the clustering model has 4 clusters?

```
plot(wisc.hclust) +
abline(h=19, col="red", lty=2)
```



```
integer(0)
```

The clustering model has 4 clusters at h=19

> Q12.Can you find a better cluster vs diagnoses match by cutting into a different number of clusters between 2 and 10?

```
wisc.hclust.clusters <- cutree(wisc.hclust, k=2)
table(wisc.hclust.clusters, diagnosis)
```

```
                    diagnosis
wisc.hclust.clusters   B   M
                   1 357 210
                   2   0   2
```

The best clustering can be found at lower cut numbers because the benign and malignant clusters are split more clearly.

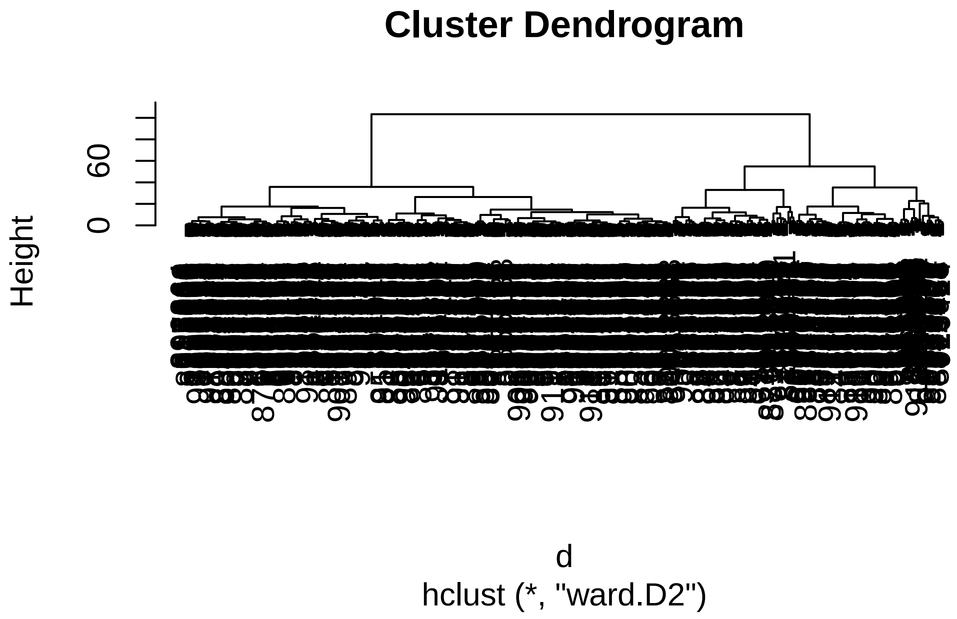
> Q13. Which method gives your favorite results for the same data.dist dataset? Explain your reasoning.

ward.D2 gives my favorite result because it minimizes the variance between clusters, which makes the graph look nice.

#Combining Methods

Instead of using our original data, we can use PCA data, shown below. We're using

```
d <- dist(wisc.pr$x[,1:3])
wisc.pr.hclust <- hclust(d, method="ward.D2")
plot(wisc.pr.hclust)
```



Generate 2 cluster groups from the hclust object by cutting the tree.

```
grps <- cutree(wisc.pr.hclust, k=2)
grps
```

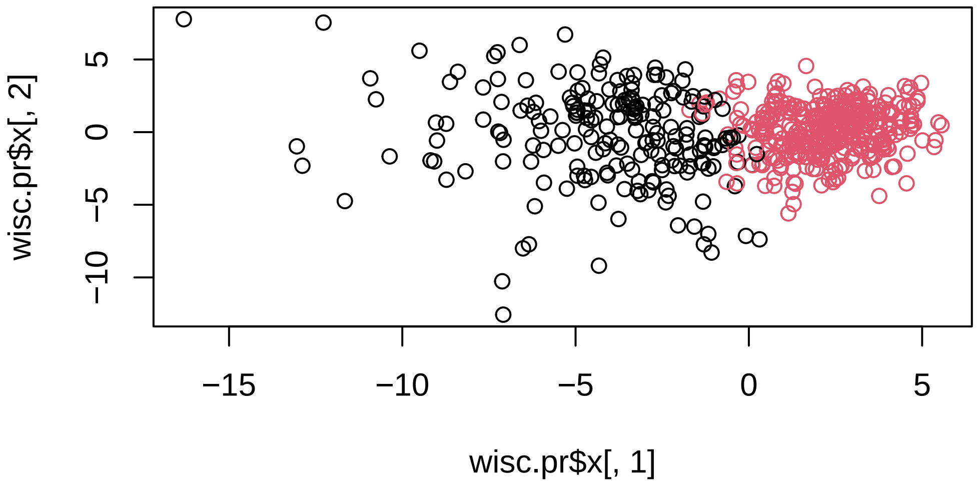
```
  842302   842517 84300903 84348301 84358402   843786   844359 84458202 
       1        1        1        1        1        1        1        1 
  844981 84501001   845636 84610002   846226   846381 84667401 84799002 
       1        1        2        1        1        2        1        1 
  848406 84862001   849014  8510426  8510653  8510824  8511133   851509 
       2        1        1        2        2        2        1        1 
```

```
   852552    852631    852763    852781    852973    853201    853401    853612
        1         1         1         1         1         2         1         1
 85382601    854002    854039    854253    854268    854941    855133    855138
        1         1         1         1         1         2         2         1
   855167    855563    855625    856106  85638502    857010  85713702     85715
        2         1         1         1         2         1         2         1
   857155    857156    857343    857373    857374    857392    857438  85759902
        2         2         2         2         2         1         2         2
   857637    857793    857810    858477    858970    858981    858986    859196
        1         1         2         2         2         2         1         2
 85922302    859283    859464    859465    859471    859487    859575    859711
        1         1         2         2         1         2         1         1
   859717    859983   8610175   8610404   8610629   8610637   8610862   8610908
        1         2         2         2         2         1         1         2
   861103   8611161   8611555   8611792   8612080   8612399  86135501  86135502
        2         1         1         1         2         1         2         1
   861597    861598    861648    861799    861853    862009    862028     86208
        2         1         2         2         2         2         1         1
    86211    862261    862485    862548    862717    862722    862965    862980
        2         2         2         1         2         2         2         2
   862989    863030    863031    863270     86355    864018    864033     86408
        2         1         2         2         1         2         2         2
    86409    864292    864496    864685    864726    864729    864877    865128
        1         2         2         2         2         1         1         2
   865137     86517    865423    865432    865468     86561    866083    866203
        2         1         1         2         2         2         2         1
   866458    866674    866714      8670  86730502    867387    867739    868202
        1         1         2         1         1         2         1         2
   868223    868682    868826    868871    868999    869104    869218    869224
        2         2         1         2         2         2         2         2
   869254    869476    869691  86973701  86973702    869931 871001501 871001502
        2         2         1         2         2         2         2         1
  8710441     87106   8711002   8711003   8711202   8711216    871122    871149
        1         2         2         2         1         2         2         2
  8711561   8711803    871201   8712064   8712289   8712291     87127   8712729
        2         1         1         2         1         2         2         2
  8712766   8712853  87139402     87163     87164    871641    871642    872113
        1         2         2         2         1         2         2         2
   872608  87281702    873357    873586    873592    873593    873701    873843
        1         1         2         2         1         1         1         2
   873885    874158    874217    874373    874662    874839    874858    875093
        2         2         2         2         2         2         1         2
   875099    875263  87556202    875878    875938    877159    877486    877500
```

```
        2         1         1         2         1         1         1         1
   877501    877989    878796     87880     87930    879523    879804    879830
        2         1         1         1         2         2         2         2
  8810158   8810436 881046502   8810528   8810703 881094802   8810955   8810987
        1         2         1         2         1         1         1         1
  8811523   8811779   8811842  88119002   8812816   8812818   8812844   8812877
        2         2         1         1         2         2         2         1
  8813129  88143502  88147101  88147102  88147202    881861    881972  88199202
        2         2         2         2         2         1         1         2
 88203002  88206102    882488  88249602  88299702    883263    883270  88330202
        2         1         2         2         1         1         2         1
 88350402    883539    883852  88411702    884180    884437    884448    884626
        2         2         1         2         1         2         2         1
 88466802    884689    884948  88518501    885429   8860702    886226    886452
        2         2         1         2         1         1         1         1
 88649001    886776    887181  88725602    887549    888264    888570    889403
        1         1         1         1         1         2         1         2
   889719  88995002   8910251   8910499   8910506   8910720   8910721   8910748
        1         1         2         2         2         2         2         2
  8910988   8910996   8911163   8911164   8911230   8911670   8911800   8911834
        1         2         2         2         2         2         2         2
  8912049   8912055     89122   8912280   8912284   8912521   8912909      8913
        1         2         1         1         2         2         2         2
  8913049  89143601  89143602      8915    891670    891703    891716    891923
        1         2         1         2         2         2         2         2
   891936    892189    892214    892399    892438    892604  89263202    892657
        2         2         2         2         1         2         1         2
    89296    893061     89344     89346    893526    893548    893783  89382601
        2         2         2         2         2         2         2         2
 89382602    893988    894047    894089    894090    894326    894329    894335
        2         2         2         2         2         1         1         2
   894604    894618    894855    895100  89511501  89511502     89524    895299
        2         1         2         1         2         2         2         2
  8953902    895633    896839    896864    897132    897137    897374  89742801
        1         1         1         2         2         2         2         1
   897604    897630    897880     89812     89813    898143     89827    898431
        2         1         2         1         1         2         2         1
 89864002    898677    898678     89869    898690    899147    899187    899667
        2         2         2         2         2         2         2         1
   899987   9010018    901011   9010258   9010259    901028   9010333 901034301
        1         1         2         2         2         2         2         2
901034302    901041   9010598   9010872   9010877    901088   9011494   9011495
        2         2         2         2         2         1         1         2
  9011971   9012000   9012315   9012568   9012795    901288   9013005    901303
        1         1         1         2         1         1         2         2
   901315   9013579   9013594   9013838    901549    901836     90250     90251
        1         2         2         1         2         2         2         2
   902727     90291    902975    902976    903011     90312  90317302    903483
        2         2         2         2         2         1         2         2
   903507    903516    903554    903811  90401601  90401602    904302    904357
        1         1         2         2         2         2         2         2
 90439701    904647    904689      9047    904969    904971    905189    905190
        1         2         2         2         2         2         2         2
 90524101    905501    905502    905520    905539    905557    905680    905686
        1         2         2         2         2         2         2         2
   905978  90602302    906024    906290    906539    906564    906616    906878
        2         1         2         2         2         1         2         2
   907145    907367    907409     90745  90769601  90769602    907914    907915
        2         2         2         2         2         2         1         2
   908194    908445    908469    908489    908916    909220    909231    909410
        1         1         2         1         2         2         2         2
   909411    909445  90944601    909777   9110127   9110720   9110732   9110944
        2         1         2         2         1         2         1         2
   911150 911157302   9111596   9111805   9111843    911201    911202   9112085
        2         1         2         1         2         2         2         2
  9112366   9112367   9112594   9112712 911296201 911296202   9113156 911320501
        2         2         2         2         1         1         2         2
911320502   9113239   9113455   9113514   9113538    911366   9113778   9113816
        2         1         2         2         1         2         2         2
   911384   9113846    911391    911408    911654    911673    911685    911916
        2         2         2         2         2         2         2         1
   912193     91227    912519    912558    912600    913063    913102    913505
        2         2         2         2         2         1         2         1
   913512    913535  91376701  91376702    914062    914101    914102    914333
        2         2         2         2         1         2         2         2
   914366    914580    914769     91485    914862     91504     91505    915143
        1         2         1         1         2         1         2         1
   915186    915276  91544001  91544002    915452    915460     91550    915664
        1         1         2         2         2         1         2         2
   915691    915940  91594602    916221    916799    916838    917062    917080
        1         2         2         2         1         1         2         2
   917092  91762702     91789    917896    917897     91805  91813701  91813702
        2         1         2         2         2         2         2         2
   918192    918465     91858  91903901  91903902  91930402    919537    919555
        2         2         2         2         2         1         2         1
 91979701    919812    921092    921362    921385    921386    921644    922296
```

```
        1         2         2         2         2         1         2         2
   922297    922576    922577    922840    923169    923465    923748    923780
        2         2         2         2         2         2         2         2
   924084    924342    924632    924934    924964    925236    925277    925291
        2         2         2         2         2         2         2         2
   925292    925311    925622    926125    926424    926682    926954    927241
        2         2         1         1         1         1         2         1
    92751
        2
```

```
plot(wisc.pr$x[,1], wisc.pr$x[,2], col=grps)
```



```
table(grps)
```

```
grps
  1   2 
203 366 
```

```
table(diagnosis)
```

```
diagnosis
  B   M 
357 212 
```

```
table(diagnosis, grps)
```

```
         grps
diagnosis   1   2
        B  24 333
        M 179  33
```

> Q15. How well does the newly created model with four clusters separate out the two diagnoses?

Fairly well, definitely better than models with more clusters. We can see in the table that there is a pretty clear split between groups which roughly corresponds with the actual diagnoses given by experts.