Class 08: Machine Learning Mini Project

Breast Cancer Project

Today we are going to explore some data from the University of Wisconsin Cancer Center on Breast Biopsy data

```
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
```

```
#diagnosis - M = Malignant, B = benign
```

> Q1. How many patient samples are in this dataset

```
nrow(wisc.df)
```

```
[1] 569
```

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

```
  B   M
357 212
```

There are 569 patients in this dataset.

> Q2. How many cancer (M) and non cancer (B) samples are there?

There are 357, 212 non cancer(B) and cancer(M) samples respectively.

Save the diagnosis for later use as a reference to compare how well we do with PCA etc.

```
diagnosis <- as.factor(wisc.df$diagnosis) # use this for categorical data is ez
#diagnosis
```

Now exclude the diagnosis column from the data

```
wisc <- wisc.df[ , -1] #remove the diagnosis, put it in a new df
ncol(wisc)
```

```
[1] 30
```

> Q3. How many variables/features/dimensions are in the data w/o the diagnosis?

There are 30 features in the data.

#Principal Component Analysis

To perform PCA in R we can use the `prcomp()` function it takes as input a numeric dataset and optional `scale = FALSE/TRUE` argument

PCA aims to take a dataset with lots of dimensions and flattens it to 2 or 3 dimensions

Scaling is an issue, the largest number factor will dominate the PCA without scaling

We generally always want to set the `scale = TRUE` but let's make sure by checking if the mean and stdev values are different across these 30 columns

```
round( colMeans(wisc))
```

```
            radius_mean            texture_mean          perimeter_mean
                     14                      19                      92
              area_mean         smoothness_mean        compactness_mean
                    655                       0                       0
         concavity_mean     concave.points_mean           symmetry_mean
                      0                       0                       0
 fractal_dimension_mean               radius_se              texture_se
                      0                       0                       1
           perimeter_se                 area_se           smoothness_se
                      3                      40                       0
         compactness_se           concavity_se      concave.points_se
                      0                       0                       0
             symmetry_se    fractal_dimension_se            radius_worst
                      0                       0                      16
          texture_worst         perimeter_worst              area_worst
                     26                     107                     881
       smoothness_worst       compactness_worst         concavity_worst
                      0                       0                       0
    concave.points_worst          symmetry_worst fractal_dimension_worst
                      0                       0                       0
```

```
pca <- prcomp(wisc, scale = T)
summary(pca)
```

```
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
```

```
#these are ordered by importance (proportion)
```

> Q4: What proportion of the original variance is captured by the first princiapl components (PC1)?

Approximately 44% is captured by PC1.

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

3 PCs are needed to get to 73% of the variance.

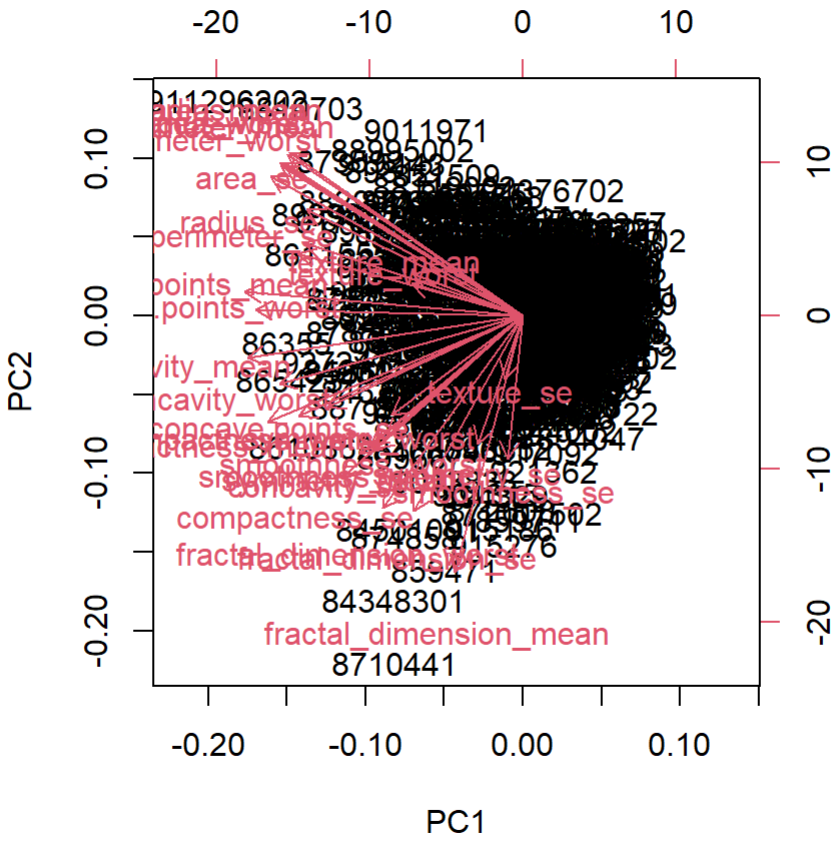
> Q6 How many principal components (PCs) are requred to describe at least 90% of the original variance in the data?

7 principal components are required to describe at least 90% of the original variance.

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

It is extremely difficult to understand as the data points and labels are overlapping and it is illegible.

```
biplot(pca)
```

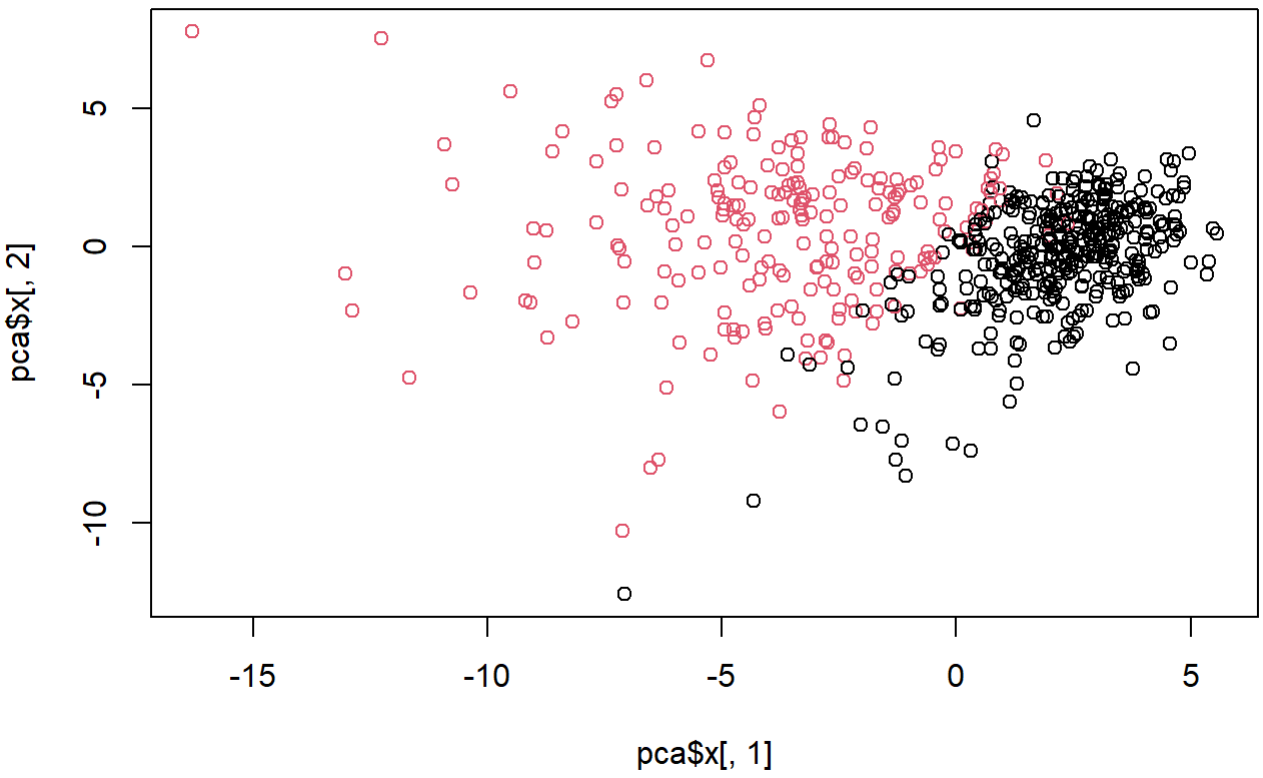



```
attributes(pca)
```

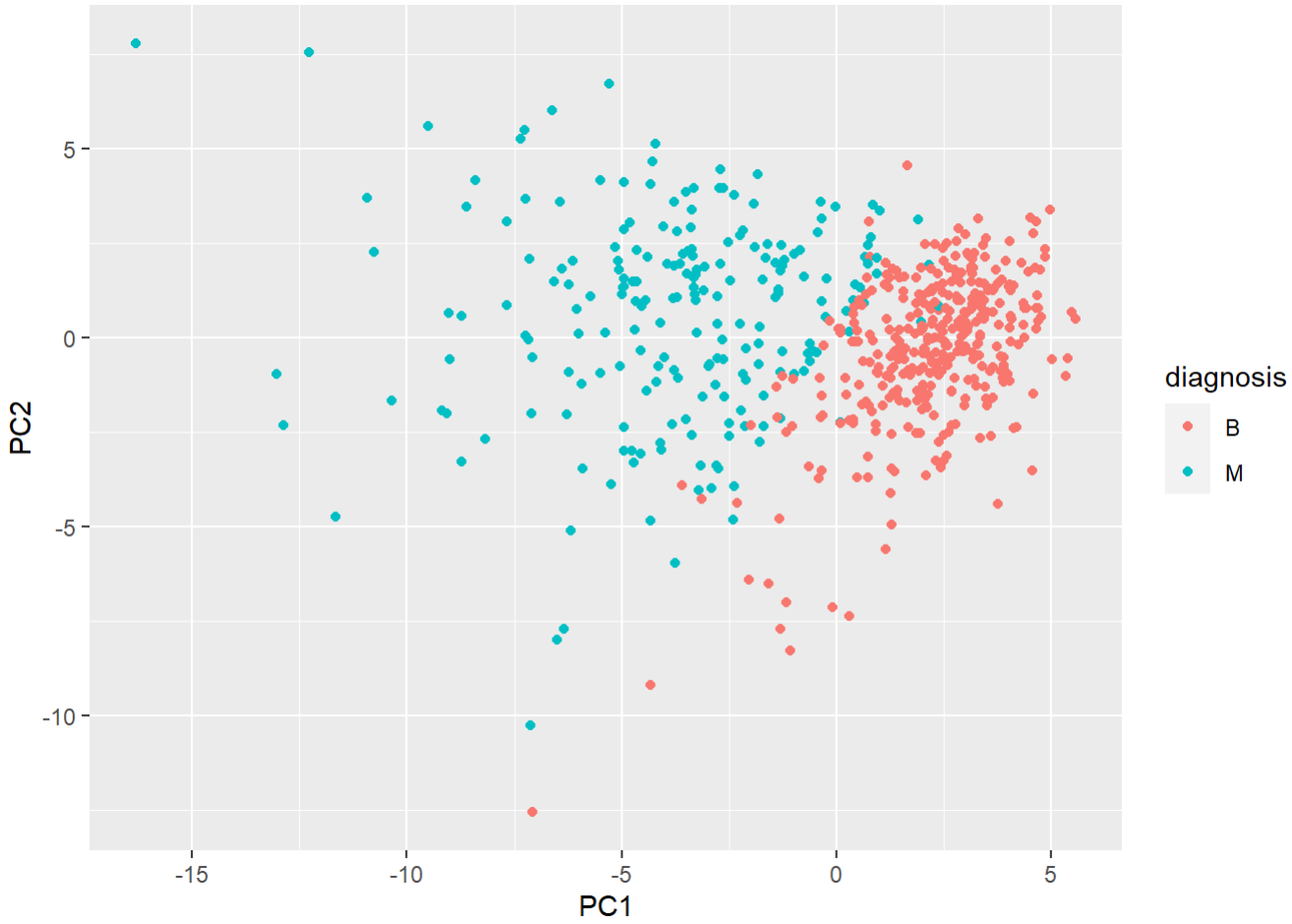
```
$names
[1] "sdev"     "rotation" "center"   "scale"    "x"

$class
[1] "prcomp"
```

```
plot(pca$x[ ,1], pca$x[ ,2], col = diagnosis) #gives where these patients lie on the axes
```



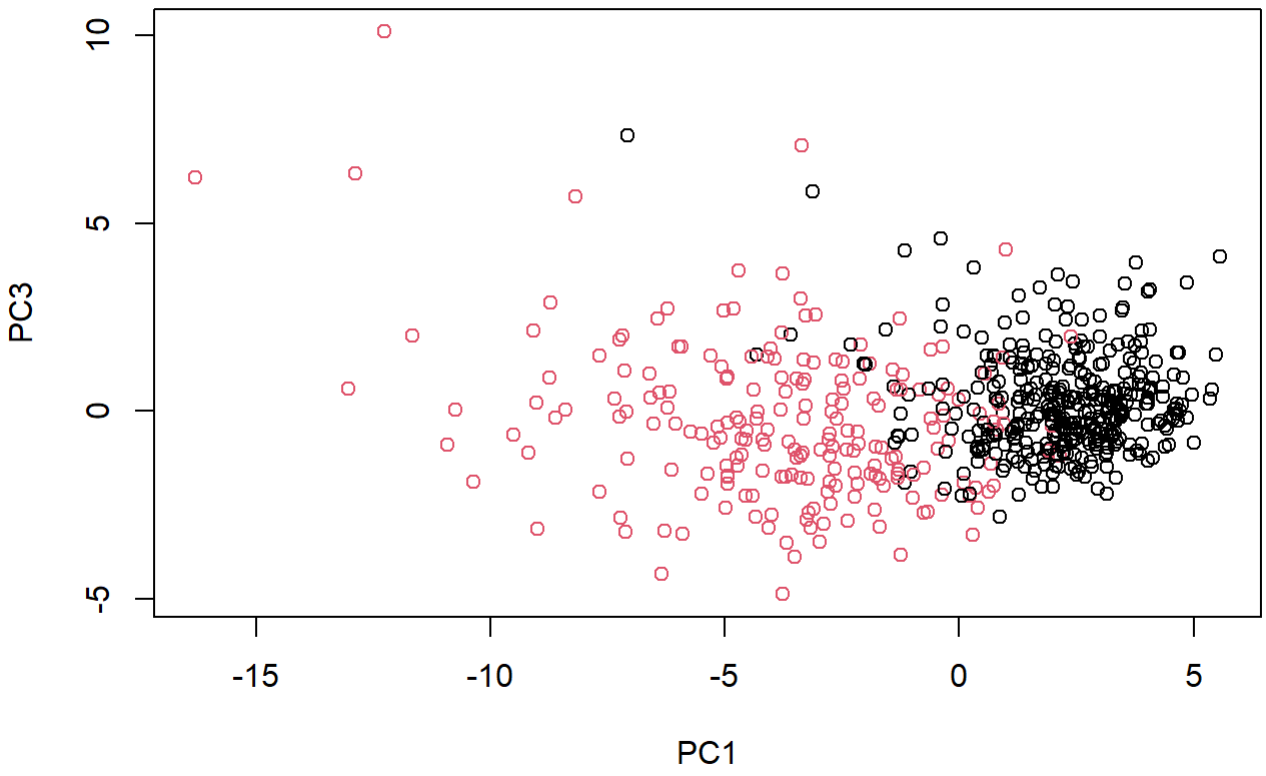

```
#same plot as above but in ggplot
x<-as.data.frame(pca$x)
library(ggplot2)
ggplot(x) +
  aes(PC1, PC2, col = diagnosis) +
  geom_point()
```



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

These plots are very similar but the second plot seems to be more centered around the 0 point of the PC axes.

```
plot(pca$x[ ,1], pca$x[ ,3], col = diagnosis,
     xlab = "PC1", ylab = "PC3")
```



> Q. How much variance is captured in the top 3 PCs?

72.6% of the variance is captured in the top PCs.

```
summary(pca)
```

```
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
```

```
#cumulative proportion at PC3 is .72636 = 72.6%
```

> 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?

This tells us how much this original feature contributes to the first PC

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

You need a minimum of 5 principal components to explain at least 80% of the variance in the data.

The weight is `rpca$rotation["concave.points_mean", 1]` for `concave.points_mean`

```
pca$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
```

```r
  #This is the weight of each variable in each PC

pca$rotation["concave.points_mean", 1]
```

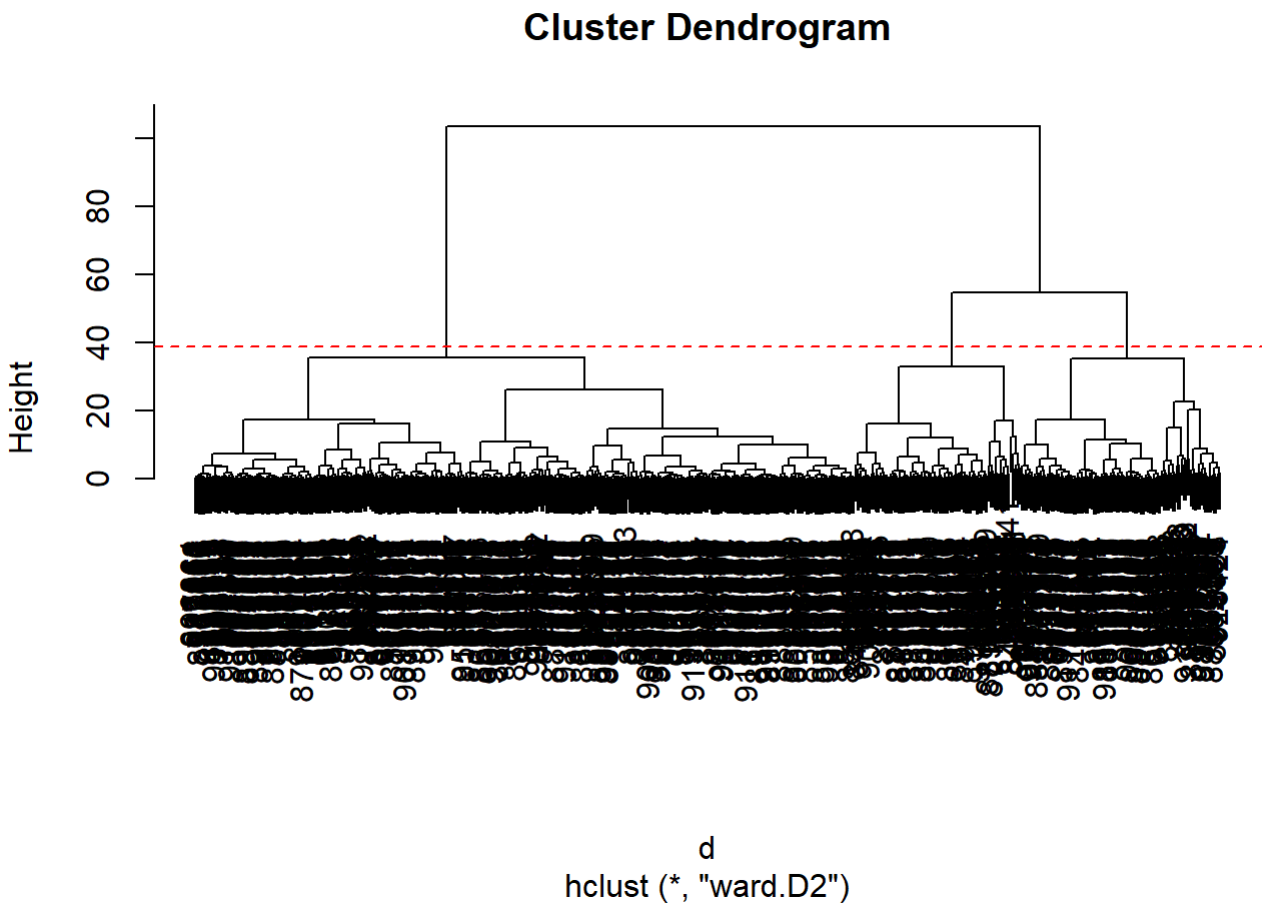
```
[1] -0.2608538
```

#Combining Methods

We can use our new PCA variables(i.e. the scores along the PCs contained in t `pca$x`) as input for other methods such as clustering

```r
#prcomp(data, scale = true)
d <- dist(pca$x[ , 1:3])

#hclust(dist(data), method =) hclust needs a distance matrix as input
hc <- hclust(d, method = 'ward.D2')
plot(hc)
abline(h = 39, col = 'red', lty = 2)
```



> Q11: What is the height at which the clustering model has 4 clusters?

The clustering model above has 4 clusters at about a height at h = 39.

To get our cluster membership vector we can use the `cutree()` function and specify a height (`h`) or the number of groups(`k`)

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

Yes the higher the number of clusters the more distinct the cluster identity is at the tail ends of the groups. However, there will always be a spread and overlapping diagnoses within the center groups.

> Q13: Which methods gives your favorite results for the same data.dist dataset?

I like to use `ward.d2` because I was able to grasp how that works during lecture and it helps me to understand what is happening overall with the data.

```
#cutree(hc, h = 80) #Cut the tree at height of 80
cutree(hc, k = 2) #Cut the tree to give me 2 groups
```

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							

```
#table(cutree(hc,h = 80))
grps <-(cutree(hc,k = 5 ))
table(grps)
```

```
grps
  1   2   3   4   5
 33  78  92 216 150
```

I want to find out how many diagnosis "M" and "B" are in each group. How?

```
table(diagnosis)
```

```
diagnosis
  B   M
357 212
```

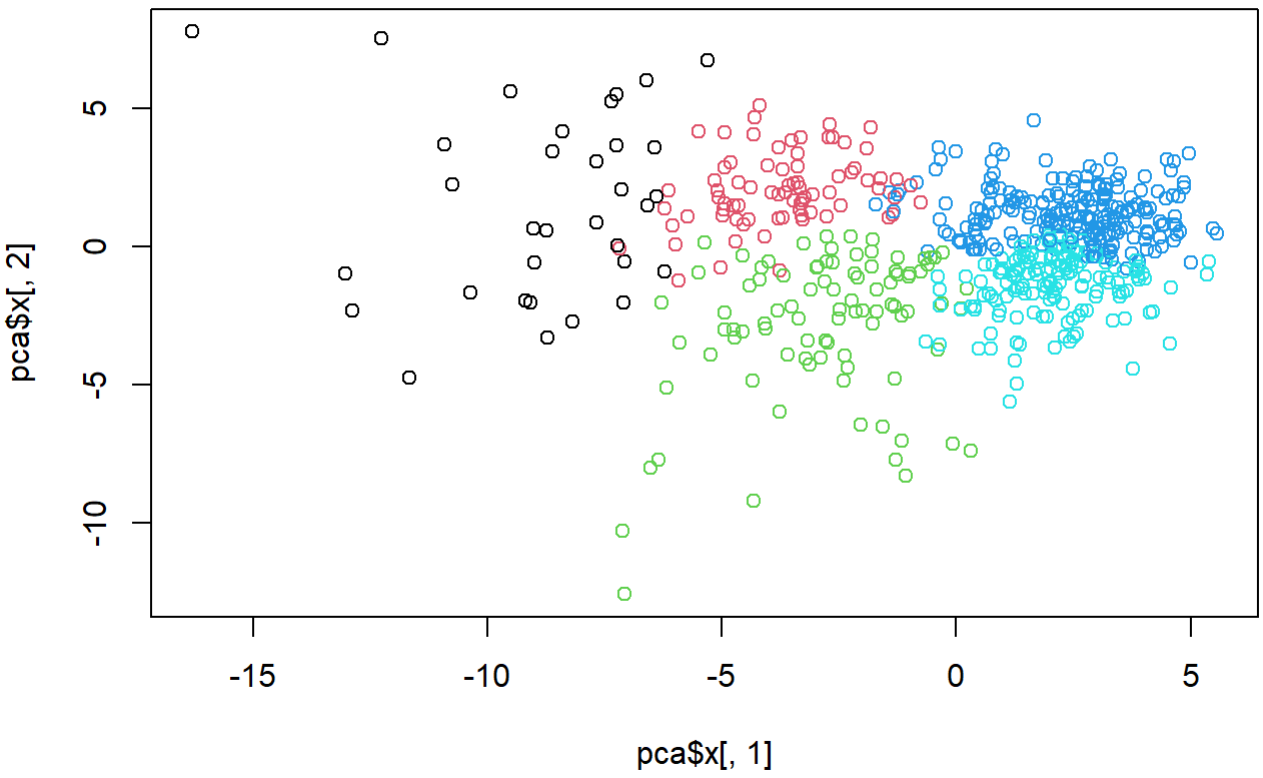
```
table(diagnosis, grps) #tells u how many b and m are in groups 1 and 2 in a confusing way
```

```
         grps
diagnosis   1   2   3   4   5
        B   0   0  24 184 149
        M  33  78  68  32   1
```

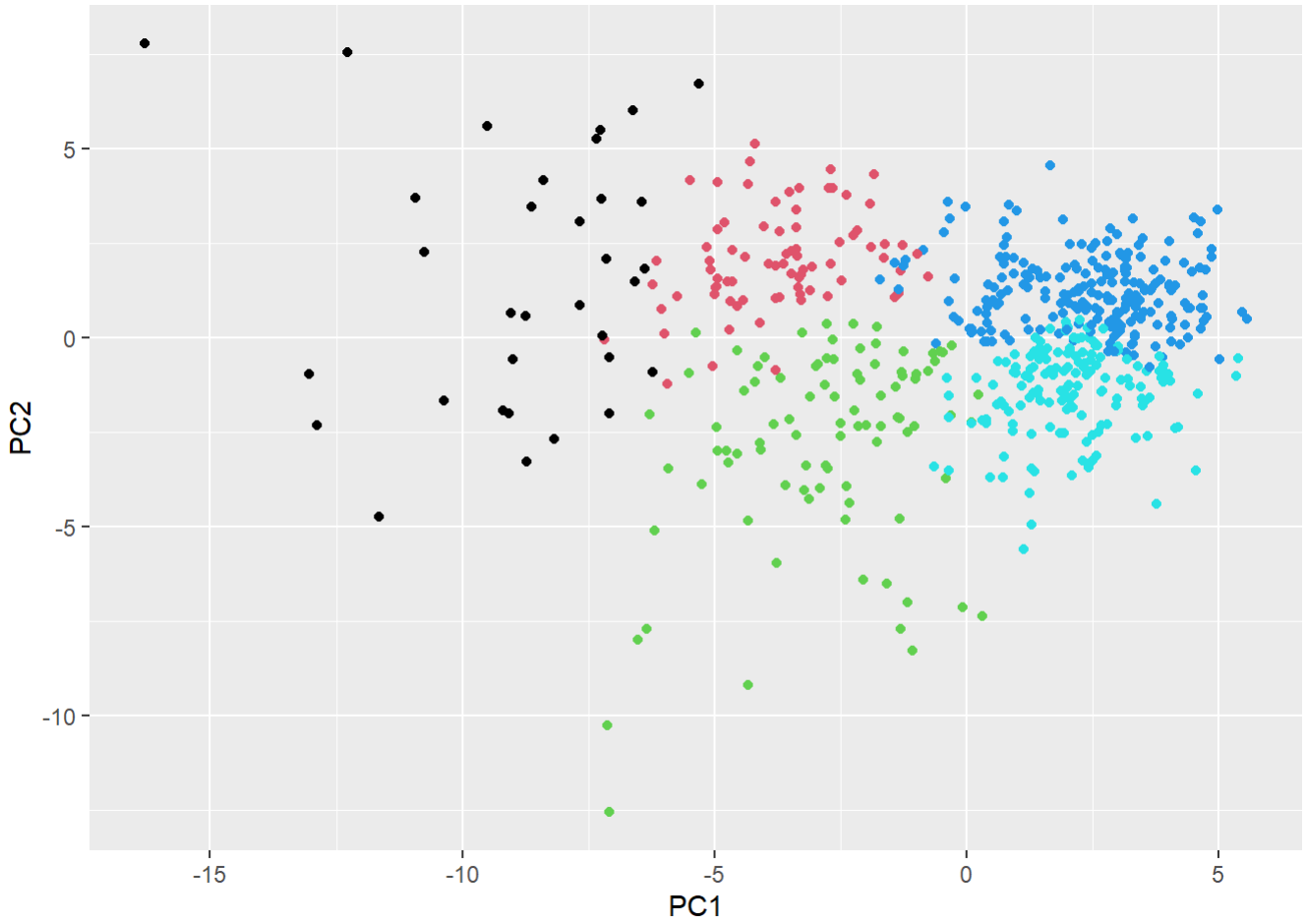
```
  #in grp 1 there were 179 malignant and 24 benign samples
  #in grp 2 there were  33 malignant and 333 benign samples
```

We can also plot our results using our clustering vector `grps`

```
plot(pca$x[ ,1], pca$x[ ,2], col = grps) #gives where these patients lie on the axes
```




```
x<-as.data.frame(pca$x)
library(ggplot2)
ggplot(x) +
  aes(PC1, PC2) +
  geom_point(col = grps)
```




```
#the overlap in both plots comes from the fact that we clustered by PC 1:3 but only plotted PC1:2
```

> Q15/ What is the specificity and sensitivity of our current results

Sensitivity - do u capture all 'positives'

Specificity - how well do u distinguish healthy from positive patients

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

```
         grps
diagnosis   1   2   3   4   5
        B   0   0  24 184 149
        M  33  78  68  32   1
```

```
sensitivity = 179/(179 + 33) # TP/(TP+FN) TP = True Pos, FN =
specificity = 333/(333 + 33) # TN/(TN+FN) TN = True Neg,
```

#Prediction

```
url <- "new_samples.csv"
url <- "https://tinyurl.com/new-samples-CSV"
new <- read.csv(url)
npc <- predict(pca, newdata=new)
npc
```

```
          PC1       PC2        PC3        PC4       PC5        PC6        PC7
[1,]  2.576616 -3.135913  1.3990492 -0.7631950  2.781648 -0.8150185 -0.3959098
[2,] -4.754928 -3.009033 -0.1660946 -0.6052952 -1.140698 -1.2189945  0.8193031
           PC8       PC9       PC10      PC11      PC12      PC13     PC14
[1,] -0.2307350 0.1029569 -0.9272861 0.3411457  0.375921 0.1610764 1.187882
[2,] -0.3307423 0.5281896 -0.4855301 0.7173233 -1.185917 0.5893856 0.303029
          PC15       PC16        PC17        PC18        PC19       PC20
[1,] 0.3216974 -0.1743616 -0.07875393 -0.11207028 -0.08802955 -0.2495216
[2,] 0.1299153  0.1448061 -0.40509706  0.06565549  0.25591230 -0.4289500
          PC21       PC22       PC23       PC24        PC25         PC26
[1,]  0.1228233 0.09358453 0.08347651  0.1223396  0.02124121  0.078884581
[2,] -0.1224776 0.01732146 0.06316631 -0.2338618 -0.20755948 -0.009833238
             PC27        PC28         PC29         PC30
[1,]  0.220199544 -0.02946023 -0.015620933  0.005269029
[2,] -0.001134152  0.09638361  0.002795349 -0.019015820
```