Class 09 Mini-Project

Shivani Khosla (PID: A59010433)

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read in data

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

show dataframe

```
#wisc.df
```

remove first column(expert diagonosis)

```
wisc.data <- wisc.df[,-1]
```

expert diagnosis

```
diagnosis <- as.factor(wisc.df[,1])
```

Q1. How many observations are in this dataset?

```
nrow(wisc.data)
```

```
## [1] 569
```

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

```
length(which(diagnosis == "M"))
```

```
## [1] 212
```

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

```
sum(grepl("*_mean", colnames(wisc.data)))
```

```
## [1] 10
```

checking means and standard devs for each column to see if it needs to be scaled

```
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
```

```
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
```

need to scale because values are vastly different among columns

```
wisc.pr <- prcomp(wisc.data, scale = TRUE)
wisc.pr
```

```
## Standard deviations (1, .., p=30):
```

```
##  [1] 3.64439401 2.38565601 1.67867477 1.40735229 1.28402903 1.09879780
##  [7] 0.82171778 0.69037464 0.64567392 0.59219377 0.54213992 0.51103950
## [13] 0.49128148 0.39624453 0.30681422 0.28260007 0.24371918 0.22938785
## [19] 0.22243559 0.17652026 0.17312681 0.16564843 0.15601550 0.13436892
## [25] 0.12442376 0.09043030 0.08306903 0.03986650 0.02736427 0.01153451
##
## Rotation (n x k) = (30 x 30):
##                                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
```

summary of PCA

```
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
```

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

44.27%

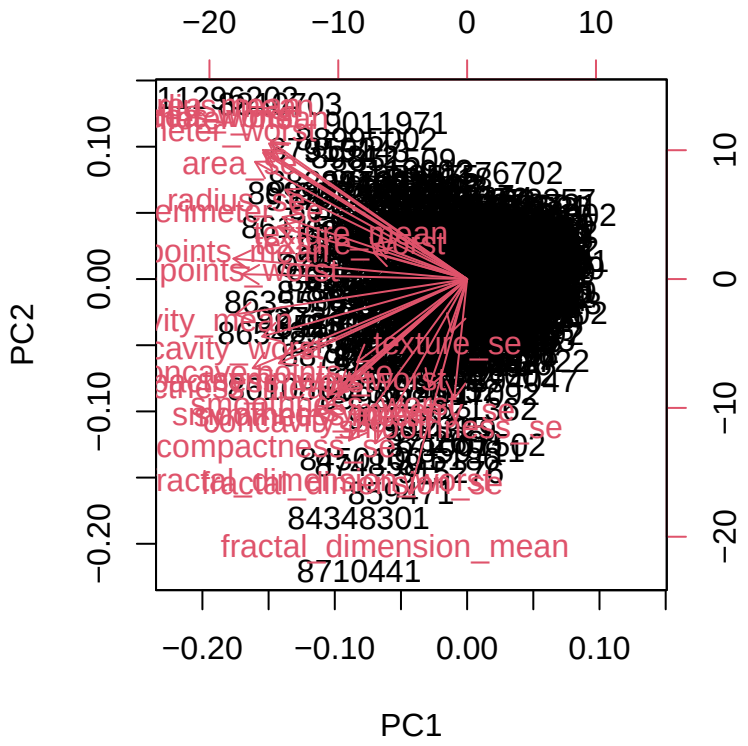
Q5. How many principal components (PCs) are required to describe at least 70% of the original variance in the data?

3 PCs, this gives 72.6% of the variance

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

7 PCs, this gives 91% of the variance

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

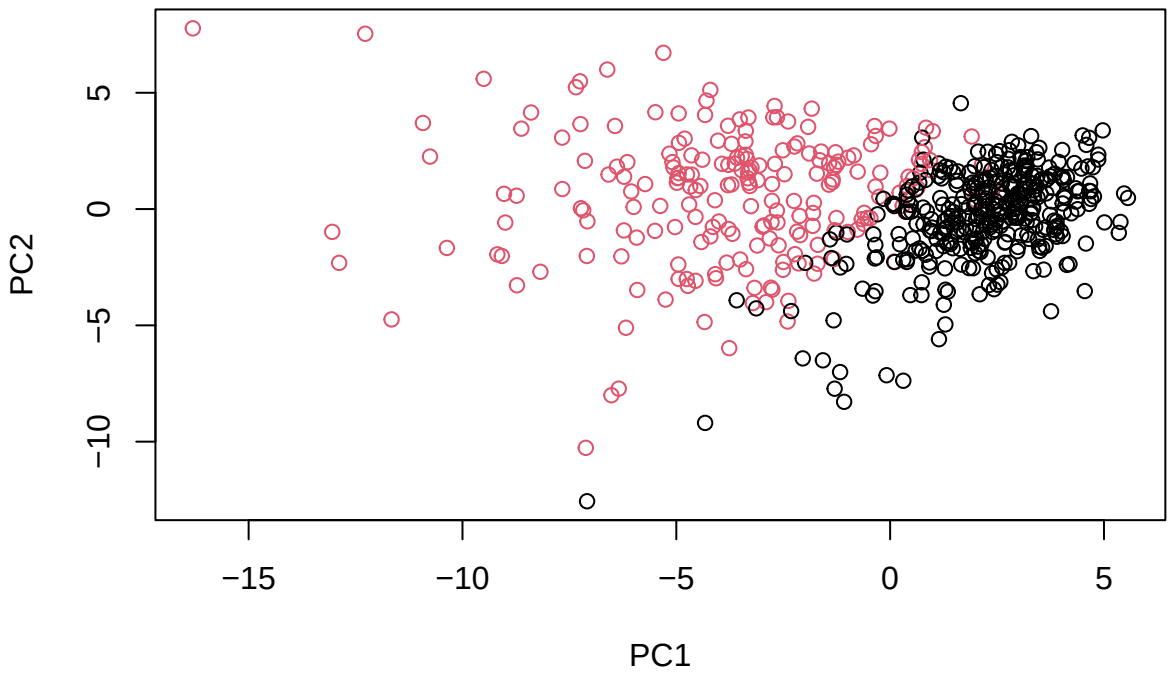


> Q7. What stands out to you about this plot? Is it easy or difficult to understand? Why?

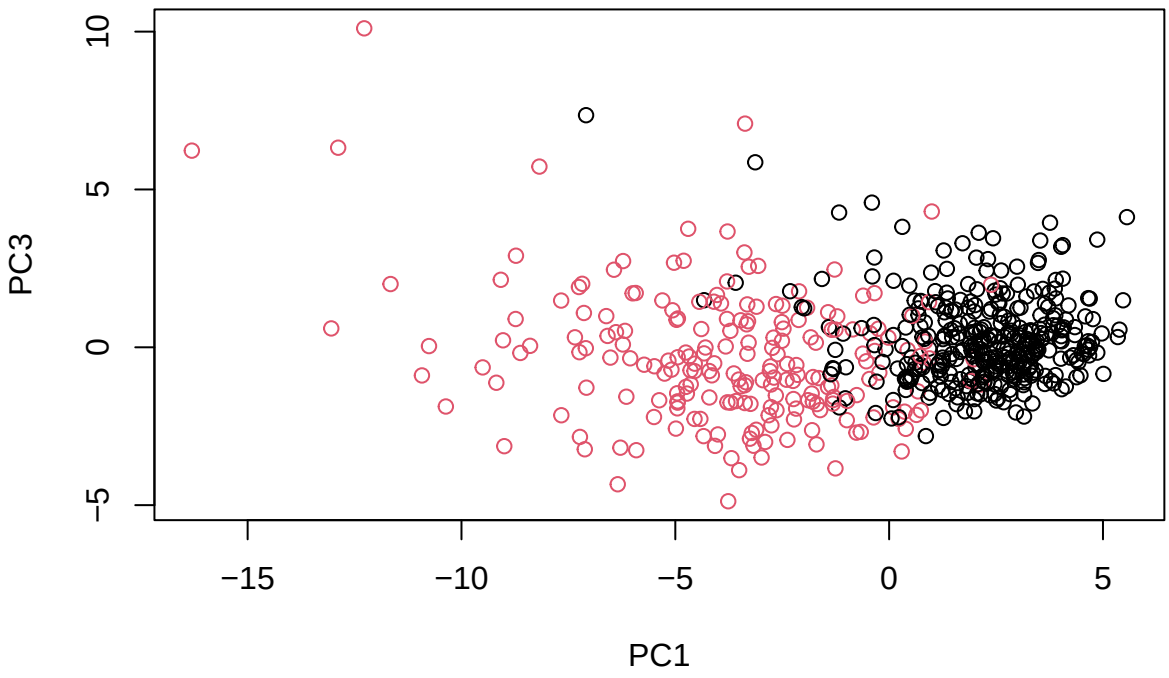
The column labels are blocking the points, which are listed as numeric values rather than dots. This is very difficult to understand.

plot for PC1 and PC2

```
plot(wisc.pr$x[,1:2], col = diagnosis ,
     xlab = "PC1", ylab = "PC2")
```




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

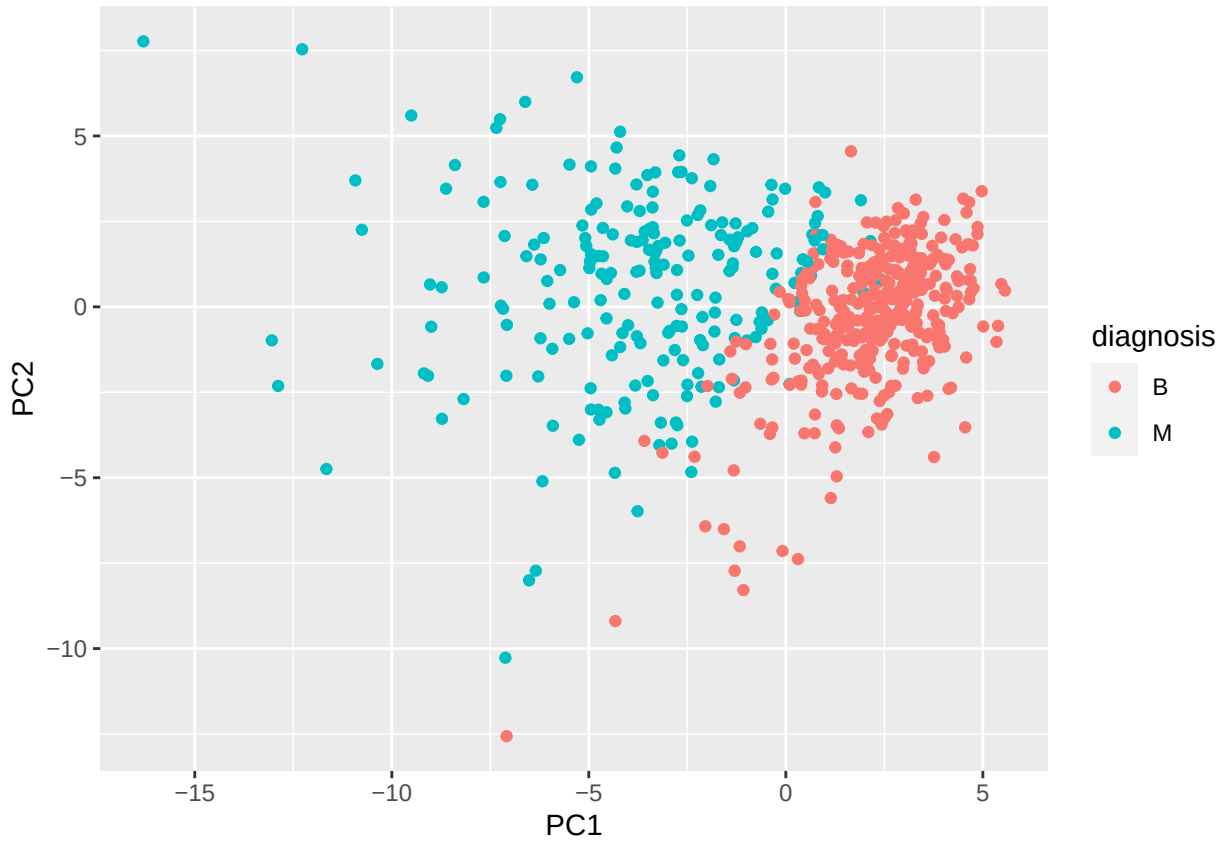


making ggplot scatterplot for PC1 vs PC2

```
df <- as.data.frame(wisc.pr$x)
df$diagnosis <- diagnosis

library(ggplot2)

ggplot(df) +
  aes(PC1, PC2, col=diagnosis) +
  geom_point()
```



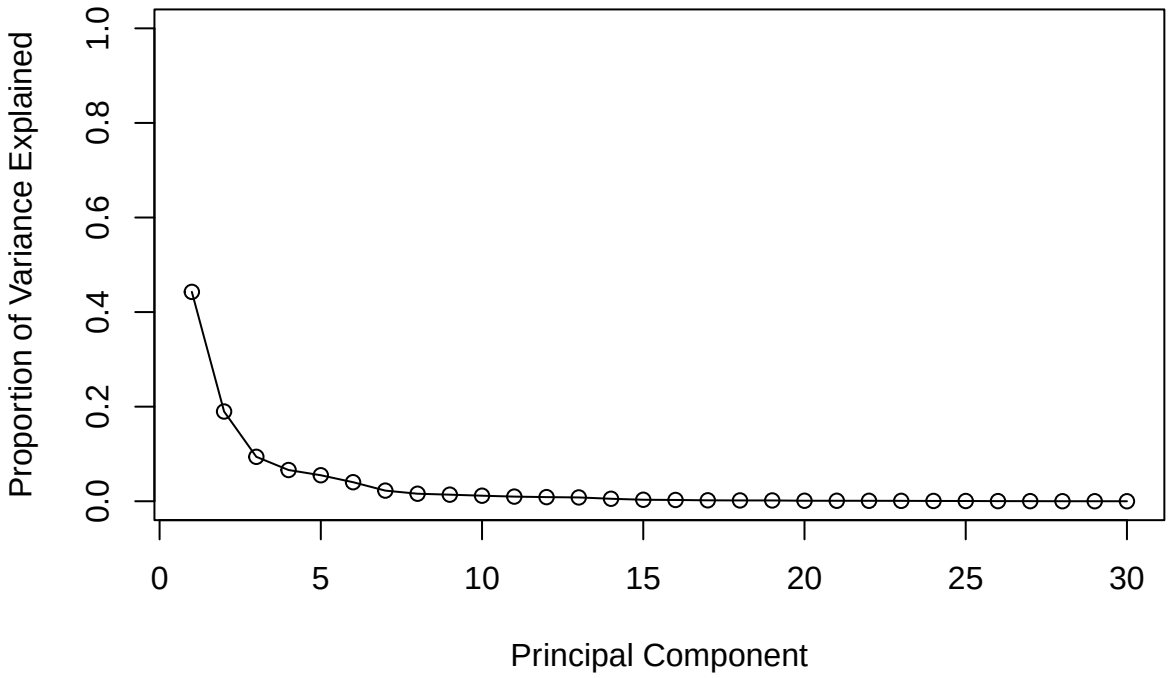
variance of each PC

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

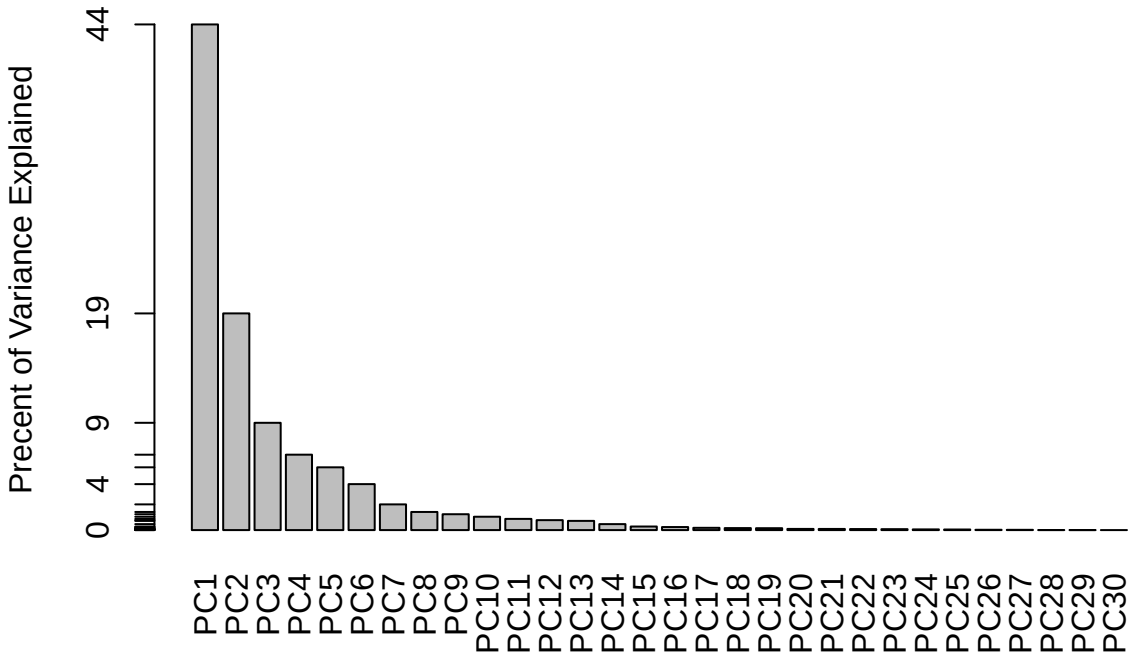
```
## [1] 13.281608  5.691355  2.817949  1.980640  1.648731  1.207357
```

```
# Variance explained by each principal component: pve
pve <- pr.var / sum(pr.var)

# Plot variance explained for each principal component
plot(pve, xlab = "Principal Component",
     ylab = "Proportion of Variance Explained",
     ylim = c(0, 1), type = "o")
```




```
# Alternative scree plot of the same data, note data driven y-axis
barplot(pve, ylab = "Precent of Variance Explained",
     names.arg=paste0("PC",1:length(pve)), las=2, axes = FALSE)
axis(2, at=pve, labels=round(pve,2)*100 )
```



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[,1]
```

```
##             radius_mean            texture_mean          perimeter_mean
##              -0.21890244              -0.10372458              -0.22753729
##               area_mean         smoothness_mean        compactness_mean
##              -0.22099499              -0.14258969              -0.23928535
##          concavity_mean     concave.points_mean           symmetry_mean
##              -0.25840048              -0.26085376              -0.13816696
##  fractal_dimension_mean               radius_se              texture_se
##              -0.06436335              -0.20597878              -0.01742803
##            perimeter_se                 area_se           smoothness_se
##              -0.21132592              -0.20286964              -0.01453145
##          compactness_se            concavity_se       concave.points_se
##              -0.17039345              -0.15358979              -0.18341740
##             symmetry_se    fractal_dimension_se             radius_worst
##              -0.04249842              -0.10256832              -0.22799663
##           texture_worst         perimeter_worst              area_worst
##              -0.10446933              -0.23663968              -0.22487053
##         smoothness_worst       compactness_worst         concavity_worst
##              -0.12795256              -0.21009588              -0.22876753
##     concave.points_worst          symmetry_worst fractal_dimension_worst
##              -0.25088597              -0.12290456              -0.13178394
```

-0.26085376

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

```
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
```

5

```
data.scaled <- scale(wisc.data)
```

```
data.dist <- dist(data.scaled)
#data.dist
```

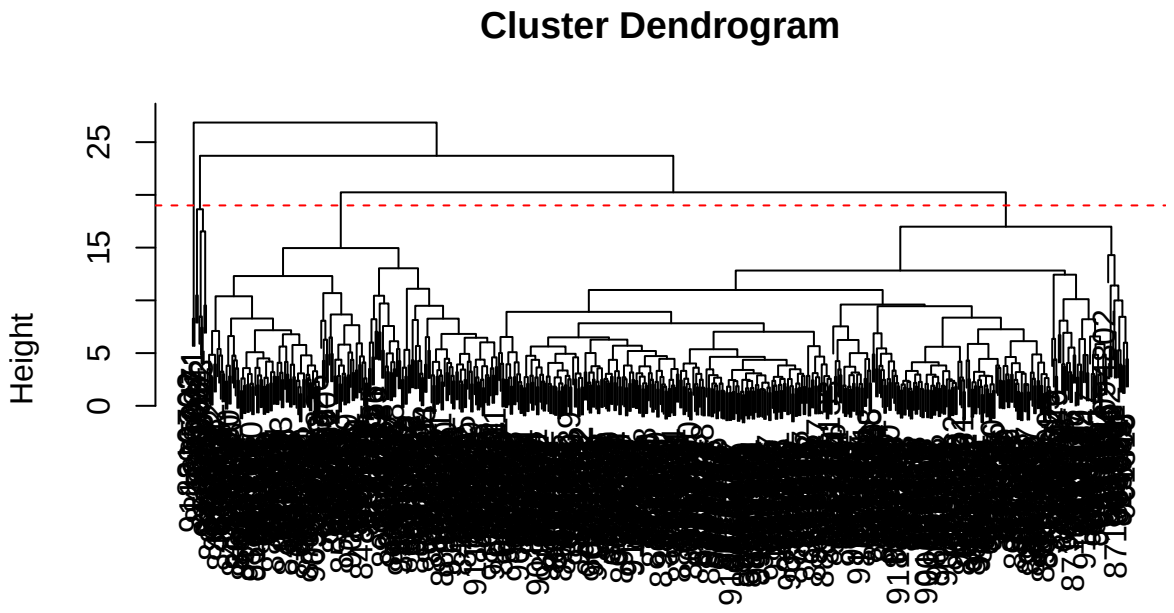
```
wisc.hclust <- hclust(data.dist)
wisc.hclust
```

```
##
## Call:
## hclust(d = data.dist)
##
## Cluster method   : complete
## Distance         : euclidean
## Number of objects: 569
```

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

h = 19

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




```
wisc.hclust.clusters <- cutree(wisc.hclust, 4)
wisc.hclust.clusters
```

```
##    842302    842517  84300903  84348301  84358402    843786    844359  84458202
##         1         1         1         2         1         1         1         1
##    844981  84501001    845636  84610002    846226    846381  84667401  84799002
##         1         2         3         1         1         3         1         1
##    848406  84862001    849014   8510426   8510653   8510824   8511133    851509
##         3         1         1         3         3         3         1         1
##    852552    852631    852763    852781    852973    853201    853401    853612
##         1         1         1         1         1         3         1         1
##  85382601    854002    854039    854253    854268    854941    855133    855138
##         1         1         1         1         1         3         3         1
##    855167    855563    855625    856106  85638502    857010  85713702     85715
##         3         1         1         1         1         1         3         1
##    857155    857156    857343    857373    857374    857392    857438  85759902
##         3         3         3         3         3         1         3         3
##    857637    857793    857810    858477    858970    858981    858986    859196
##         1         1         3         3         3         3         1         3
##  85922302    859283    859464    859465    859471    859487    859575    859711
##         1         1         3         3         2         3         1         3
##    859717    859983   8610175   8610404   8610629   8610637   8610862   8610908
```

```
##       1       1       3       3       3       1       2       3
##  861103 8611161 8611555 8611792 8612080 8612399 86135501 86135502
##       3       1       1       1       3       1       3       1
##  861597  861598  861648  861799  861853  862009  862028   86208
##       3       1       3       3       3       3       1       1
##   86211  862261  862485  862548  862717  862722  862965  862980
##       3       3       3       3       3       3       3       3
##  862989  863030  863031  863270   86355  864018  864033   86408
##       3       1       1       3       1       3       3       3
##   86409  864292  864496  864685  864726  864729  864877  865128
##       3       3       3       3       3       1       1       3
##  865137   86517  865423  865432  865468   86561  866083  866203
##       3       1       2       3       3       3       1       3
##  866458  866674  866714    8670 86730502  867387  867739  868202
##       1       1       3       1       1       3       1       3
##  868223  868682  868826  868871  868999  869104  869218  869224
##       3       3       1       3       3       3       3       3
##  869254  869476  869691 86973701 86973702  869931 871001501 871001502
##       3       3       1       3       3       3       3       3
## 8710441   87106 8711002 8711003 8711202 8711216  871122  871149
##       2       3       3       3       1       3       3       3
## 8711561 8711803  871201 8712064 8712289 8712291   87127 8712729
##       3       1       1       3       1       3       3       3
## 8712766 8712853 87139402   87163   87164  871641  871642  872113
##       1       3       3       3       1       3       3       3
##  872608 87281702  873357  873586  873592  873593  873701  873843
##       3       1       3       3       1       1       1       3
##  873885  874158  874217  874373  874662  874839  874858  875093
##       1       3       3       3       3       3       2       3
##  875099  875263 87556202  875878  875938  877159  877486  877500
##       3       1       1       3       1       3       1       1
##  877501  877989  878796   87880   87930  879523  879804  879830
##       3       3       1       1       3       3       3       3
## 8810158 8810436 881046502 8810528 8810703 881094802 8810955 8810987
##       1       3       1       3       4       3       1       1
## 8811523 8811779 8811842 88119002 8812816 8812818 8812844 8812877
##       3       3       1       1       3       3       3       1
## 8813129 88143502 88147101 88147102 88147202  881861  881972 88199202
##       3       3       3       3       3       1       1       3
## 88203002 88206102  882488 88249602 88299702  883263  883270 88330202
##       3       1       3       3       1       1       3       1
## 88350402  883539  883852 88411702  884180  884437  884448  884626
##       3       3       3       3       1       3       3       3
## 88466802  884689  884948 88518501  885429 8860702  886226  886452
##       3       3       1       3       1       3       1       3
## 88649001  886776  887181 88725602  887549  888264  888570  889403
##       1       1       1       1       1       3       1       3
##  889719 88995002 8910251 8910499 8910506 8910720 8910721 8910748
##       1       1       3       3       3       3       3       3
## 8910988 8910996 8911163 8911164 8911230 8911670 8911800 8911834
##       1       3       3       3       3       3       3       3
## 8912049 8912055   89122 8912280 8912284 8912521 8912909    8913
##       1       3       1       1       3       3       3       3
## 8913049 89143601 89143602    8915  891670  891703  891716  891923
```

```
##         3         3         3         3         3         3         3         3
##    891936    892189    892214    892399    892438    892604  89263202    892657
##         3         3         3         3         1         3         1         3
##     89296    893061     89344     89346    893526    893548    893783  89382601
##         3         3         3         3         3         3         3         3
##  89382602    893988    894047    894089    894090    894326    894329    894335
##         3         3         3         3         3         1         3         3
##    894604    894618    894855    895100  89511501  89511502     89524    895299
##         3         3         3         1         3         3         3         3
##   8953902    895633    896839    896864    897132    897137    897374  89742801
##         1         1         1         1         3         3         3         1
##    897604    897630    897880     89812     89813    898143     89827    898431
##         3         1         3         1         3         3         3         1
##  89864002    898677    898678     89869    898690    899147    899187    899667
##         3         3         3         3         3         3         3         1
##    899987   9010018    901011   9010258   9010259    901028   9010333 901034301
##         1         1         3         3         3         3         3         3
## 901034302    901041   9010598   9010872   9010877    901088   9011494   9011495
##         3         3         3         3         3         1         1         3
##   9011971   9012000   9012315   9012568   9012795    901288   9013005    901303
##         1         1         1         3         1         1         3         3
##    901315   9013579   9013594   9013838    901549    901836     90250     90251
##         3         3         3         1         3         3         3         3
##    902727     90291    902975    902976    903011     90312  90317302    903483
##         3         3         3         3         3         1         3         3
##    903507    903516    903554    903811  90401601  90401602    904302    904357
##         1         1         3         3         3         3         3         3
##  90439701    904647    904689      9047    904969    904971    905189    905190
##         1         3         3         3         3         3         3         3
##  90524101    905501    905502    905520    905539    905557    905680    905686
##         1         3         3         3         3         3         3         3
##    905978  90602302    906024    906290    906539    906564    906616    906878
##         3         1         3         3         3         1         3         3
##    907145    907367    907409     90745  90769601  90769602    907914    907915
##         3         3         3         3         3         3         1         3
##    908194    908445    908469    908489    908916    909220    909231    909410
##         1         1         3         1         3         3         3         3
##    909411    909445  90944601    909777   9110127   9110720   9110732   9110944
##         3         3         3         3         3         3         1         3
##    911150 911157302   9111596   9111805   9111843    911201    911202   9112085
##         3         1         3         1         3         3         3         3
##   9112366   9112367   9112594   9112712 911296201 911296202   9113156 911320501
##         3         3         3         3         1         4         3         3
## 911320502   9113239   9113455   9113514   9113538    911366   9113778   9113816
##         3         3         3         3         1         1         3         3
##    911384   9113846    911391    911408    911654    911673    911685    911916
##         3         3         3         3         3         3         3         1
##    912193     91227    912519    912558    912600    913063    913102    913505
##         3         3         3         3         3         3         3         1
##    913512    913535  91376701  91376702    914062    914101    914102    914333
##         3         3         3         3         1         3         3         3
##    914366    914580    914769     91485    914862     91504     91505    915143
##         1         3         1         1         3         1         3         1
##    915186    915276  91544001  91544002    915452    915460     91550    915664
```

```
##         3         3         3         3         3         1         3         3
##    915691    915940  91594602    916221    916799    916838    917062    917080
##         1         3         3         3         1         1         3         3
##    917092  91762702     91789    917896    917897     91805  91813701  91813702
##         3         1         3         3         3         3         1         3
##    918192    918465     91858  91903901  91903902  91930402    919537    919555
##         3         3         3         3         3         1         3         1
##  91979701    919812    921092    921362    921385    921386    921644    922296
##         3         1         3         3         3         1         3         3
##    922297    922576    922577    922840    923169    923465    923748    923780
##         3         3         3         3         3         3         3         3
##    924084    924342    924632    924934    924964    925236    925277    925291
##         3         3         3         3         3         3         3         3
##    925292    925311    925622    926125    926424    926682    926954    927241
##         3         3         1         1         1         1         3         1
##     92751
##         3
```

```
table(wisc.hclust.clusters, diagnosis)
```

```
##                     diagnosis
## wisc.hclust.clusters   B   M
##                    1  12 165
##                    2   2   5
##                    3 343  40
##                    4   0   2
```

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

Our group determined that a cluster of 4 is optimal, from trying different values. There is good separation between B and M.

```
wisc.hclust.clusters2 <- cutree(wisc.hclust, 5)
table(wisc.hclust.clusters2, diagnosis)
```

```
##                      diagnosis
## wisc.hclust.clusters2   B   M
##                     1  12 165
##                     2   0   5
##                     3 343  40
##                     4   2   0
##                     5   0   2
```

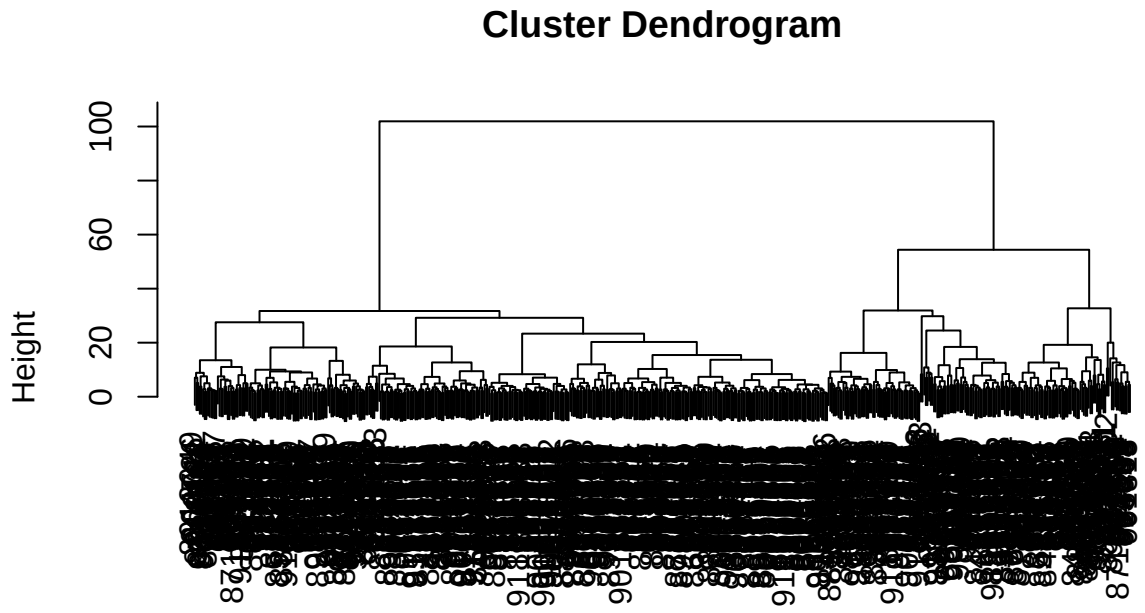
> Q13. Which method gives your favorite results for the same data.dist dataset? Explain your reasoning.

Our group decided that the ward.D2 method splits the data more cleanly than the other methods

```
wisc.hclust2 <- hclust(data.dist, method = "ward.D2")
wisc.hclust2
```

```
##
## Call:
## hclust(d = data.dist, method = "ward.D2")
##
## Cluster method   : ward.D2
## Distance         : euclidean
## Number of objects: 569
```

```
plot(wisc.hclust2)
```




```
wisc.pr.hclust <- hclust(dist(wisc.pr$x[,1:4]), method = "ward.D2")
```

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

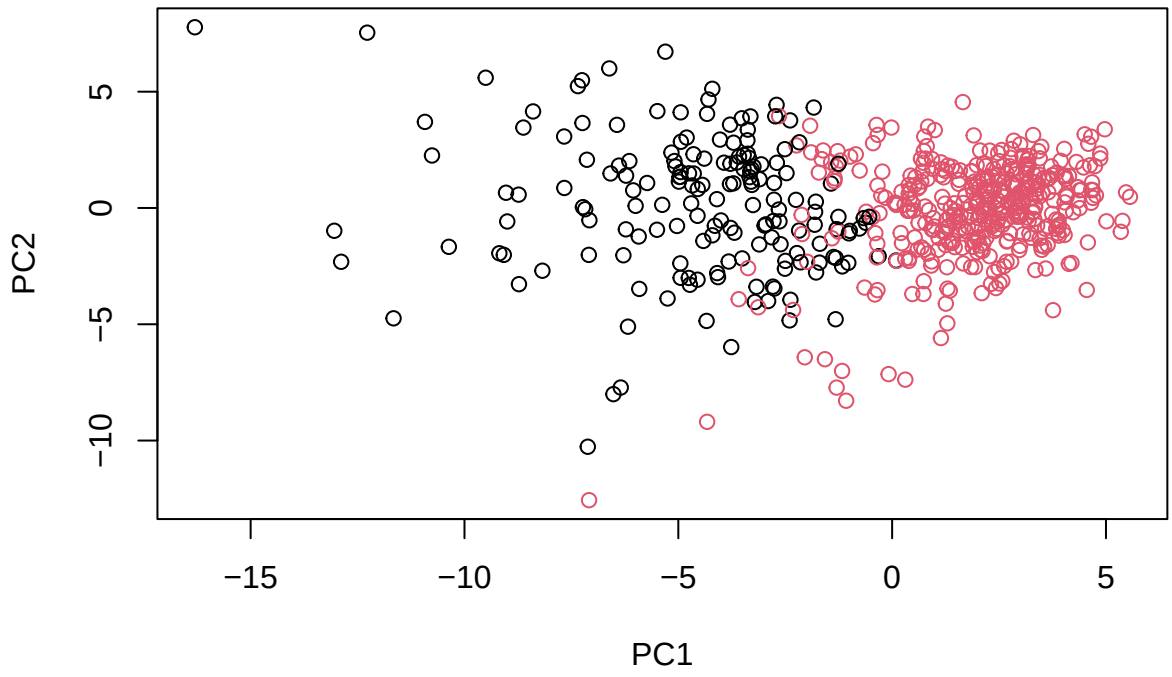
```
## grps
##   1   2
## 171 398
```

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

```
##     diagnosis
## grps   B   M
##    1   6 165
##    2 351  47
```

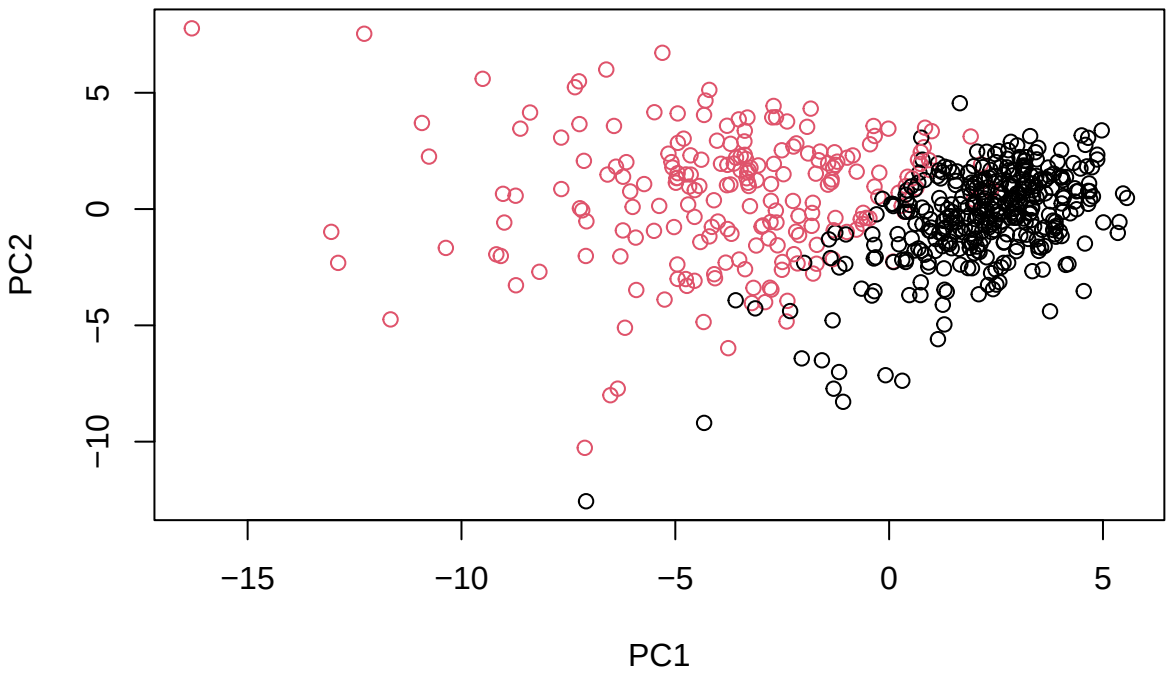
plot hclust, by group

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



plot hclust by diagnosis

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



Find cluster membership vector by cutting tree into k = 2 groups

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

```
## grps
##   1   2
## 171 398
```

compare to the expert M and B vector

```
table(diagnosis)
```

```
## diagnosis
##   B   M
## 357 212
```

cross-table by giving the table() function two inputs

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

```
##     diagnosis
## grps   B   M
##    1   6 165
##    2 351  47
```

accuracy: how many did we get correct?

```
(165 + 351) / nrow(wisc.data)
```

```
## [1] 0.9068541
```

specificity: tn/(tn + fn)

```
351 / (351 + 47)
```

```
## [1] 0.8819095
```

sensitivity: tp/(tp + fn)

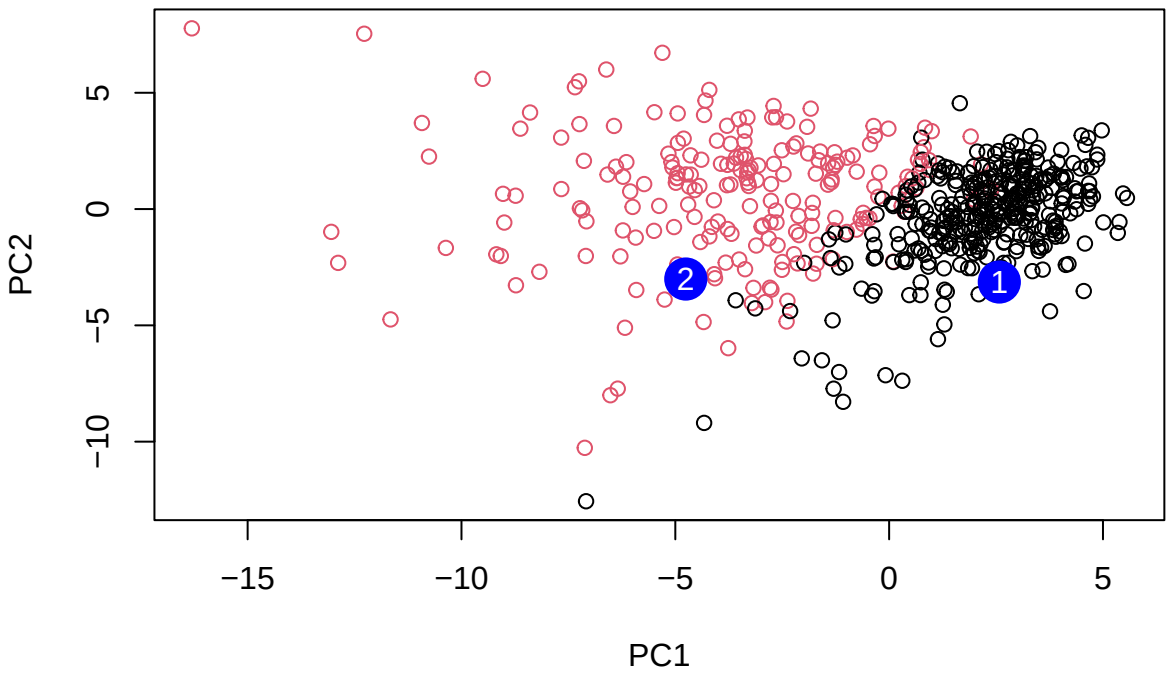
```
165/(165 + 6)
```

```
## [1] 0.9649123
```

predictions

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

```
plot(wisc.pr$x[,1:2], col=diagnosis)
points(npc[,1], npc[,2], col="blue", pch=16, cex=3)
text(npc[,1], npc[,2], c(1,2), col="white")
```


PC2
5
0
−5
−10
−15
−10
−5
0
5
PC1
2
1