Class 8 PCA Mini Project

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It is important to consider scalling your data before analysis such as PCA.

For example:

```r
head(mtcars)
```

```
                   mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

```r
colMeans(mtcars)
```

```
       mpg        cyl       disp         hp       drat         wt       qsec
 20.090625   6.187500 230.721875 146.687500   3.596563   3.217250  17.848750
        vs         am       gear       carb
  0.437500   0.406250   3.687500   2.812500
```

```r
apply(mtcars, 2, sd)
```

```
        mpg        cyl       disp         hp       drat         wt
  6.0269481  1.7859216 123.9386938  68.5628685   0.5346787   0.9784574
       qsec         vs         am       gear       carb
  1.7869432  0.5040161   0.4989909   0.7378041   1.6152000
```

```r
x <- scale(mtcars)
head(x)
```

```
                          mpg        cyl        disp          hp        drat
Mazda RX4          0.1508848 -0.1049878 -0.57061982 -0.5350928  0.5675137
Mazda RX4 Wag      0.1508848 -0.1049878 -0.57061982 -0.5350928  0.5675137
Datsun 710         0.4495434 -1.2248578 -0.99018209 -0.7830405  0.4739996
Hornet 4 Drive     0.2172534 -0.1049878  0.22009369 -0.5350928 -0.9661175
Hornet Sportabout -0.2307345  1.0148821  1.04308123  0.4129422 -0.8351978
Valiant           -0.3302874 -0.1049878 -0.04616698 -0.6080186 -1.5646078
                           wt       qsec         vs         am        gear
Mazda RX4         -0.610399567 -0.7771651 -0.8680278  1.1899014  0.4235542
Mazda RX4 Wag     -0.349785269 -0.4637808 -0.8680278  1.1899014  0.4235542
Datsun 710        -0.917004624  0.4260068  1.1160357  1.1899014  0.4235542
Hornet 4 Drive    -0.002299538  0.8904872  1.1160357 -0.8141431 -0.9318192
Hornet Sportabout  0.227654255 -0.4637808 -0.8680278 -0.8141431 -0.9318192
Valiant            0.248094592  1.3269868  1.1160357 -0.8141431 -0.9318192
                        carb
Mazda RX4          0.7352031
Mazda RX4 Wag      0.7352031
Datsun 710        -1.1221521
Hornet 4 Drive    -1.1221521
Hornet Sportabout -0.5030337
Valiant           -1.1221521
```

```r
round(colMeans(x), 2)
```

```
 mpg  cyl disp   hp drat   wt qsec   vs   am gear carb
   0    0    0    0    0    0    0    0    0    0    0
```

Key-point: It is usually always a good idea to scale your data before to PCA...

Breast Cancer Biopsy Analysis

```r
# Save your input data file into your Project directory
fna.data <- "WisconsinCancer.csv"

# Complete the following code to input the data and store as wisc.df
wisc.df <- read.csv(fna.data, 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 <- wisc.df[,1]
table(diagnosis)
```

```
diagnosis
  B   M
357 212
```

Remove this first 'diagnosis' column from the dataset as I don't want to pass this to PCA ect.
It is esentially the expert "answer" that we will compare our analysis results to.

```
# We can use -1 here to remove the first column
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
```

```r
# Create diagnosis vector for later
diagnosis <- as.factor(wisc.df$diagnosis)
```

Exploratory data analysis

Q1. How many observations are in this dataset?

```r
# Count the number of observations in the dataset
num_observations <- nrow(wisc.df)
num_observations
```

```
[1] 569
```

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

```r
# Count the number of malignant diagnoses
num_malignant <- sum(diagnosis == "M")
num_malignant
```

```
[1] 212
```

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

```r
colnames(wisc.data)
```

```
 [1] "radius_mean"            "texture_mean"
 [3] "perimeter_mean"         "area_mean"
 [5] "smoothness_mean"        "compactness_mean"
 [7] "concavity_mean"         "concave.points_mean"
 [9] "symmetry_mean"          "fractal_dimension_mean"
[11] "radius_se"              "texture_se"
[13] "perimeter_se"           "area_se"
[15] "smoothness_se"          "compactness_se"
[17] "concavity_se"           "concave.points_se"
[19] "symmetry_se"            "fractal_dimension_se"
```

```
[21] "radius_worst"          "texture_worst"
[23] "perimeter_worst"       "area_worst"
[25] "smoothness_worst"      "compactness_worst"
[27] "concavity_worst"       "concave.points_worst"
[29] "symmetry_worst"        "fractal_dimension_worst"
```

```
length(grep("_mean", colnames(wisc.data)))
```

```
[1] 10
```

Principal Component Analysis

```
# Check column 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
```

```
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

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

See what is in our PCA result object:

```
attributes(wisc.pr)
```

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

$class
[1] "prcomp"
```

```
head(wisc.pr$x)
```

```
                 PC1        PC2        PC3       PC4        PC5         PC6
842302    -9.184755  -1.946870 -1.1221788 3.6305364  1.1940595  1.41018364
842517    -2.385703   3.764859 -0.5288274 1.1172808 -0.6212284  0.02863116
84300903  -5.728855   1.074229 -0.5512625 0.9112808  0.1769302  0.54097615
84348301  -7.116691 -10.266556 -3.2299475 0.1524129  2.9582754  3.05073750
84358402  -3.931842   1.946359  1.3885450 2.9380542 -0.5462667 -1.22541641
843786    -2.378155  -3.946456 -2.9322967 0.9402096  1.0551135 -0.45064213
                 PC7         PC8         PC9       PC10       PC11        PC12
842302    2.15747152  0.39805698 -0.15698023 -0.8766305 -0.2627243 -0.8582593
842517    0.01334635 -0.24077660 -0.71127897  1.1060218 -0.8124048  0.1577838
84300903 -0.66757908 -0.09728813  0.02404449  0.4538760  0.6050715  0.1242777
84348301  1.42865363 -1.05863376 -1.40420412 -1.1159933  1.1505012  1.0104267
84358402 -0.93538950 -0.63581661 -0.26357355  0.3773724 -0.6507870 -0.1104183
843786    0.49001396  0.16529843 -0.13335576 -0.5299649 -0.1096698  0.0813699
                 PC13        PC14         PC15        PC16        PC17
842302    0.10329677 -0.690196797  0.601264078  0.74446075 -0.26523740
842517   -0.94269981 -0.652900844 -0.008966977 -0.64823831 -0.01719707
84300903 -0.41026561  0.016665095 -0.482994760  0.32482472  0.19075064
84348301 -0.93245070 -0.486988399  0.168699395  0.05132509  0.48220960
84358402  0.38760691 -0.538706543 -0.310046684 -0.15247165  0.13302526
843786   -0.02625135  0.003133944 -0.178447576 -0.01270566  0.19671335
                 PC18       PC19       PC20         PC21        PC22
842302   -0.54907956  0.1336499  0.34526111  0.096430045 -0.06878939
842517    0.31801756 -0.2473470 -0.11403274 -0.077259494  0.09449530
84300903 -0.08789759 -0.3922812 -0.20435242  0.310793246  0.06025601
```

```
84348301 -0.03584323 -0.0267241  -0.46432511  0.433811661  0.20308706
84358402 -0.01869779  0.4610302   0.06543782 -0.116442469  0.01763433
843786   -0.29727706 -0.1297265  -0.07117453 -0.002400178  0.10108043
                 PC23        PC24         PC25         PC26        PC27
842302    0.08444429  0.175102213  0.150887294 -0.201326305 -0.25236294
842517   -0.21752666 -0.011280193  0.170360355 -0.041092627  0.18111081
84300903 -0.07422581 -0.102671419 -0.171007656  0.004731249  0.04952586
84348301 -0.12399554 -0.153294780 -0.077427574 -0.274982822  0.18330078
84358402  0.13933105  0.005327110 -0.003059371  0.039219780  0.03213957
843786    0.03344819 -0.002837749 -0.122282765 -0.030272333 -0.08438081
                 PC28        PC29         PC30
842302   -0.0338846387  0.045607590  0.0471277407
842517    0.0325955021 -0.005682424  0.0018662342
84300903  0.0469844833  0.003143131 -0.0007498749
84348301  0.0424469831 -0.069233868  0.0199198881
84358402 -0.0347556386  0.005033481 -0.0211951203
843786    0.0007296587 -0.019703996 -0.0034564331
```

Main "PC score plot", "PC1 vs PC2 plot"

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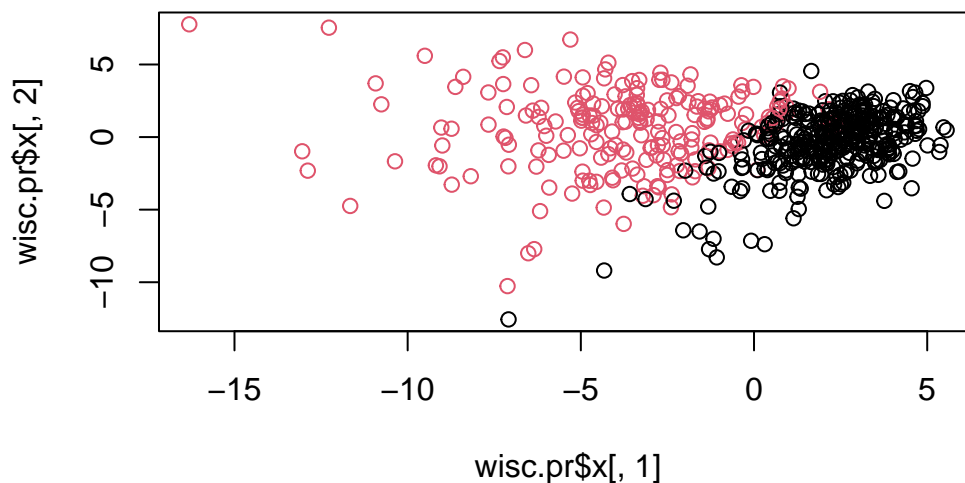
```
#plot(wisc.pr$x)
```

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

```
# Perform PCA on the data (assuming wisc.data is already prepared)
pca_result <- prcomp(wisc.data, scale. = TRUE)

# Calculate the proportion of variance captured by PC1
proportion_pc1 <- (pca_result$sdev[1]^2/sum(pca_result$sdev^2))

# Print the proportion
proportion_pc1
```

```
[1] 0.4427203
```

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

```
# Perform PCA and calculate the number of PCs needed to explain at least
# 70% of the variance
num_pcs_70 <- which(cumsum((pca_result <- prcomp(wisc.data, scale. = TRUE))
                           $sdev^2 / sum(pca_result$sdev^2)) >= 0.70)[1]

# Print the number of PCs required
num_pcs_70
```

```
[1] 3
```

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

```
# Perform PCA and calculate the number of PCs needed to explain at least
# 90% of the variance
num_pcs_90 <- which(cumsum((pca_result <- prcomp(wisc.data,
                                                 scale. = TRUE))
                           $sdev^2 / sum(pca_result$sdev^2)) >= 0.90)[1]

# Print the number of PCs required
num_pcs_90
```

```
[1] 7
```

```
x <- summary(wisc.pr)
plot(x$importance[2,], typ="b")
```
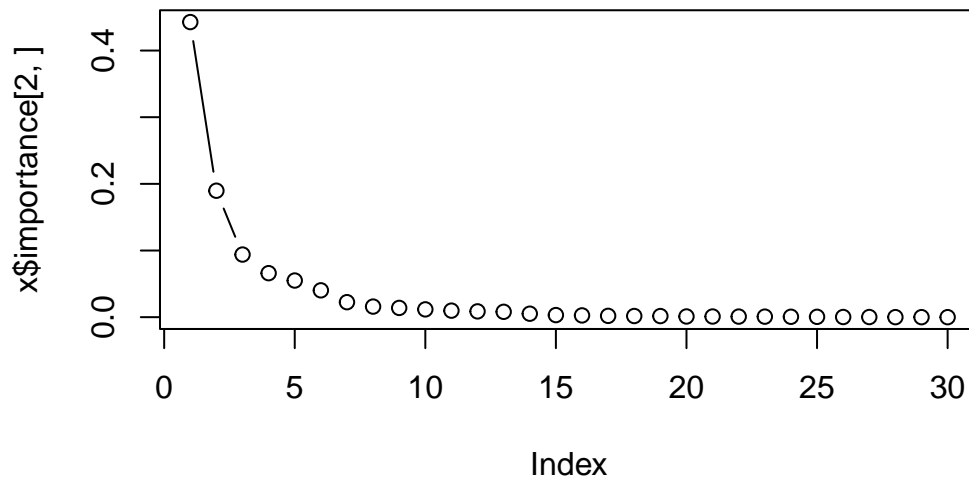

Q7. What stands out to you about this plot? Is it easy or difficult to understand?
Why?

```
# Perform PCA on the data
pca_result <- prcomp(wisc.data, scale. = TRUE)

# Create a biplot
biplot(pca_result)
```

```
# Something that stands out are the overlapping in plot. It is hard to
# understand because there is no visible relationship in the plot.
```

```
# Scatter plot observations by components 1 and 2
plot( pca_result$x[, 1], pca_result$x[, 2], col = diagnosis ,
      xlab = "PC1", ylab = "PC2")
```
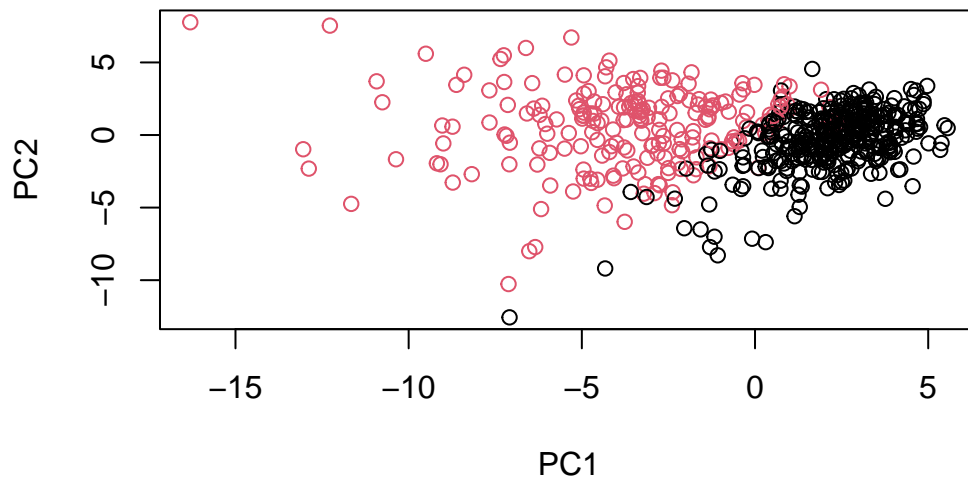
Q8. Generate a similar plot for principal components 1 and 3. What do you notice about these plots?

```
# Repeat for components 1 and 3
plot(wisc.pr$x[, 1 ], wisc.pr$x[,3], col = diagnosis,
     xlab = "PC1", ylab = "PC3")
```
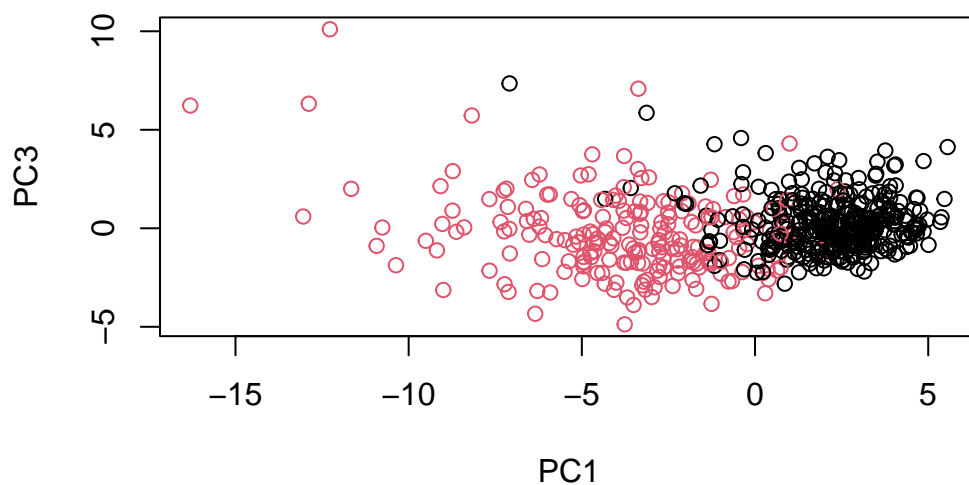
```r
# Create a data.frame for ggplot
df <- as.data.frame(wisc.pr$x)
df$diagnosis <- diagnosis

# Load the ggplot2 package
library(ggplot2)

# Make a scatter plot colored by diagnosis
ggplot(df) +
  aes(PC1, PC2, col=diagnosis) +
  geom_point() +
  labs(title = "PCA Scatter Plot of PC1 vs PC2",
       x = "PC1",
       y = "PC2")
```

PCA Scatter Plot of PC1 vs PC2
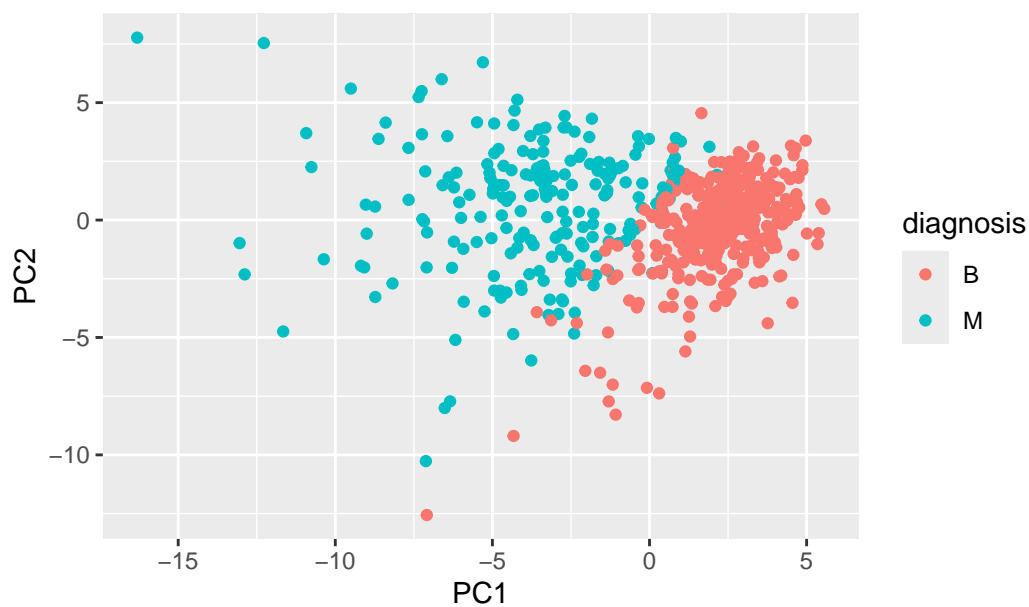

```
# Calculate variance of each component
pr.var <- wisc.pr$sdev^2
head(pr.var)
```

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

```
# Variance explained by each principal component: pve
pve <- pca_result$sdev^2 / sum(pca_result$sdev^2)

# Plot variance explained for each principal component
plot(pve, xlab = "Principal Component",
     ylab = "Proportion of Variance Explained",
     ylim = c(0, 1), type = "o")
```
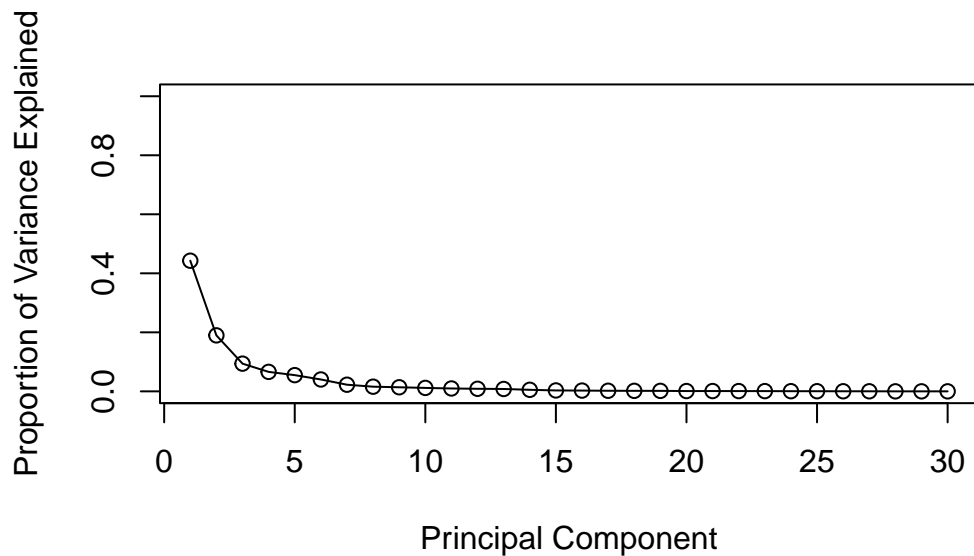
Q9.For the first principal component, what is the component of the loading vector (i.e. wisc.pr$rotation[,1]) for the feature concave.points_mean?

```
# Assuming pca_result is the result of the PCA
loading_concave_points_mean <- pca_result$rotation["concave.points_mean", 1]
loading_concave_points_mean
```

```
[1] -0.2608538
```

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

```
# Calculate the proportion of variance
pve <- pca_result$sdev^2 / sum(pca_result$sdev^2)

# Calculate cumulative variance
cumulative_variance <- cumsum(pve)

# at least 80% of the variance
num_pcs_80 <- which(cumulative_variance >= 0.80)[1]
num_pcs_80
```

```
[1] 5
```

Hierarchical Clustering

```
# Scale the wisc.data data using the "scale()" function
data.scaled <- scale(wisc.data)

data.dist <- dist(data.scaled)

wisc.hclust <- hclust(data.dist, method = "complete")
```

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

```
plot(wisc.hclust, main = "Dendrogram of Hierarchical Clustering",
     xlab = "Observations", ylab = "Height")

abline(h = 4, col = "red", lty = 2)
```
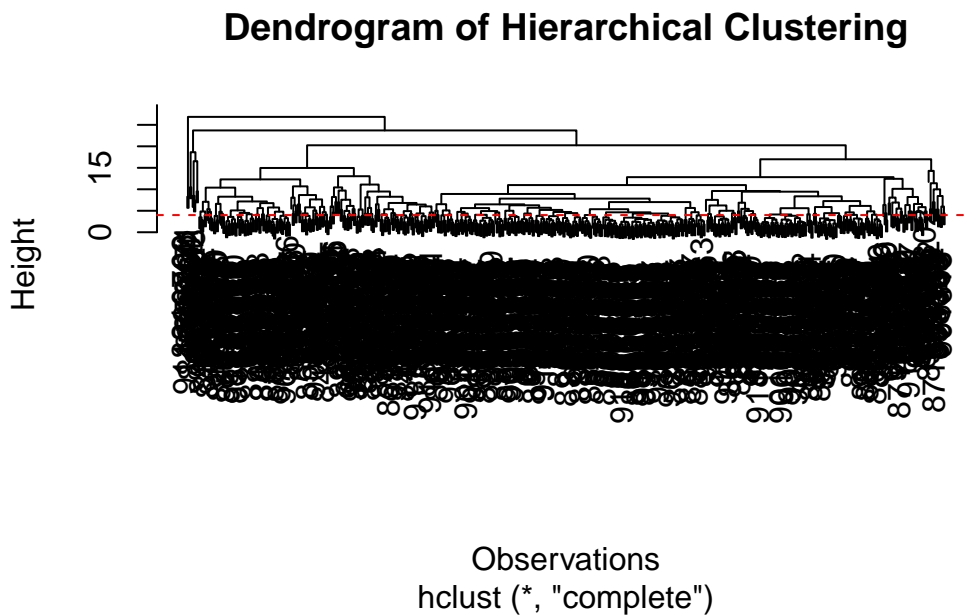

Combine PCA and clustering

Our PCA results were in 'wisc.pr'

```
# distance matrix from PCA results
d <- dist(wisc.pr$x[,1:3])
hc <- hclust(d, method= "ward.D2")
plot(hc)
```

Cluster Dendrogram
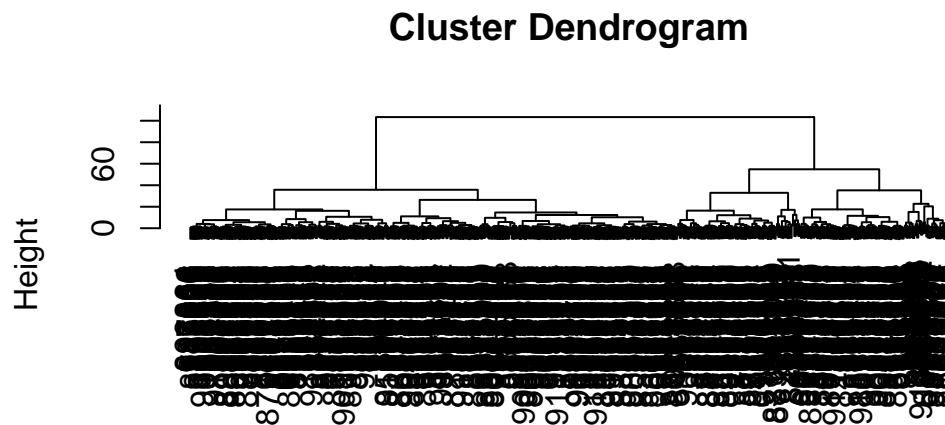
d
hclust (*, "ward.D2")

Cut tree into two groups/branches/clusters...

```
grps <- cutree(hc, k=2)
```

```
plot(wisc.pr$x, col=grps)
```
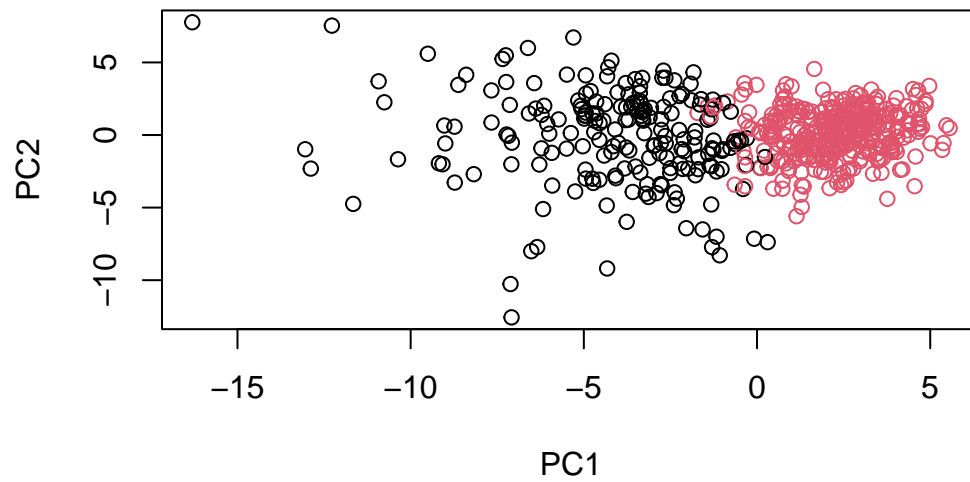
```
wisc.hclust.clusters <- cutree(wisc.hclust, k=4)
table(wisc.hclust.clusters, diagnosis)
```

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

Compare my clustering result (my 'grps') to to expert 'diagnosis':

```
table(diagnosis)
```

```
diagnosis
  B   M
357 212
```

```
table(grps)
```

```
grps
  1   2
203 366
```

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

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

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

```
# Initialize results list
results <- lapply(2:10, function(k) {
  clusters <- cutree(wisc.hclust, k)
  table_clusters <- table(clusters, diagnosis)
  accuracy <- sum(apply(table_clusters, 1, max)) / nrow(wisc.data)
  list(clusters = clusters, table = table_clusters, accuracy = accuracy)
})

# Name the results list by cluster count
names(results) <- 2:10
results
```

```
$`2`
$`2`$clusters
   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         1         1         1         1         1         1
   848406  84862001    849014   8510426   8510653   8510824   8511133    851509
        1         1         1         1         1         1         1         1
   852552    852631    852763    852781    852973    853201    853401    853612
        1         1         1         1         1         1         1         1
 85382601    854002    854039    854253    854268    854941    855133    855138
        1         1         1         1         1         1         1         1
   855167    855563    855625    856106  85638502    857010  85713702     85715
        1         1         1         1         1         1         1         1
   857155    857156    857343    857373    857374    857392    857438  85759902
        1         1         1         1         1         1         1         1
```

857637	857793	857810	858477	858970	858981	858986	859196
1	1	1	1	1	1	1	1
85922302	859283	859464	859465	859471	859487	859575	859711
1	1	1	1	1	1	1	1
859717	859983	8610175	8610404	8610629	8610637	8610862	8610908
1	1	1	1	1	1	1	1
861103	8611161	8611555	8611792	8612080	8612399	86135501	86135502
1	1	1	1	1	1	1	1
861597	861598	861648	861799	861853	862009	862028	86208
1	1	1	1	1	1	1	1
86211	862261	862485	862548	862717	862722	862965	862980
1	1	1	1	1	1	1	1
862989	863030	863031	863270	86355	864018	864033	86408
1	1	1	1	1	1	1	1
86409	864292	864496	864685	864726	864729	864877	865128
1	1	1	1	1	1	1	1
865137	86517	865423	865432	865468	86561	866083	866203
1	1	1	1	1	1	1	1
866458	866674	866714	8670	86730502	867387	867739	868202
1	1	1	1	1	1	1	1
868223	868682	868826	868871	868999	869104	869218	869224
1	1	1	1	1	1	1	1
869254	869476	869691	86973701	86973702	869931	871001501	871001502
1	1	1	1	1	1	1	1
8710441	87106	8711002	8711003	8711202	8711216	871122	871149
1	1	1	1	1	1	1	1
8711561	8711803	871201	8712064	8712289	8712291	87127	8712729
1	1	1	1	1	1	1	1
8712766	8712853	87139402	87163	87164	871641	871642	872113
1	1	1	1	1	1	1	1
872608	87281702	873357	873586	873592	873593	873701	873843
1	1	1	1	1	1	1	1
873885	874158	874217	874373	874662	874839	874858	875093
1	1	1	1	1	1	1	1
875099	875263	87556202	875878	875938	877159	877486	877500
1	1	1	1	1	1	1	1
877501	877989	878796	87880	87930	879523	879804	879830
1	1	1	1	1	1	1	1
8810158	8810436	881046502	8810528	8810703	881094802	8810955	8810987
1	1	1	1	2	1	1	1
8811523	8811779	8811842	88119002	8812816	8812818	8812844	8812877
1	1	1	1	1	1	1	1
8813129	88143502	88147101	88147102	88147202	881861	881972	88199202

1	1	1	1	1	1	1	1
88203002	88206102	882488	88249602	88299702	883263	883270	88330202
1	1	1	1	1	1	1	1
88350402	883539	883852	88411702	884180	884437	884448	884626
1	1	1	1	1	1	1	1
88466802	884689	884948	88518501	885429	8860702	886226	886452
1	1	1	1	1	1	1	1
88649001	886776	887181	88725602	887549	888264	888570	889403
1	1	1	1	1	1	1	1
889719	88995002	8910251	8910499	8910506	8910720	8910721	8910748
1	1	1	1	1	1	1	1
8910988	8910996	8911163	8911164	8911230	8911670	8911800	8911834
1	1	1	1	1	1	1	1
8912049	8912055	89122	8912280	8912284	8912521	8912909	8913
1	1	1	1	1	1	1	1
8913049	89143601	89143602	8915	891670	891703	891716	891923
1	1	1	1	1	1	1	1
891936	892189	892214	892399	892438	892604	89263202	892657
1	1	1	1	1	1	1	1
89296	893061	89344	89346	893526	893548	893783	89382601
1	1	1	1	1	1	1	1
89382602	893988	894047	894089	894090	894326	894329	894335
1	1	1	1	1	1	1	1
894604	894618	894855	895100	89511501	89511502	89524	895299
1	1	1	1	1	1	1	1
8953902	895633	896839	896864	897132	897137	897374	89742801
1	1	1	1	1	1	1	1
897604	897630	897880	89812	89813	898143	89827	898431
1	1	1	1	1	1	1	1
89864002	898677	898678	89869	898690	899147	899187	899667
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899987	9010018	901011	9010258	9010259	901028	9010333	901034301
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901034302	901041	9010598	9010872	9010877	901088	9011494	9011495
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9011971	9012000	9012315	9012568	9012795	901288	9013005	901303
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901315	9013579	9013594	9013838	901549	901836	90250	90251
1	1	1	1	1	1	1	1
902727	90291	902975	902976	903011	90312	90317302	903483
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903507	903516	903554	903811	90401601	90401602	904302	904357
1	1	1	1	1	1	1	1

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907145	907367	907409	90745	90769601	90769602	907914	907915
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908194	908445	908469	908489	908916	909220	909231	909410
1	1	1	1	1	1	1	1
909411	909445	90944601	909777	9110127	9110720	9110732	9110944
1	1	1	1	1	1	1	1
911150	911157302	9111596	9111805	9111843	911201	911202	9112085
1	1	1	1	1	1	1	1
9112366	9112367	9112594	9112712	911296201	911296202	9113156	911320501
1	1	1	1	1	2	1	1
911320502	9113239	9113455	9113514	9113538	911366	9113778	9113816
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911384	9113846	911391	911408	911654	911673	911685	911916
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912193	91227	912519	912558	912600	913063	913102	913505
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913512	913535	91376701	91376702	914062	914101	914102	914333
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914366	914580	914769	91485	914862	91504	91505	915143
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915186	915276	91544001	91544002	915452	915460	91550	915664
1	1	1	1	1	1	1	1
915691	915940	91594602	916221	916799	916838	917062	917080
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917092	91762702	91789	917896	917897	91805	91813701	91813702
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918192	918465	91858	91903901	91903902	91930402	919537	919555
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91979701	919812	921092	921362	921385	921386	921644	922296
1	1	1	1	1	1	1	1
922297	922576	922577	922840	923169	923465	923748	923780
1	1	1	1	1	1	1	1
924084	924342	924632	924934	924964	925236	925277	925291
1	1	1	1	1	1	1	1
925292	925311	925622	926125	926424	926682	926954	927241
1	1	1	1	1	1	1	1
92751							

```
         1

$`2`$table
       diagnosis
clusters  B   M
      1 357 210
      2   0   2

$`2`$accuracy
[1] 0.6309315


$`3`
$`3`$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         1         1         1         1         1         1
   848406  84862001    849014   8510426   8510653   8510824   8511133    851509
        1         1         1         1         1         1         1         1
   852552    852631    852763    852781    852973    853201    853401    853612
        1         1         1         1         1         1         1         1
 85382601    854002    854039    854253    854268    854941    855133    855138
        1         1         1         1         1         1         1         1
   855167    855563    855625    856106  85638502    857010  85713702     85715
        1         1         1         1         1         1         1         1
   857155    857156    857343    857373    857374    857392    857438  85759902
        1         1         1         1         1         1         1         1
   857637    857793    857810    858477    858970    858981    858986    859196
        1         1         1         1         1         1         1         1
 85922302    859283    859464    859465    859471    859487    859575    859711
        1         1         1         1         2         1         1         1
   859717    859983   8610175   8610404   8610629   8610637   8610862   8610908
        1         1         1         1         1         1         2         1
   861103   8611161   8611555   8611792   8612080   8612399  86135501  86135502
        1         1         1         1         1         1         1         1
   861597    861598    861648    861799    861853    862009    862028     86208
        1         1         1         1         1         1         1         1
    86211    862261    862485    862548    862717    862722    862965    862980
        1         1         1         1         1         1         1         1
   862989    863030    863031    863270     86355    864018    864033     86408
        1         1         1         1         1         1         1         1
    86409    864292    864496    864685    864726    864729    864877    865128
```

1	1	1	1	1	1	1	1
865137	86517	865423	865432	865468	86561	866083	866203
1	1	2	1	1	1	1	1
866458	866674	866714	8670	86730502	867387	867739	868202
1	1	1	1	1	1	1	1
868223	868682	868826	868871	868999	869104	869218	869224
1	1	1	1	1	1	1	1
869254	869476	869691	86973701	86973702	869931	871001501	871001502
1	1	1	1	1	1	1	1
8710441	87106	8711002	8711003	8711202	8711216	871122	871149
2	1	1	1	1	1	1	1
8711561	8711803	871201	8712064	8712289	8712291	87127	8712729
1	1	1	1	1	1	1	1
8712766	8712853	87139402	87163	87164	871641	871642	872113
1	1	1	1	1	1	1	1
872608	87281702	873357	873586	873592	873593	873701	873843
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873885	874158	874217	874373	874662	874839	874858	875093
1	1	1	1	1	1	2	1
875099	875263	87556202	875878	875938	877159	877486	877500
1	1	1	1	1	1	1	1
877501	877989	878796	87880	87930	879523	879804	879830
1	1	1	1	1	1	1	1
8810158	8810436	881046502	8810528	8810703	881094802	8810955	8810987
1	1	1	1	3	1	1	1
8811523	8811779	8811842	88119002	8812816	8812818	8812844	8812877
1	1	1	1	1	1	1	1
8813129	88143502	88147101	88147102	88147202	881861	881972	88199202
1	1	1	1	1	1	1	1
88203002	88206102	882488	88249602	88299702	883263	883270	88330202
1	1	1	1	1	1	1	1
88350402	883539	883852	88411702	884180	884437	884448	884626
1	1	1	1	1	1	1	1
88466802	884689	884948	88518501	885429	8860702	886226	886452
1	1	1	1	1	1	1	1
88649001	886776	887181	88725602	887549	888264	888570	889403
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889719	88995002	8910251	8910499	8910506	8910720	8910721	8910748
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8910988	8910996	8911163	8911164	8911230	8911670	8911800	8911834
1	1	1	1	1	1	1	1
8912049	8912055	89122	8912280	8912284	8912521	8912909	8913
1	1	1	1	1	1	1	1

8913049	89143601	89143602	8915	891670	891703	891716	891923
1	1	1	1	1	1	1	1
891936	892189	892214	892399	892438	892604	89263202	892657
1	1	1	1	1	1	1	1
89296	893061	89344	89346	893526	893548	893783	89382601
1	1	1	1	1	1	1	1
89382602	893988	894047	894089	894090	894326	894329	894335
1	1	1	1	1	1	1	1
894604	894618	894855	895100	89511501	89511502	89524	895299
1	1	1	1	1	1	1	1
8953902	895633	896839	896864	897132	897137	897374	89742801
1	1	1	1	1	1	1	1
897604	897630	897880	89812	89813	898143	89827	898431
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89864002	898677	898678	89869	898690	899147	899187	899667
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    913512     913535   91376701   91376702     914062     914101     914102     914333
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    914366     914580     914769      91485     914862      91504      91505     915143
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$`3`$table
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$`3`$accuracy
[1] 0.6362039


$`4`
$`4`$clusters
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8711561	8711803	871201	8712064	8712289	8712291	87127	8712729
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8712766	8712853	87139402	87163	87164	871641	871642	872113

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88203002   88206102     882488   88249602   88299702     883263     883270   88330202
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88466802     884689     884948   88518501     885429    8860702     886226     886452
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911150	911157302	9111596	9111805	9111843	911201	911202	9112085
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  924084     924342     924632     924934     924964     925236     925277     925291
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$`4`$table
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$`4`$accuracy
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    857155     857156     857343     857373     857374     857392     857438   85759902
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915691	915940	91594602	916221	916799	916838	917062	917080
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924084	924342	924632	924934	924964	925236	925277	925291
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925292	925311	925622	926125	926424	926682	926954	927241
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$`5`$table
       diagnosis
clusters   B   M
       1  12 165
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       3 343  40
       4   2   0
       5   0   2


$`5`$accuracy
[1] 0.9086116



$`6`
$`6`$clusters
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         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
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  85382601    854002    854039    854253    854268    854941    855133    855138
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    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
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  85922302    859283    859464    859465    859471    859487    859575    859711
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    859717    859983   8610175   8610404   8610629   8610637   8610862   8610908
         1         1         3         3         3         1         2         3
    861103   8611161   8611555   8611792   8612080   8612399  86135501  86135502
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    861597    861598    861648    861799    861853    862009    862028     86208
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     86211    862261    862485    862548    862717    862722    862965    862980
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908194	908445	908469	908489	908916	909220	909231	909410
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911320502     9113239    9113455    9113514    9113538     911366    9113778    9113816
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   911384     9113846     911391     911408     911654     911673     911685     911916
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   912193       91227     912519     912558     912600     913063     913102     913505
        3           3          3          3          3          5          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
        5           5          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          5          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
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$`6`$table
       diagnosis
clusters   B   M
       1  12 165
       2   0   5
       3 331  39
       4   2   0
       5  12   1
       6   0   2
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$`6`$accuracy
[1] 0.9086116



$`7`
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    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
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    855167    855563    855625    856106  85638502    857010  85713702     85715
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    857155    857156    857343    857373    857374    857392    857438  85759902
         3         3         3         3         3         1         3         3
    857637    857793    857810    858477    858970    858981    858986    859196
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  85922302    859283    859464    859465    859471    859487    859575    859711
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    859717    859983   8610175   8610404   8610629   8610637   8610862   8610908
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    861597    861598    861648    861799    861853    862009    862028     86208
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     86409    864292    864496    864685    864726    864729    864877    865128
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    868223    868682    868826    868871    868999    869104    869218    869224
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8712766	8712853	87139402	87163	87164	871641	871642	872113
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875099	875263	87556202	875878	875938	877159	877486	877500
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8810158	8810436	881046502	8810528	8810703	881094802	8810955	8810987
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88350402	883539	883852	88411702	884180	884437	884448	884626
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901315	9013579	9013594	9013838	901549	901836	90250	90251
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   915691    915940  91594602    916221    916799    916838    917062    917080
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   918192    918465     91858  91903901  91903902  91930402    919537    919555
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   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
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$`7`$table
       diagnosis
clusters   B   M
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       2   0   3
       3 331  39
       4   2   0
       5  12   1
       6   0   2
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$`7`$accuracy
[1] 0.9086116


$`8`
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85382601	854002	854039	854253	854268	854941	855133	855138
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855167	855563	855625	856106	85638502	857010	85713702	85715
4	1	2	1	1	2	4	1
857155	857156	857343	857373	857374	857392	857438	85759902
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911320502	9113239	9113455	9113514	9113538	911366	9113778	9113816
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911384	9113846	911391	911408	911654	911673	911685	911916
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912193	91227	912519	912558	912600	913063	913102	913505
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913512	913535	91376701	91376702	914062	914101	914102	914333
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914366	914580	914769	91485	914862	91504	91505	915143
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915186	915276	91544001	91544002	915452	915460	91550	915664
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915691	915940	91594602	916221	916799	916838	917062	917080
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917092	91762702	91789	917896	917897	91805	91813701	91813702
4	2	4	4	4	4	1	4

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        4         1         4         6         4         1         4         4
   922297    922576    922577    922840    923169    923465    923748    923780
        4         4         4         4         4         4         4         4
   924084    924342    924632    924934    924964    925236    925277    925291
        4         4         4         4         4         4         4         4
   925292    925311    925622    926125    926424    926682    926954    927241
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$`8`$table
       diagnosis
clusters   B   M
       1  12  86
       2   0  79
       3   0   3
       4 331  39
       5   2   0
       6  12   1
       7   0   2
       8   0   2

$`8`$accuracy
[1] 0.9086116



$`9`
$`9`$clusters
   842302    842517  84300903  84348301  84358402    843786    844359  84458202
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        1         3         4         1         2         4         1         1
   848406  84862001    849014   8510426   8510653   8510824   8511133    851509
        4         1         2         4         4         4         1         2
   852552    852631    852763    852781    852973    853201    853401    853612
        2         1         1         2         1         4         1         1
 85382601    854002    854039    854253    854268    854941    855133    855138
        1         1         1         1         1         4         4         1
   855167    855563    855625    856106  85638502    857010  85713702     85715
        4         1         2         1         1         2         4         1
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857637	857793	857810	858477	858970	858981	858986	859196
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85922302	859283	859464	859465	859471	859487	859575	859711
1	1	4	4	5	4	2	6
859717	859983	8610175	8610404	8610629	8610637	8610862	8610908
1	1	4	4	4	2	7	4
861103	8611161	8611555	8611792	8612080	8612399	86135501	86135502
4	1	2	2	4	2	4	2
861597	861598	861648	861799	861853	862009	862028	86208
4	1	4	4	4	4	1	2
86211	862261	862485	862548	862717	862722	862965	862980
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862989	863030	863031	863270	86355	864018	864033	86408
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86409	864292	864496	864685	864726	864729	864877	865128
6	4	4	4	4	1	1	4
865137	86517	865423	865432	865468	86561	866083	866203
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866458	866674	866714	8670	86730502	867387	867739	868202
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868223	868682	868826	868871	868999	869104	869218	869224
4	4	1	4	4	4	4	4
869254	869476	869691	86973701	86973702	869931	871001501	871001502
4	4	1	4	4	4	4	6
8710441	87106	8711002	8711003	8711202	8711216	871122	871149
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8711561	8711803	871201	8712064	8712289	8712291	87127	8712729
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8712766	8712853	87139402	87163	87164	871641	871642	872113
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872608	87281702	873357	873586	873592	873593	873701	873843
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873885	874158	874217	874373	874662	874839	874858	875093
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875099	875263	87556202	875878	875938	877159	877486	877500
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8810158	8810436	881046502	8810528	8810703	881094802	8810955	8810987
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8811523	8811779	8811842	88119002	8812816	8812818	8812844	8812877

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8813129	88143502	88147101	88147102	88147202	881861	881972	88199202
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88203002	88206102	882488	88249602	88299702	883263	883270	88330202
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88350402	883539	883852	88411702	884180	884437	884448	884626
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88466802	884689	884948	88518501	885429	8860702	886226	886452
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88649001	886776	887181	88725602	887549	888264	888570	889403
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894604	894618	894855	895100	89511501	89511502	89524	895299
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924084	924342	924632	924934	924964	925236	925277	925291
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925292	925311	925622	926125	926424	926682	926954	927241

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$`9`$table
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      4 331  39
      5   2   0
      6  12   0
      7   0   2
      8   0   2
      9   0   1
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$`9`$accuracy
[1] 0.9103691

$`10`
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   848406   84862001     849014    8510426    8510653    8510824    8511133     851509
        4          1          2          4          4          4          1          2
   852552     852631     852763     852781     852973     853201     853401     853612
        2          1          1          2          1          4          1          1
 85382601     854002     854039     854253     854268     854941     855133     855138
        1          1          1          1          1          4          4          1
   855167     855563     855625     856106   85638502     857010   85713702      85715
        4          1          5          1          1          2          4          1
   857155     857156     857343     857373     857374     857392     857438   85759902
        4          4          4          4          4          2          4          4
   857637     857793     857810     858477     858970     858981     858986     859196
        2          1          4          4          4          4          1          4
 85922302     859283     859464     859465     859471     859487     859575     859711
        1          1          4          4          6          4          2          7
   859717     859983    8610175    8610404    8610629    8610637    8610862    8610908
        1          1          4          4          4          5          8          4
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86211	862261	862485	862548	862717	862722	862965	862980
4	4	4	4	4	4	4	4
862989	863030	863031	863270	86355	864018	864033	86408
4	1	1	4	5	4	4	4
86409	864292	864496	864685	864726	864729	864877	865128
7	4	4	4	4	1	1	4
865137	86517	865423	865432	865468	86561	866083	866203
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866458	866674	866714	8670	86730502	867387	867739	868202
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868223	868682	868826	868871	868999	869104	869218	869224
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869254	869476	869691	86973701	86973702	869931	871001501	871001502
4	4	1	4	4	4	4	7
8710441	87106	8711002	8711003	8711202	8711216	871122	871149
6	4	4	4	2	4	4	4
8711561	8711803	871201	8712064	8712289	8712291	87127	8712729
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8712766	8712853	87139402	87163	87164	871641	871642	872113
5	4	4	4	1	4	4	4
872608	87281702	873357	873586	873592	873593	873701	873843
7	1	4	4	2	5	1	4
873885	874158	874217	874373	874662	874839	874858	875093
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875099	875263	87556202	875878	875938	877159	877486	877500
4	1	1	4	1	4	2	1
877501	877989	878796	87880	87930	879523	879804	879830
4	4	5	1	4	4	4	4
8810158	8810436	881046502	8810528	8810703	881094802	8810955	8810987
1	4	2	4	9	10	1	1
8811523	8811779	8811842	88119002	8812816	8812818	8812844	8812877
4	4	2	2	4	4	4	1
8813129	88143502	88147101	88147102	88147202	881861	881972	88199202
4	4	4	4	4	1	1	4
88203002	88206102	882488	88249602	88299702	883263	883270	88330202
4	2	4	4	2	2	4	2
88350402	883539	883852	88411702	884180	884437	884448	884626
4	4	7	4	2	4	4	4
88466802	884689	884948	88518501	885429	8860702	886226	886452

```
       4          4          5          4          1          4          2          4
88649001     886776     887181   88725602     887549     888264     888570     889403
       5          1          5          1          2          4          2          4
  889719   88995002    8910251    8910499    8910506    8910720    8910721    8910748
       1          2          4          4          4          4          4          4
 8910988    8910996    8911163    8911164    8911230    8911670    8911800    8911834
       5          4          4          4          4          4          4          4
 8912049    8912055      89122    8912280    8912284    8912521    8912909       8913
       1          4          2          1          4          4          4          4
 8913049   89143601   89143602       8915     891670     891703     891716     891923
       4          4          7          4          4          4          4          4
  891936     892189     892214     892399     892438     892604   89263202     892657
       4          4          4          4          5          4          5          4
   89296     893061      89344      89346     893526     893548     893783   89382601
       4          4          4          4          4          4          4          4
89382602     893988     894047     894089     894090     894326     894329     894335
       4          4          4          4          4          1          7          4
  894604     894618     894855     895100   89511501   89511502      89524     895299
       4          4          4          1          4          4          4          4
 8953902     895633     896839     896864     897132     897137     897374   89742801
       1          1          1          1          4          4          4          2
  897604     897630     897880      89812      89813     898143      89827     898431
       4          2          4          2          4          4          4          2
89864002     898677     898678      89869     898690     899147     899187     899667
       4          4          4          4          4          4          4          1
  899987    9010018     901011    9010258    9010259     901028    9010333  901034301
       2          1          4          4          4          4          4          4
901034302    901041    9010598    9010872    9010877     901088    9011494    9011495
       4          4          4          4          4          2          2          4
 9011971    9012000    9012315    9012568    9012795     901288    9013005     901303
       2          2          1          4          2          2          4          4
  901315    9013579    9013594    9013838     901549     901836      90250      90251
       7          4          4          1          4          4          4          4
  902727      90291     902975     902976     903011      90312   90317302     903483
       4          4          4          4          4          5          4          4
  903507     903516     903554     903811   90401601   90401602     904302     904357
       1          1          4          4          4          4          4          4
90439701     904647     904689       9047     904969     904971     905189     905190
       1          4          4          4          4          4          4          4
90524101     905501     905502     905520     905539     905557     905680     905686
       1          4          4          4          4          4          4          4
  905978   90602302     906024     906290     906539     906564     906616     906878
       4          5          4          4          4          1          4          4
```

```
    907145      907367      907409       90745    90769601    90769602      907914      907915
         4           4           4           4           4           4           1           4
    908194      908445      908469      908489      908916      909220      909231      909410
         2           2           4           1           4           4           4           4
    909411      909445    90944601      909777     9110127     9110720     9110732     9110944
         4           4           4           4           4           4           2           4
    911150   911157302     9111596     9111805     9111843      911201      911202     9112085
         4           2           4           2           4           4           4           4
   9112366     9112367     9112594     9112712   911296201   911296202     9113156   911320501
         4           4           4           4           2           9           4           4
 911320502     9113239     9113455     9113514     9113538      911366     9113778     9113816
         4           4           4           4           5           1           4           4
    911384     9113846      911391      911408      911654      911673      911685      911916
         4           4           4           4           4           4           4           1
    912193       91227      912519      912558      912600      913063      913102      913505
         4           4           4           4           4           7           4           1
    913512      913535    91376701    91376702      914062      914101      914102      914333
         4           4           4           4           2           4           4           4
    914366      914580      914769       91485      914862       91504       91505      915143
         1           4           2           1           4           1           4           2
    915186      915276    91544001    91544002      915452      915460       91550      915664
         7           7           4           4           4           1           4           4
    915691      915940    91594602      916221      916799      916838      917062      917080
         1           4           4           4           1           2           4           4
    917092    91762702       91789      917896      917897       91805    91813701    91813702
         4           2           4           4           4           4           1           4
    918192      918465       91858    91903901    91903902    91930402      919537      919555
         4           4           4           4           4           2           4           2
  91979701      919812      921092      921362      921385      921386      921644      922296
         4           1           4           7           4           1           4           4
    922297      922576      922577      922840      923169      923465      923748      923780
         4           4           4           4           4           4           4           4
    924084      924342      924632      924934      924964      925236      925277      925291
         4           4           4           4           4           4           4           4
    925292      925311      925622      926125      926424      926682      926954      927241
         4           4           1           5           2           2           4           5
     92751
         4

$`10`$table
       diagnosis
clusters  B   M
       1  12  86
```

```
2     0  59
3     0   3
4   331  39
5     0  20
6     2   0
7    12   0
8     0   2
9     0   2
10    0   1
```

```
$`10`$accuracy
[1] 0.9103691
```

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

```
#ward.d2 this method reduces cluster variance and allows for more clarity
# within clusters
```