# Class 8 Mini Project

AUTHOR
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#Outline Today we will apply the machine learning methods we introduced in the last class on breast cancer biopsy data from fine needle aspiration (FNA).

```
wisc.df <- read.csv("WisconsinCancer.csv")
head(wisc.df)
```

```
        id diagnosis radius_mean texture_mean perimeter_mean area_mean
1   842302         M       17.99        10.38         122.80    1001.0
2   842517         M       20.57        17.77         132.90    1326.0
3 84300903         M       19.69        21.25         130.00    1203.0
4 84348301         M       11.42        20.38          77.58     386.1
5 84358402         M       20.29        14.34         135.10    1297.0
6   843786         M       12.45        15.70          82.57     477.1
  smoothness_mean compactness_mean concavity_mean concave.points_mean
1         0.11840          0.27760         0.3001             0.14710
2         0.08474          0.07864         0.0869             0.07017
3         0.10960          0.15990         0.1974             0.12790
4         0.14250          0.28390         0.2414             0.10520
5         0.10030          0.13280         0.1980             0.10430
6         0.12780          0.17000         0.1578             0.08089
  symmetry_mean fractal_dimension_mean radius_se texture_se perimeter_se
1        0.2419                0.07871    1.0950     0.9053        8.589
2        0.1812                0.05667    0.5435     0.7339        3.398
3        0.2069                0.05999    0.7456     0.7869        4.585
4        0.2597                0.09744    0.4956     1.1560        3.445
5        0.1809                0.05883    0.7572     0.7813        5.438
6        0.2087                0.07613    0.3345     0.8902        2.217
  area_se smoothness_se compactness_se concavity_se concave.points_se
1  153.40      0.006399        0.04904      0.05373           0.01587
2   74.08      0.005225        0.01308      0.01860           0.01340
3   94.03      0.006150        0.04006      0.03832           0.02058
4   27.23      0.009110        0.07458      0.05661           0.01867
5   94.44      0.011490        0.02461      0.05688           0.01885
6   27.19      0.007510        0.03345      0.03672           0.01137
  symmetry_se fractal_dimension_se radius_worst texture_worst perimeter_worst
1     0.03003             0.006193        25.38         17.33          184.60
2     0.01389             0.003532        24.99         23.41          158.80
3     0.02250             0.004571        23.57         25.53          152.50
4     0.05963             0.009208        14.91         26.50           98.87
5     0.01756             0.005115        22.54         16.67          152.20
6     0.02165             0.005082        15.47         23.75          103.40
  area_worst smoothness_worst compactness_worst concavity_worst
1     2019.0           0.1622            0.6656          0.7119
2     1956.0           0.1238            0.1866          0.2416
3     1709.0           0.1444            0.4245          0.4504
4      567.7           0.2098            0.8663          0.6869
5     1575.0           0.1374            0.2050          0.4000
6      741.6           0.1791            0.5249          0.5355
  concave.points_worst symmetry_worst fractal_dimension_worst
1               0.2654         0.4601                 0.11890
2               0.1860         0.2750                 0.08902
3               0.2430         0.3613                 0.08758
4               0.2575         0.6638                 0.17300
5               0.1625         0.2364                 0.07678
6               0.1741         0.3985                 0.12440
```

```r
rownames(wisc.df) <- wisc.df$id
wisc.df$id <- NULL
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
```

```
# 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
```

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

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

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

```
[1] 569
```

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

```
  B   M
357 212
```

```
sum(wisc.df$diagnosis == "M")
```

```
[1] 212
```

```
col_names <- colnames(wisc.df)
mean_columns <- grep("_mean$", col_names)
num_mean_columns <- length(mean_columns)
num_mean_columns
```

```
[1] 10
```

Q1: 569 observations Q2: 212 malignant diagnosis Q3: 10 variables/features in the data are suffixed with _mean.

```
# 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
```

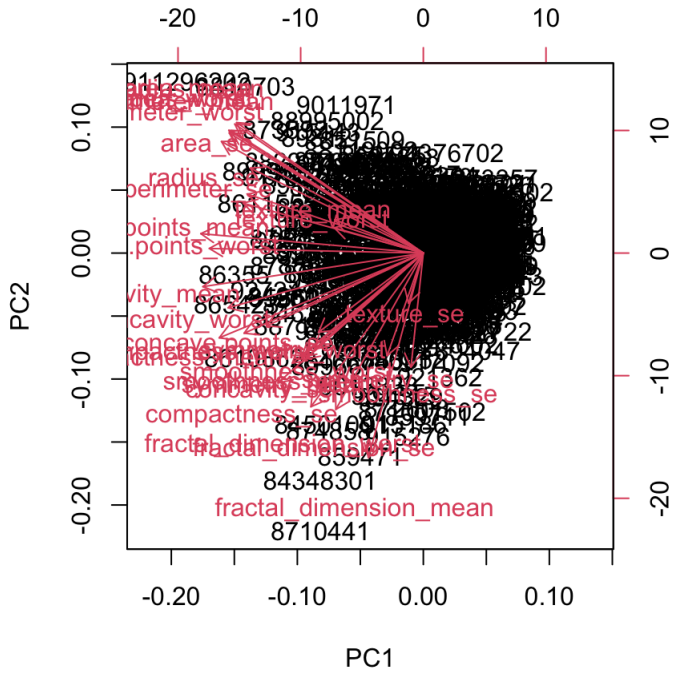
We need to sclae our input data before PCA as some of the columns are measured in terms of very different units with different means and different variances. The upshot here is we set 'scale =TRUE' argument to 'prcomp()'

```
# Perform PCA on wisc.data by completing the following code
wisc.pr <- prcomp(wisc.data, scale = TRUE)
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
```

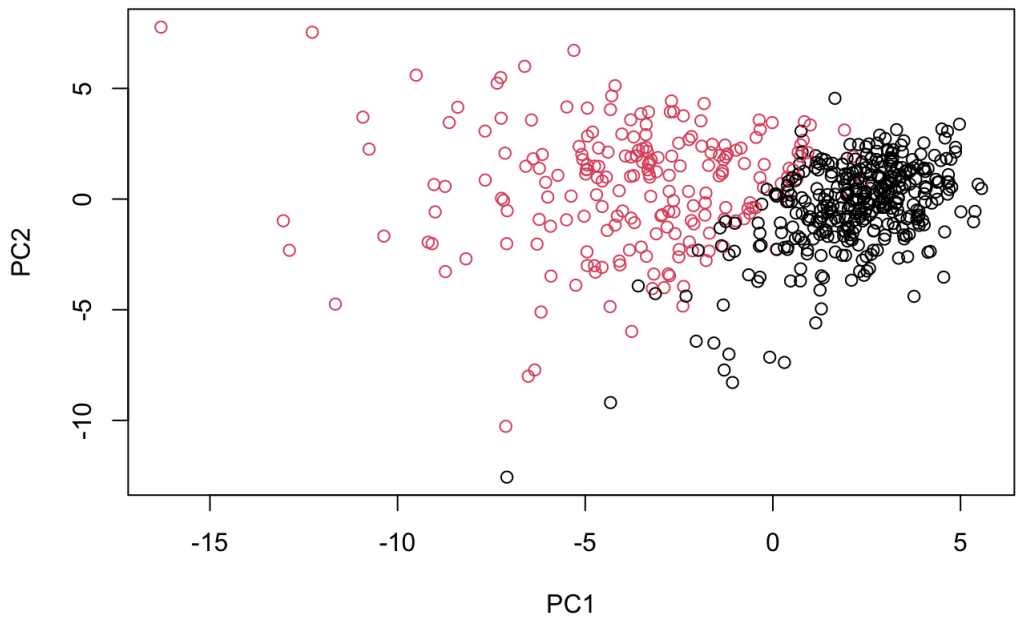
Q4: PC1 captures 0.4427 variance Q5: 3 pricipal components, PC1,2,3. Q6: 7 principal components

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




Q7: The plot is too dense and hard to read.

```
# Scatter plot observations by components 1 and 2
plot(wisc.pr$x[,1], wisc.pr$x[,2], col = diagnosis,
     xlab = "PC1", ylab = "PC2")
```

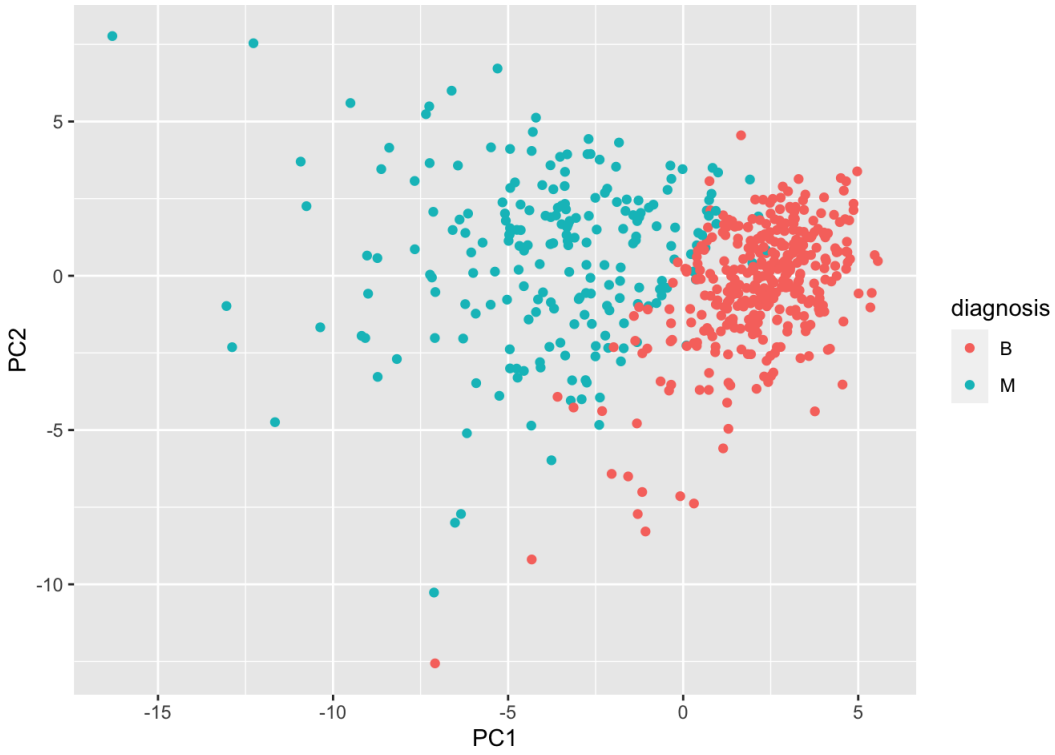



Q8: Most malignant samples are on the left (PC1<0), most benign samples are on the right (PC1>0).

```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()
```

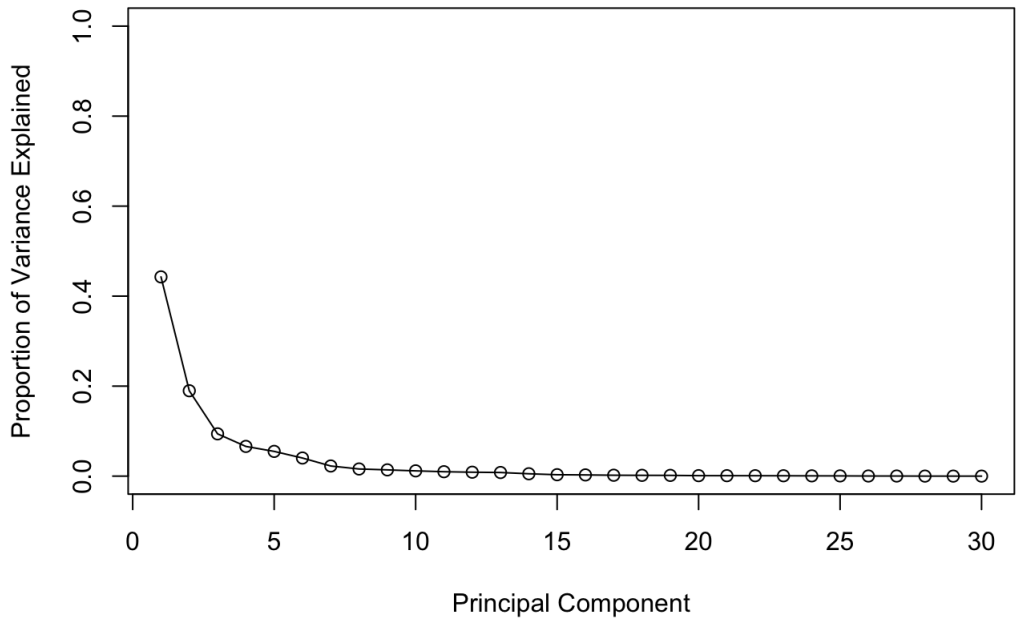



```r
# Calculate variance of each component
pr.var <- wisc.pr$sdev^2
head(pr.var)
```

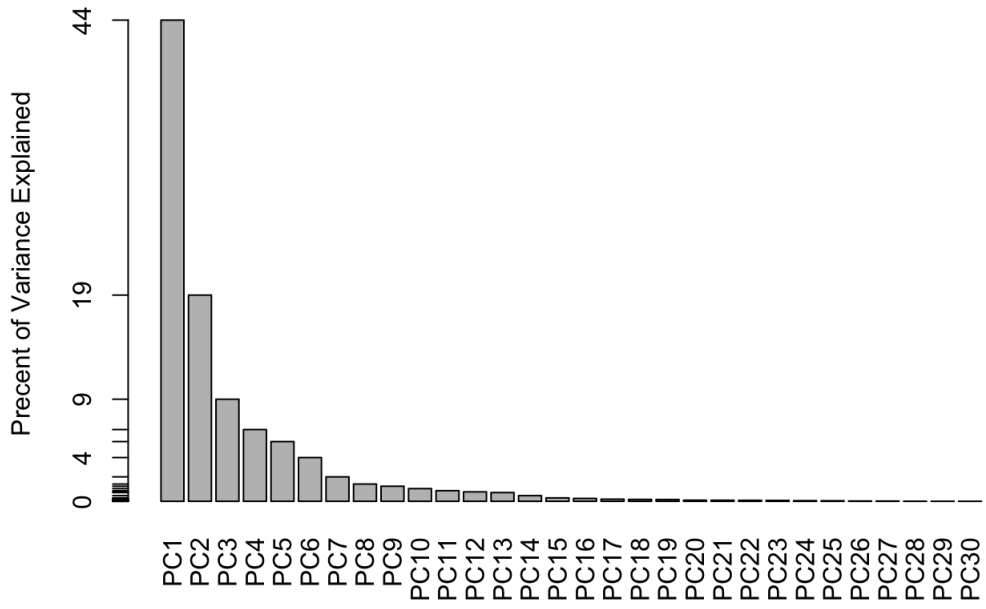
```
[1] 13.281608  5.691355  2.817949  1.980640  1.648731  1.207357
```

```r
# 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")
```



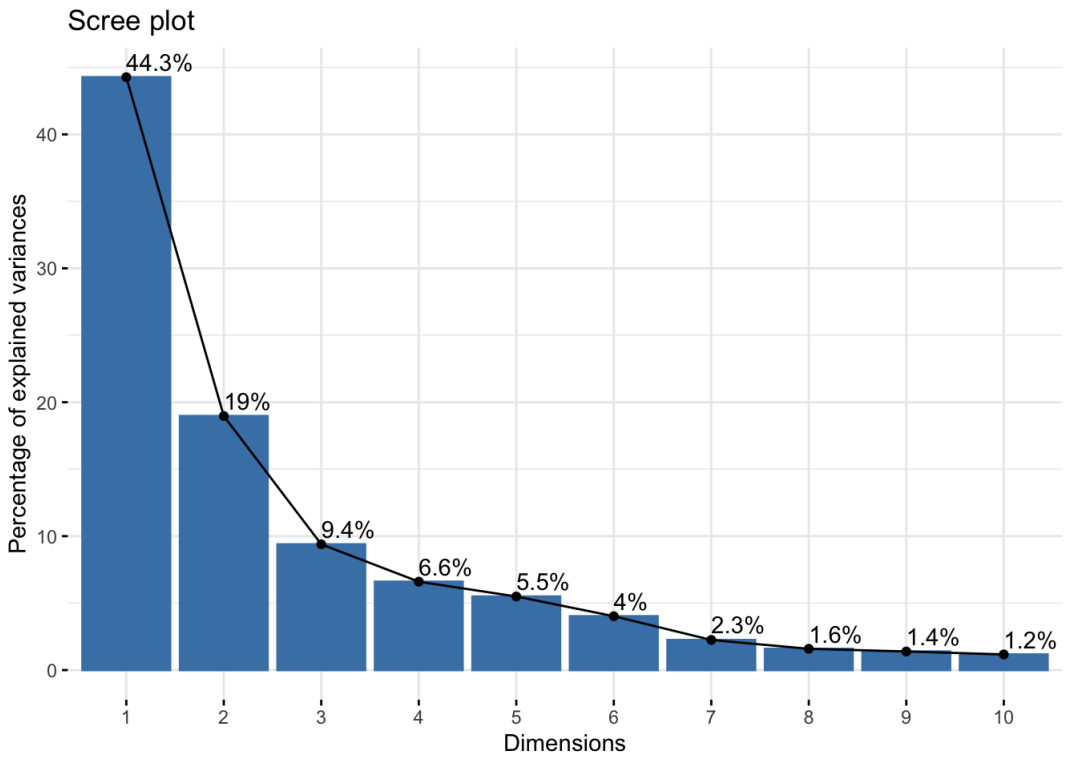

```
# Alternative scree plot of the same data, note data driven y-axis
barplot(pve, ylab = "Precent of Variance Explained",
     names.arg=paste0("PC",1:length(pve)), las=2, axes = FALSE)
axis(2, at=pve, labels=round(pve,2)*100 )
```




```
## ggplot based graph
library(factoextra)
```

```
Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

```
fviz_eig(wisc.pr, addlabels = TRUE)
```



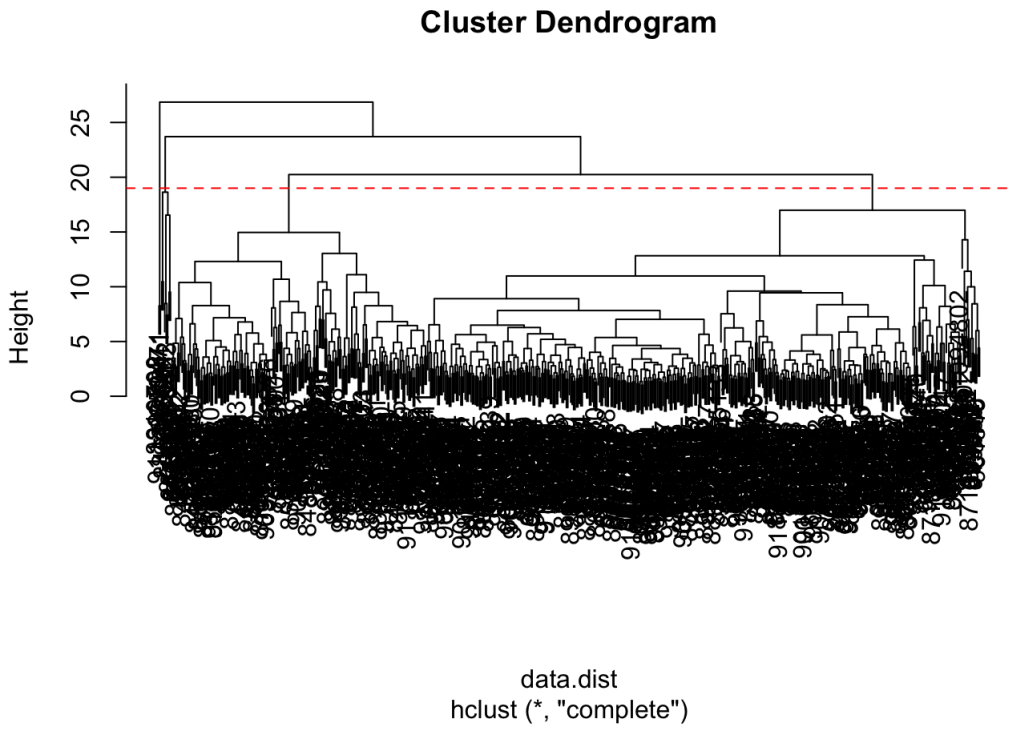

```
pc1 <- wisc.pr$rotation[,1]
pc1['concave.points_mean']
```

```
concave.points_mean
         -0.2608538
```

Q9.-0.2608538. Q10.5 principal components.

```
# 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")
```

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




Q11: 19

```
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
```

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

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

```
wisc.hclust.clusters <- cutree(wisc.hclust, k = 10)
table(wisc.hclust.clusters, diagnosis)
```

```
                   diagnosis
wisc.hclust.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
```

Q12.Cluster 2 gives a better cluster vs diagnoses match. Ward2 is the best method.

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

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

```
wisc.pr$x[,1:3]
```

```
                  PC1           PC2          PC3
842302     -9.18475521  -1.946870030 -1.122178766
842517     -2.38570263   3.764859063 -0.528827374
84300903   -5.72885549   1.074228589 -0.551262540
84348301   -7.11669126 -10.266555635 -3.229947535
84358402   -3.93184247   1.946358977  1.388544953
843786     -2.37815462  -3.946456430 -2.932296681
844359     -2.23691506   2.687666414 -1.638471247
84458202   -2.14141428  -2.338186649 -0.871180715
844981     -3.17213315  -3.388831138 -3.117243065
84501001   -6.34616284  -7.720380945 -4.338098744
845636      0.80970132   2.656937673 -0.488400053
84610002   -2.64876984  -0.066509405 -1.525113359
846226     -8.17783882  -2.698602007  5.725193241
846381     -0.34182514   0.967428026  1.715661982
84667401   -4.33856172  -4.856809832 -2.813639832
84799002   -4.07207318  -2.974443983 -3.122526655
848406     -0.22985277   1.563382114 -0.801813642
84862001   -4.41412695  -1.417423150 -2.268323145
849014     -4.94435304   4.110716528 -0.314472408
8510426     1.23597583   0.188049490 -0.592761930
8510653     1.57677384  -0.572304625 -1.799863016
8510824     3.55420904  -1.661487969  0.450790799
8511133    -4.72904972  -3.302058265 -1.465247427
851509     -4.20482441   5.123858059 -0.751740573
852552     -4.94528075   1.542395143 -1.711687827
852631     -7.09232236  -2.016835734 -0.028984132
852763     -3.50717666  -2.169715994 -3.891122637
852781     -3.06136021   1.874902631  2.579478032
852973     -4.00374127  -0.536769860 -2.759197831
853201     -1.71380176   1.522365502  0.146058578
853401     -6.05411853   0.756511800 -0.348932376
853612     -2.89968469  -4.001774373 -2.998823809
85382601   -4.55077848  -0.337239419 -0.753637681
854002     -4.98621538   1.131593223 -2.575118337
854039     -2.98271631  -0.757756497 -3.490690279
854253     -2.76393718   0.354044421 -1.895295337
854268     -1.29505925  -0.912393466 -1.574383382
854941      3.74601730   1.412230504  1.730784885
855133      0.99719148   3.348346731  4.301788720
855138     -0.76459136  -0.885464837 -2.702540362
855167      2.14906252   1.922300194 -1.179446370
855563      0.09324934  -2.258764532 -1.903051997
855625     -9.08001023  -2.016898441  2.139343894
856106     -0.98958304  -0.984064148 -2.308702241
85638502    0.29328849   0.136978564 -3.299029123
857010     -5.37620991   0.134758404 -1.677366657
85713702    4.57790860  -1.482915508  0.042037623
85715      -1.69851237  -2.350203862 -3.075383081
857155      2.13456708  -0.095745364 -1.491099878
```

| | | | |
|---|---|---|---|
| 857156 | 1.56610099 | 1.207370855 | -0.368834570 |
| 857343 | 3.53979091 | 1.281368110 | 1.017315805 |
| 857373 | 3.15503795 | 1.687473796 | -0.495857416 |
| 857374 | 3.44745515 | 0.497780720 | -0.152383875 |
| 857392 | -3.29964761 | 1.129943574 | 0.825666100 |
| 857438 | 0.67402621 | 2.114549137 | -1.394992302 |
| 85759902 | 2.85564577 | -0.152588874 | 0.428557855 |
| 857637 | -4.64465207 | 2.308301508 | -0.728168145 |
| 857793 | -2.17494916 | -0.971261438 | -1.942179421 |
| 857810 | 3.71818738 | 1.786070097 | 1.278807604 |
| 858477 | 4.13232693 | -2.401679261 | -1.241865694 |
| 858970 | 2.38373822 | -2.755233814 | 1.213018303 |
| 858981 | 2.57661610 | -3.135912650 | 1.399049169 |
| 858986 | -4.75492832 | -3.009032875 | -0.166094576 |
| 859196 | 2.31209785 | -3.265116721 | 2.793766025 |
| 85922302 | -1.69012080 | -1.539322116 | -1.798262954 |
| 859283 | -1.81071217 | -0.722104815 | -1.464960560 |
| 859464 | 2.78347559 | -2.308617372 | 0.472309720 |
| 859465 | 3.51555502 | 0.657730736 | 0.590855071 |
| 859471 | -4.32619605 | -9.194435552 | 1.491650337 |
| 859487 | 3.25841241 | 0.937013647 | 0.204949679 |
| 859575 | -2.70221851 | 4.433240985 | 0.307075192 |
| 859711 | 0.30758513 | -7.381317396 | 3.815728542 |
| 859717 | -5.49886689 | -0.937500513 | -2.208188675 |
| 859983 | 0.36139121 | -0.119633821 | -2.039161544 |
| 8610175 | 2.62766457 | 0.696696349 | -0.583428281 |
| 8610404 | -1.42691206 | 1.965372092 | 1.110961327 |
| 8610629 | 0.83378424 | -1.963876860 | 0.789737653 |
| 8610637 | -6.22541880 | -0.919260690 | 0.089748341 |
| 8610862 | -11.65845644 | -4.744442593 | 2.004115633 |
| 8610908 | 2.01980045 | 0.254675746 | -0.647302452 |
| 861103 | 1.63694460 | -1.714440587 | 0.433824539 |
| 8611161 | -1.16643527 | -2.512305286 | -1.904043397 |
| 8611555 | -10.75977535 | 2.255997858 | 0.038801648 |
| 8611792 | -5.03038488 | -0.773728357 | 2.679979922 |
| 8612080 | 2.17255269 | -0.496441169 | -0.948257444 |
| 8612399 | -3.28534463 | 1.666770480 | 0.146802675 |
| 86135501 | -0.60707378 | -0.162071919 | 1.635935419 |
| 86135502 | -3.58041324 | 2.204721916 | -1.703037100 |
| 861597 | 0.93333687 | -0.926885919 | -0.040128345 |
| 861598 | -1.25849730 | -1.014684255 | -0.080521995 |
| 861648 | 1.58686770 | 1.618232954 | 0.309726682 |
| 861799 | -0.25227559 | 0.530884425 | 0.588809736 |
| 861853 | 2.84492835 | 2.891103732 | 0.527524677 |
| 862009 | 1.96322268 | 0.964308498 | -0.081136715 |
| 862028 | -2.77342525 | -0.557509977 | -0.605238702 |
| 86208 | -4.39236314 | 2.121640892 | 0.579000549 |
| 86211 | 2.58980407 | -0.213446120 | 1.034701089 |
| 862261 | 3.90090576 | -1.189020421 | 1.550616806 |
| 862485 | 2.81575365 | -0.367560567 | -1.350247556 |
| 862548 | -0.61573908 | -0.638349988 | -0.199743121 |
| 862717 | 0.43247968 | 1.390820523 | -0.082646762 |
| 862722 | 4.55102442 | -3.525683788 | -0.215074716 |
| 862965 | 3.44515217 | 1.423370040 | -0.088646005 |
| 862980 | 2.11410008 | -1.847747782 | -0.556184595 |
| 862989 | 2.68898618 | -1.418813334 | 0.968298772 |
| 863030 | -3.21109134 | -4.043198634 | -2.712997305 |
| 863031 | 0.74861266 | -1.796058175 | -0.567866143 |
| 863270 | 3.15622889 | 1.034838878 | -1.489373670 |
| 86355 | -13.04464395 | -0.980650357 | 0.598286247 |
| 864018 | 2.22672053 | -0.666823902 | -1.090600727 |
| 864033 | 2.49063954 | -2.596401708 | 1.668257671 |
| 86408 | 0.10325957 | -2.278139015 | 2.107708229 |

| | | | |
|---|---|---|---|
| 86409 | -3.58813694 | -3.922881433 | 2.045207163 |
| 864292 | 1.34776279 | -3.553098748 | 1.730668471 |
| 864496 | 2.50791098 | -3.248461200 | -1.686140767 |
| 864685 | 2.04423086 | -0.304616836 | -0.533369397 |
| 864726 | 2.09522559 | -3.663872062 | 3.629007335 |
| 864729 | -3.10779316 | -1.568009873 | -2.611638159 |
| 864877 | -4.95236801 | -2.382749650 | -1.933405900 |
| 865128 | -0.85026612 | 2.304707468 | 0.566963050 |
| 865137 | 2.96339173 | -0.371179883 | -2.064716427 |
| 86517 | -3.33120209 | 1.324392029 | 0.727373652 |
| 865423 | -12.88327621 | -2.314585873 | 6.323133317 |
| 865432 | 0.77006610 | 0.064052860 | -1.133411514 |
| 865468 | 2.20057925 | 0.734958544 | 0.266845303 |
| 86561 | 3.14064881 | 1.875758557 | -0.669779705 |
| 866083 | 0.63831885 | 0.910564828 | -2.140840449 |
| 866203 | -1.91744627 | 3.534971966 | 1.253821297 |
| 866458 | -1.40762980 | -1.303782215 | 0.640864876 |
| 866674 | -4.63960895 | 1.480714297 | -1.169651383 |
| 866714 | 1.87581684 | -1.421979452 | -1.069870821 |
| 8670 | -1.43081046 | 1.048681220 | -1.260901861 |
| 86730502 | -1.35143790 | 1.153126842 | -1.208729712 |
| 867387 | 0.70849143 | 1.566853657 | -0.669405084 |
| 867739 | -2.16950708 | 2.823776101 | -0.561613332 |
| 868202 | 1.97510247 | 0.419018755 | -0.380240597 |
| 868223 | 2.59850310 | 0.481911436 | 1.870726668 |
| 868682 | 3.25514318 | 0.417953651 | -0.691197447 |
| 868826 | -3.77870160 | -0.859625218 | 3.667773435 |
| 868871 | 1.99028348 | -1.328186508 | 1.134246527 |
| 868999 | 5.01059989 | -0.574194748 | -0.841697543 |
| 869104 | -1.34383800 | 1.273650278 | 0.555354894 |
| 869218 | 2.45380972 | -0.897665441 | 0.352823033 |
| 869224 | 1.83566648 | 0.090946742 | -1.444010288 |
| 869254 | 4.34266862 | 0.892786708 | 0.638694049 |
| 869476 | 0.73216868 | -3.698927716 | 0.657926113 |
| 869691 | -2.39788795 | -4.833735642 | -1.027253164 |
| 86973701 | -0.39275308 | -1.082115915 | 2.245629588 |
| 86973702 | 0.41196533 | 0.389288784 | -1.044851048 |
| 869931 | 3.04724369 | 2.235817239 | -0.469040276 |
| 871001501 | 1.44129554 | -0.305601552 | 0.551062974 |
| 871001502 | -0.08311297 | -7.144073768 | -0.059957215 |
| 8710441 | -7.08707084 | -12.562140869 | 7.352238887 |
| 87106 | 3.74011364 | -0.250281306 | -0.097297641 |
| 8711002 | 0.96832079 | -0.944113582 | -0.890028129 |
| 8711003 | 2.41659356 | -0.005547532 | -0.797678511 |
| 8711202 | -4.09718264 | 0.378470806 | 1.445046044 |
| 8711216 | 0.75094226 | 3.067949187 | 1.447907672 |
| 871122 | 3.65143365 | 0.674055644 | -0.906188637 |
| 871149 | 4.67609710 | 1.102886823 | -0.257081973 |
| 8711561 | 0.59725624 | -1.784081072 | 1.480433343 |
| 8711803 | -3.38435289 | 2.908477953 | 3.004594027 |
| 871201 | -6.14447970 | 2.015878994 | -1.564766888 |
| 8712064 | 1.32386648 | -1.468002337 | 0.847675513 |
| 8712289 | -5.48932277 | 4.162167037 | -0.600732185 |
| 8712291 | 2.99476813 | 2.736453261 | -0.161042080 |
| 87127 | 4.38287625 | -0.006866240 | -0.947274735 |
| 8712729 | -1.21256768 | 2.037246395 | 0.979834026 |
| 8712766 | -5.06520424 | 1.783582969 | 1.172615291 |
| 8712853 | 1.97596280 | 1.841159394 | -0.277115927 |
| 87139402 | 2.51266554 | -0.114151857 | -0.496186180 |
| 87163 | 0.94665494 | 1.683272444 | -0.350877607 |
| 87164 | -2.81688978 | -1.263990953 | -2.151251366 |
| 871641 | 3.48092345 | -1.618268077 | 2.673117328 |
| 871642 | 4.65463399 | 0.222718846 | 1.557987797 |

| | | | |
|---|---|---|---|
| 872113 | 5.34691339 | -1.025855214 | 0.324700222 |
| 872608 | -1.16986842 | -7.008319996 | 4.268106508 |
| 87281702 | -2.95370292 | -0.705800822 | -1.041419103 |
| 873357 | 4.97132782 | 3.383227983 | 0.439451738 |
| 873586 | 4.06045289 | 1.245070643 | 0.573972801 |
| 873592 | -9.50430706 | 5.598558052 | -0.636679193 |
| 873593 | -8.99924714 | -0.580520281 | -3.131959404 |
| 873701 | -0.75821134 | 1.607118481 | -1.513763762 |
| 873843 | 2.65702172 | -0.539461132 | 1.705514033 |
| 873885 | 0.38967611 | 0.988372689 | -2.582896564 |
| 874158 | 3.88564657 | -0.815354285 | 1.014824328 |
| 874217 | -0.36455538 | 3.571318842 | -2.222023387 |
| 874373 | 2.83339783 | 0.398379162 | -0.347139642 |
| 874662 | 3.30737348 | -0.155604280 | 0.541002917 |
| 874839 | 3.35435293 | 1.102762109 | 0.151956099 |
| 874858 | -6.51738201 | -8.004126824 | -0.326136731 |
| 875093 | 1.71622508 | 0.542688019 | 3.295475582 |
| 875099 | 5.56084294 | 0.477427493 | 4.123834207 |
| 875263 | -1.77809695 | -2.774146213 | -0.941934046 |
| 87556202 | -2.60918908 | -1.560049030 | -0.217995141 |
| 875878 | 2.81656023 | 0.969257722 | -0.382255094 |
| 875938 | -2.49624245 | -2.276479790 | 1.318318594 |
| 877159 | -1.27590451 | 2.441111044 | 2.464148795 |
| 877486 | -3.47014398 | 2.275846405 | -1.237595112 |
| 877500 | -1.25557034 | -0.382057094 | -3.834946034 |
| 877501 | 1.47213604 | -0.116787496 | -0.214479145 |
| 877989 | -1.64801062 | 2.100442902 | -0.974414210 |
| 878796 | -9.02864522 | 0.654596849 | 0.221085545 |
| 87880 | -4.55058603 | -3.083925626 | -2.268408346 |
| 87930 | 0.78050321 | -0.652275325 | -0.643091145 |
| 879523 | 0.22289648 | 0.701204504 | -2.268765765 |
| 879804 | 3.45185811 | -1.305789765 | -0.029238791 |
| 879830 | -0.44615183 | 2.785257008 | 0.443991604 |
| 8810158 | -0.31416180 | -2.075734301 | -2.081480386 |
| 8810436 | 2.05738166 | 2.470613908 | -1.460433790 |
| 881046502 | -4.80474158 | 3.026440019 | 2.741606351 |
| 8810528 | 2.99607430 | 0.396429212 | -0.595941573 |
| 8810703 | -12.27421974 | 7.536778599 | 10.103533703 |
| 881094802 | -3.36923202 | -2.585550416 | 7.085840019 |
| 8810955 | -2.50656080 | -2.612349885 | 0.206198902 |
| 8810987 | -1.31690973 | -2.152585453 | -1.785061911 |
| 8811523 | 0.38841453 | -2.274796314 | 0.626780574 |
| 8811779 | 2.75450931 | -1.085879226 | 1.705737291 |
| 8811842 | -4.93923501 | 2.845820436 | 0.913075404 |
| 88119002 | -4.29429880 | 4.662172958 | -0.006834994 |
| 8812816 | 2.37141521 | 0.732757814 | -1.524685925 |
| 8812818 | 0.96634003 | -0.438052741 | -1.446423567 |
| 8812844 | 2.97318270 | -1.809381711 | -0.223238842 |
| 8812877 | -1.80166175 | -0.166314618 | -2.626288708 |
| 8813129 | 2.47618073 | 1.417329346 | -0.316254972 |
| 88143502 | 0.82531310 | 1.249148354 | 0.267725157 |
| 88147101 | 3.89127342 | -0.538097276 | -0.880783727 |
| 88147102 | 0.38923560 | 0.613875324 | -1.351679911 |
| 88147202 | 1.45604019 | 0.201549415 | -1.097912687 |
| 881861 | -2.75314552 | -3.462726769 | -2.471875866 |
| 881972 | -3.25439115 | 0.125090426 | -2.893551435 |
| 88199202 | 4.01560693 | 1.353056834 | -0.360155815 |
| 88203002 | 3.67318128 | 1.290493562 | 0.424237023 |
| 88206102 | -3.31340866 | 3.935689268 | -0.205273062 |
| 882488 | 4.03305870 | -1.161524089 | 0.189581014 |
| 88249602 | 2.33218128 | 1.347793816 | 0.232482459 |
| 88299702 | -8.39645911 | 4.150252991 | 0.046927784 |
| 883263 | -2.64524110 | 3.947699392 | 1.370675284 |

| | | | |
|---|---|---|---|
| 883270 | 0.68116951 | 1.134992457 | 1.232581929 |
| 88330202 | -3.34735048 | 2.152675899 | -1.107968825 |
| 88350402 | 2.22576208 | 1.213931555 | -0.192244621 |
| 883539 | 4.47364832 | 1.739598699 | -0.887426246 |
| 883852 | -1.32145867 | -4.785266054 | -0.661952674 |
| 88411702 | 1.84846341 | 1.582735509 | 1.262806090 |
| 884180 | -3.79222888 | 1.025330459 | 0.897845626 |
| 884437 | 2.27931254 | -2.075859442 | 2.428512195 |
| 884448 | 3.22593164 | 1.171043084 | 0.264431658 |
| 884626 | -1.02499890 | -2.359186109 | -1.615464155 |
| 88466802 | 2.58028546 | -0.728572047 | -0.547660903 |
| 884689 | 2.48369783 | -0.460191483 | -0.598393817 |
| 884948 | -7.13756174 | 2.073018195 | 1.087430513 |
| 88518501 | 3.02981522 | 0.648897838 | 0.310409540 |
| 885429 | -7.07878207 | -0.527758800 | -1.278861780 |
| 8860702 | -1.31294375 | 1.773865017 | -1.671161321 |
| 886226 | -3.70838653 | 2.805008998 | -1.754649703 |
| 886452 | -0.46007427 | -0.393819769 | -1.003815294 |
| 88649001 | -6.38703001 | 1.821491443 | 0.479427881 |
| 886776 | -5.25092469 | -3.891107226 | -0.833120389 |
| 887181 | -8.72618338 | -3.276993966 | 2.901146761 |
| 88725602 | -3.68807276 | -1.064709236 | -3.512498419 |
| 887549 | -3.37528098 | 3.368264175 | -1.765224543 |
| 888264 | 0.83947101 | 3.497008034 | 0.182323228 |
| 888570 | -3.28148526 | 0.989802279 | 2.552140777 |
| 889403 | 1.90709089 | 3.119201237 | -1.062121558 |
| 889719 | -1.61336234 | 2.472397898 | -1.989384336 |
| 88995002 | -6.61390681 | 5.997998811 | 0.988507976 |
| 8910251 | 1.46338831 | -1.685149061 | 1.168877382 |
| 8910499 | 2.01038350 | 1.102516460 | 1.336847795 |
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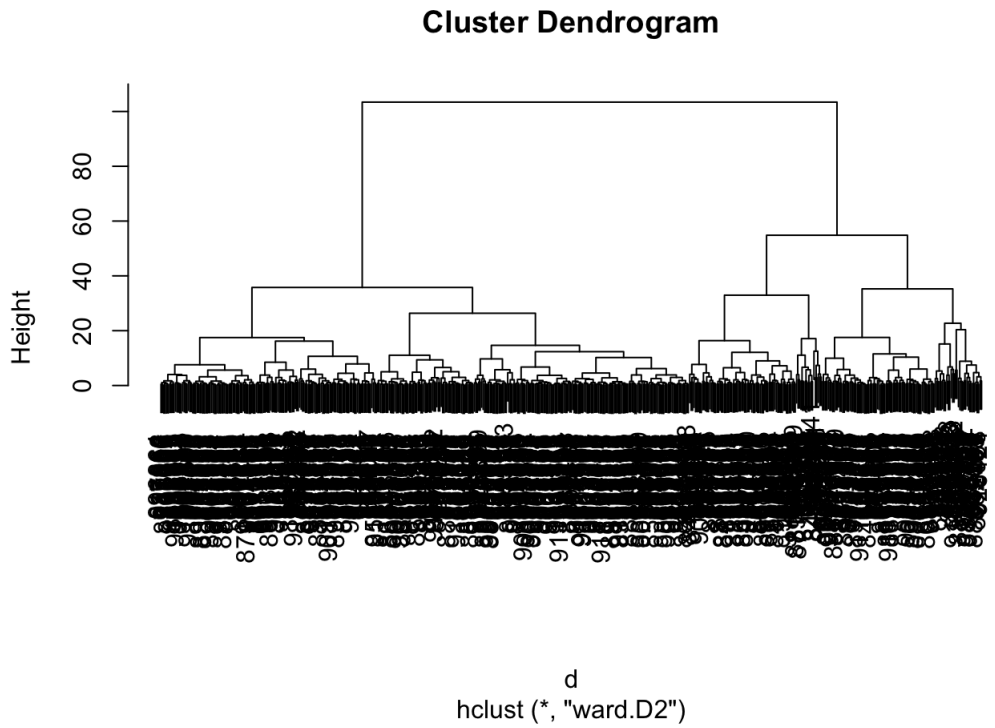
```
924342      3.49912218  -1.799249342  2.764024589
924632      2.15201013   0.829339088  0.564300199
924934      2.05327740  -1.615038205  1.837342797
924964      3.87388097  -1.083301553  1.858308794
925236      4.06028949  -0.122061034  3.235925374
925277      0.09858059   0.213372093  0.388587548
925291      1.08841850  -1.291711328  1.428122289
925292      0.48134743   0.177863190  1.031200235
925311      4.86602793   2.129232607  3.411187296
925622     -5.91241029  -3.479575000 -3.259923297
926125     -8.73365338   0.573350185  0.896301447
926424     -6.43365455   3.573672989  2.457324373
926682     -3.79004753   3.580897052  2.086640366
926954     -1.25507494   1.900624364  0.562235817
927241    -10.36567336  -1.670540206 -1.875379194
92751       5.47042990   0.670047220  1.489132801
```

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




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

```
  842302   842517 84300903 84348301 84358402   843786
       1        1        1        1        1        1
```

```
table(grps)
```

```
grps
  1   2
203 366
```

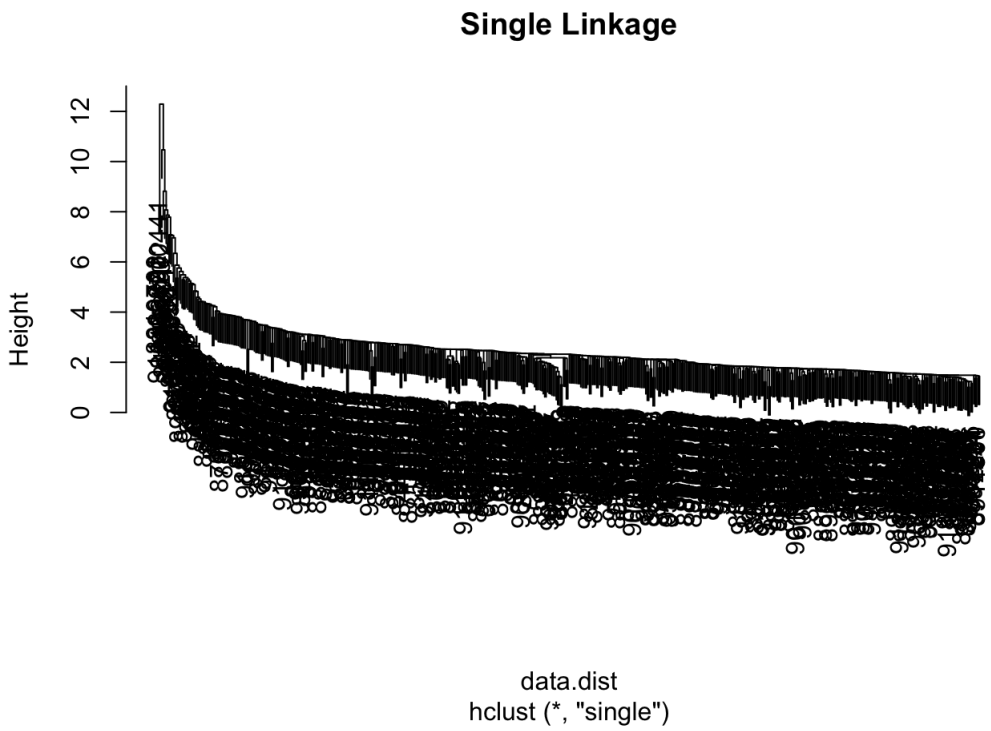
```
table(diagnosis)
```

```
diagnosis
  B   M
357 212
```

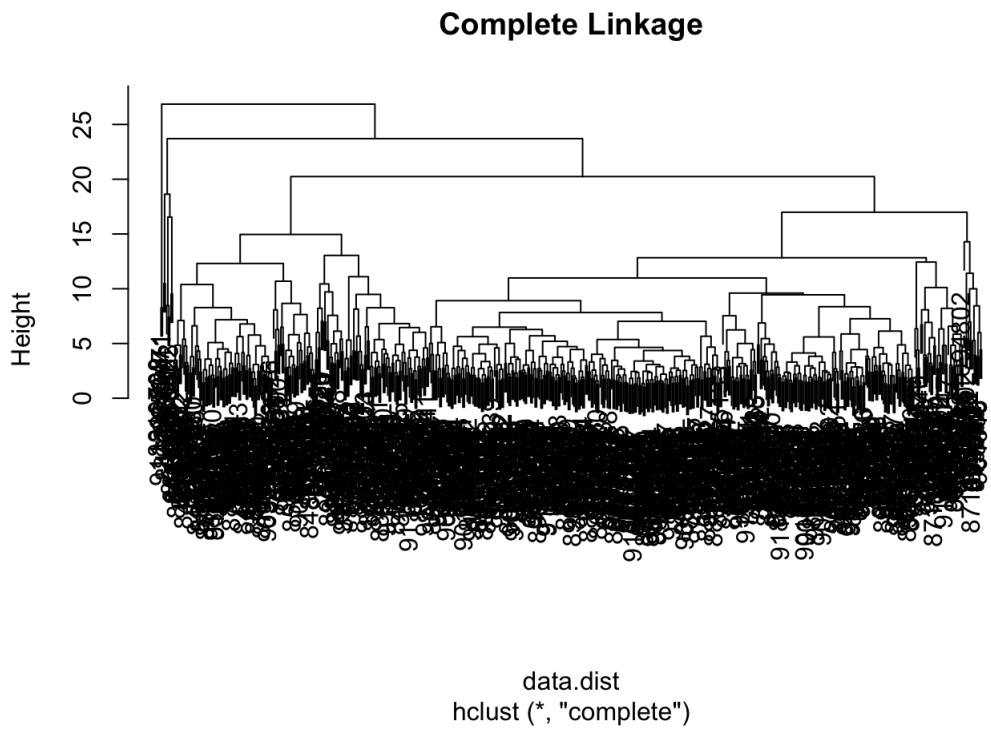
```
table(diagnosis,grps)
```

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

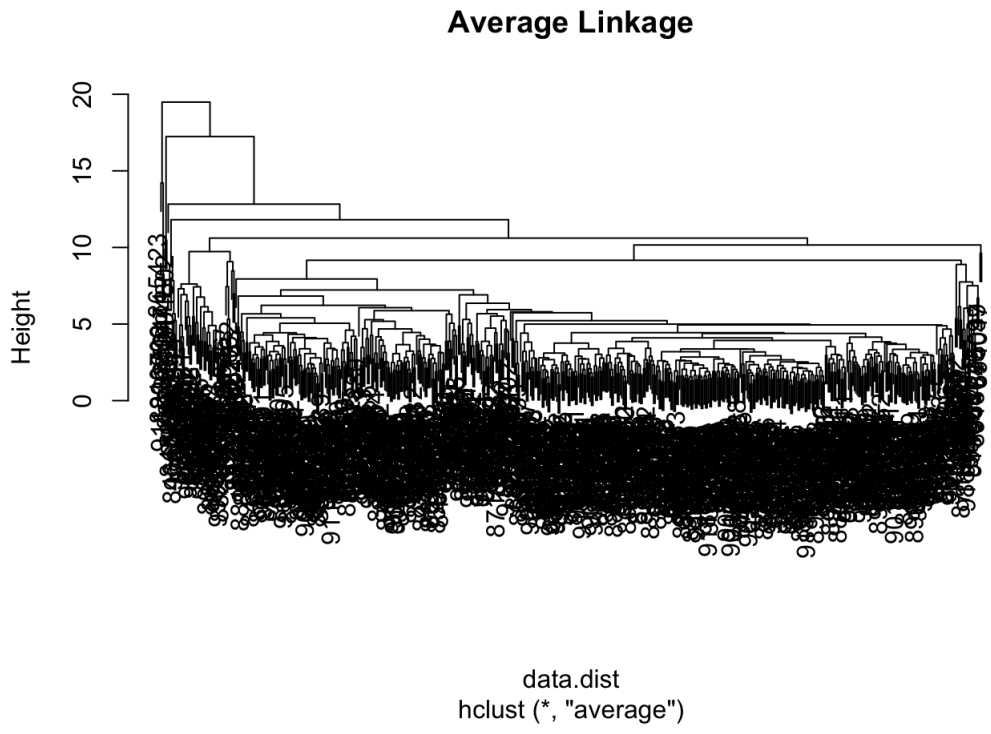
```
hc_single <- hclust(data.dist, method = "single")
hc_complete <- hclust(data.dist, method = "complete")
hc_average <- hclust(data.dist, method = "average")
hc_ward <- hclust(data.dist, method = "ward.D2")
plot(hc_single, main = "Single Linkage")
```



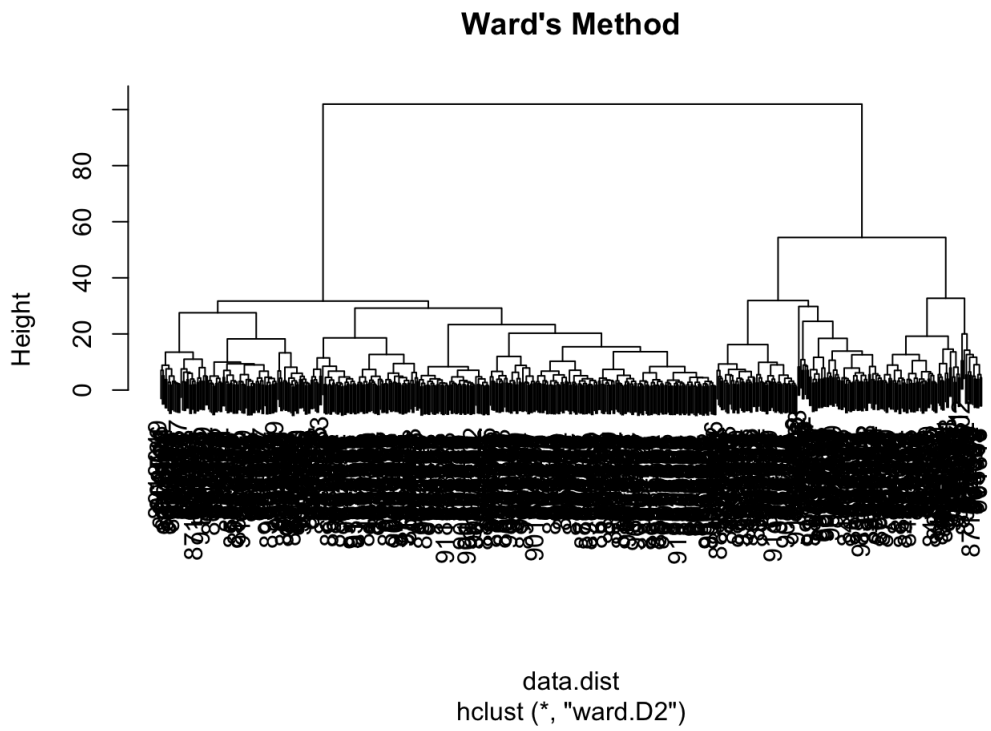

```
plot(hc_complete, main = "Complete Linkage")
```




```
plot(hc_average, main = "Average Linkage")
```




```
plot(hc_ward, main = "Ward's Method")
```




Q13. ward.D2 gives most reasonable because it creates groups such that variance is minimized within clusters, it minimizes mismatch with diagnosis.