mini-project

Vanesa Fernandez

```
# 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)
```

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

```
head(wisc.df) ## The id and diagnosis columns will not be used for most of the following ste
```

```
        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
# We can use -1 here to remove the first column
wisc.data <- wisc.df[,-1]

head(wisc.data)
```

```
  diagnosis radius_mean texture_mean perimeter_mean area_mean smoothness_mean
1         M       17.99        10.38         122.80    1001.0         0.11840
2         M       20.57        17.77         132.90    1326.0         0.08474
3         M       19.69        21.25         130.00    1203.0         0.10960
4         M       11.42        20.38          77.58     386.1         0.14250
5         M       20.29        14.34         135.10    1297.0         0.10030
6         M       12.45        15.70          82.57     477.1         0.12780
  compactness_mean concavity_mean concave.points_mean symmetry_mean
```

```
1          0.27760         0.3001             0.14710        0.2419
2          0.07864         0.0869             0.07017        0.1812
3          0.15990         0.1974             0.12790        0.2069
4          0.28390         0.2414             0.10520        0.2597
5          0.13280         0.1980             0.10430        0.1809
6          0.17000         0.1578             0.08089        0.2087
  fractal_dimension_mean radius_se texture_se perimeter_se area_se
1                0.07871    1.0950     0.9053        8.589  153.40
2                0.05667    0.5435     0.7339        3.398   74.08
3                0.05999    0.7456     0.7869        4.585   94.03
4                0.09744    0.4956     1.1560        3.445   27.23
5                0.05883    0.7572     0.7813        5.438   94.44
6                0.07613    0.3345     0.8902        2.217   27.19
  smoothness_se compactness_se concavity_se concave.points_se symmetry_se
1      0.006399        0.04904      0.05373           0.01587     0.03003
2      0.005225        0.01308      0.01860           0.01340     0.01389
3      0.006150        0.04006      0.03832           0.02058     0.02250
4      0.009110        0.07458      0.05661           0.01867     0.05963
5      0.011490        0.02461      0.05688           0.01885     0.01756
6      0.007510        0.03345      0.03672           0.01137     0.02165
  fractal_dimension_se radius_worst texture_worst perimeter_worst area_worst
1             0.006193        25.38         17.33          184.60     2019.0
2             0.003532        24.99         23.41          158.80     1956.0
3             0.004571        23.57         25.53          152.50     1709.0
4             0.009208        14.91         26.50           98.87      567.7
5             0.005115        22.54         16.67          152.20     1575.0
6             0.005082        15.47         23.75          103.40      741.6
  smoothness_worst compactness_worst concavity_worst concave.points_worst
1           0.1622            0.6656          0.7119               0.2654
2           0.1238            0.1866          0.2416               0.1860
3           0.1444            0.4245          0.4504               0.2430
4           0.2098            0.8663          0.6869               0.2575
5           0.1374            0.2050          0.4000               0.1625
6           0.1791            0.5249          0.5355               0.1741
  symmetry_worst fractal_dimension_worst
1         0.4601                 0.11890
2         0.2750                 0.08902
3         0.3613                 0.08758
4         0.6638                 0.17300
5         0.2364                 0.07678
6         0.3985                 0.12440
```

```r
# Create diagnosis vector for later
diagnosis <- as.factor(wisc.df$diagnosis) ## Factors are for categorical data and modeling,

head(diagnosis)
```

```
[1] M M M M M M
Levels: B M
```

Q1 How many rows/ subjects?

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

```
[1] 569
```

Q2. How many M (cancer) B (healthy) patients?

```r
table(diagnosis)
```

```
diagnosis
  B   M 
357 212 
```

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

```r
colnames(wisc.data) ## We could use `colnames` and count manually but it could be time consu
```

```
 [1] "diagnosis"               "radius_mean"            
 [3] "texture_mean"            "perimeter_mean"         
 [5] "area_mean"               "smoothness_mean"        
 [7] "compactness_mean"        "concavity_mean"         
 [9] "concave.points_mean"     "symmetry_mean"          
[11] "fractal_dimension_mean"  "radius_se"              
[13] "texture_se"              "perimeter_se"           
[15] "area_se"                 "smoothness_se"          
[17] "compactness_se"          "concavity_se"           
[19] "concave.points_se"       "symmetry_se"            
[21] "fractal_dimension_se"    "radius_worst"           
[23] "texture_worst"           "perimeter_worst"        
[25] "area_worst"              "smoothness_worst"       
[27] "compactness_worst"       "concavity_worst"        
[29] "concave.points_worst"    "symmetry_worst"         
[31] "fractal_dimension_worst"
```

Or we could use grep() ## To finding Pattern Matching

```r
length(grep("_mean", colnames(wisc.data), value = T))
```

```
[1] 10
```

Principal Component Analysis

```r
# Check column means and standard deviations to determine if the data should be scaled.

colMeans(wisc.data[,2:31])
```

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

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

```
Warning in var(if (is.vector(x) || is.factor(x)) x else as.double(x), na.rm =
na.rm): NAs introduced by coercion
```

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

We want to scale our data before PCA by setting the `scale=TRUE` argument!

```r
wisc.pr <- prcomp(wisc.data[,2:31], scale = TRUE)
```

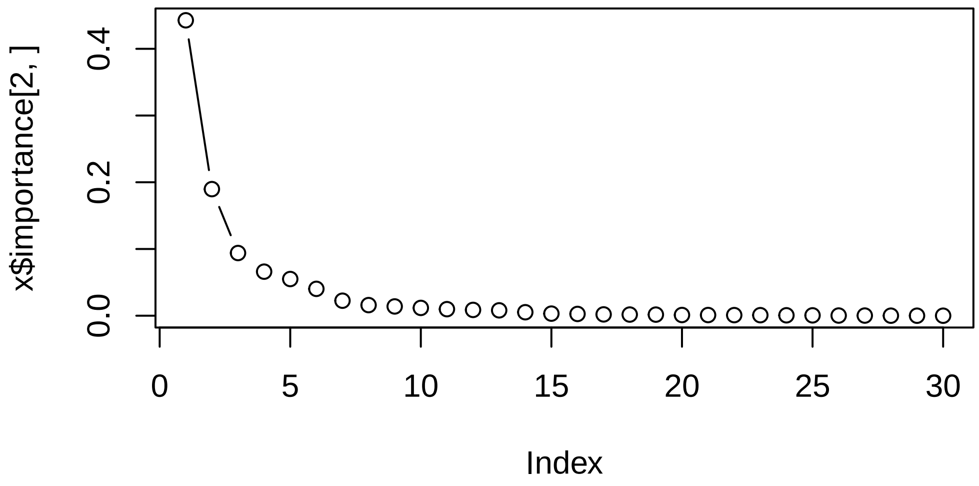
How much variance captured in each PC?

```r
x <- summary (wisc.pr)
x$importance
```

```
                            PC1      PC2      PC3      PC4      PC5      PC6
Standard deviation     3.644394 2.385656 1.678675 1.407352 1.284029 1.098798
Proportion of Variance 0.442720 0.189710 0.093930 0.066020 0.054960 0.040250
Cumulative Proportion  0.442720 0.632430 0.726360 0.792390 0.847340 0.887590
                             PC7       PC8       PC9      PC10      PC11
Standard deviation     0.8217178 0.6903746 0.6456739 0.5921938 0.5421399
Proportion of Variance 0.0225100 0.0158900 0.0139000 0.0116900 0.0098000
Cumulative Proportion  0.9101000 0.9259800 0.9398800 0.9515700 0.9613700
                            PC12      PC13      PC14      PC15      PC16
```

```
Standard deviation     0.5110395 0.4912815 0.3962445 0.3068142 0.2826001
Proportion of Variance 0.0087100 0.0080500 0.0052300 0.0031400 0.0026600
Cumulative Proportion  0.9700700 0.9781200 0.9833500 0.9864900 0.9891500
                            PC17      PC18      PC19      PC20      PC21
Standard deviation     0.2437192 0.2293878 0.2224356 0.1765203 0.1731268
Proportion of Variance 0.0019800 0.0017500 0.0016500 0.0010400 0.0010000
Cumulative Proportion  0.9911300 0.9928800 0.9945300 0.9955700 0.9965700
                            PC22      PC23      PC24      PC25      PC26
Standard deviation     0.1656484 0.1560155 0.1343689 0.1244238 0.0904303
Proportion of Variance 0.0009100 0.0008100 0.0006000 0.0005200 0.0002700
Cumulative Proportion  0.9974900 0.9983000 0.9989000 0.9994200 0.9996900
                             PC27      PC28       PC29       PC30
Standard deviation     0.08306903 0.0398665 0.02736427 0.01153451
Proportion of Variance 0.00023000 0.0000500 0.00002000 0.00000000
Cumulative Proportion  0.99992000 0.9999700 1.00000000 1.00000000
```

```
plot(x$importance[2,], typ="b")
```



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

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

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

$class
[1] "prcomp"
```

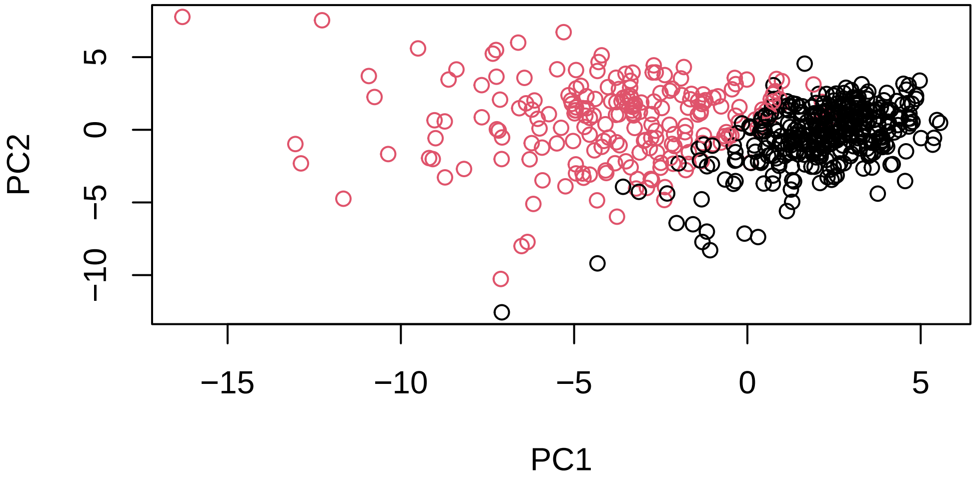
```r
head(wisc.pr$x)
```

```
           PC1        PC2        PC3       PC4        PC5         PC6
[1,] -9.184755  -1.946870 -1.1221788 3.6305364  1.1940595  1.41018364
[2,] -2.385703   3.764859 -0.5288274 1.1172808 -0.6212284  0.02863116
[3,] -5.728855   1.074229 -0.5512625 0.9112808  0.1769302  0.54097615
[4,] -7.116691 -10.266556 -3.2299475 0.1524129  2.9582754  3.05073750
[5,] -3.931842   1.946359  1.3885450 2.9380542 -0.5462667 -1.22541641
[6,] -2.378155  -3.946456 -2.9322967 0.9402096  1.0551135 -0.45064213
             PC7         PC8         PC9       PC10       PC11       PC12
[1,]  2.15747152  0.39805698 -0.15698023 -0.8766305 -0.2627243 -0.8582593
[2,]  0.01334635 -0.24077660 -0.71127897  1.1060218 -0.8124048  0.1577838
[3,] -0.66757908 -0.09728813  0.02404449  0.4538760  0.6050715  0.1242777
[4,]  1.42865363 -1.05863376 -1.40420412 -1.1159933  1.1505012  1.0104267
[5,] -0.93538950 -0.63581661 -0.26357355  0.3773724 -0.6507870 -0.1104183
[6,]  0.49001396  0.16529843 -0.13335576 -0.5299649 -0.1096698  0.0813699
            PC13         PC14         PC15        PC16        PC17        PC18
[1,]  0.10329677 -0.690196797  0.601264078  0.74446075 -0.26523740 -0.54907956
[2,] -0.94269981 -0.652900844 -0.008966977 -0.64823831 -0.01719707  0.31801756
[3,] -0.41026561  0.016665095 -0.482994760  0.32482472  0.19075064 -0.08789759
[4,] -0.93245070 -0.486988399  0.168699395  0.05132509  0.48220960 -0.03584323
[5,]  0.38760691 -0.538706543 -0.310046684 -0.15247165  0.13302526 -0.01869779
[6,] -0.02625135  0.003133944 -0.178447576 -0.01270566  0.19671335 -0.29727706
           PC19        PC20         PC21        PC22        PC23         PC24
[1,]  0.1336499  0.34526111  0.096430045 -0.06878939  0.08444429  0.175102213
[2,] -0.2473470 -0.11403274 -0.077259494  0.09449530 -0.21752666 -0.011280193
[3,] -0.3922812 -0.20435242  0.310793246  0.06025601 -0.07422581 -0.102671419
[4,] -0.0267241 -0.46432511  0.433811661  0.20308706 -0.12399554 -0.153294780
[5,]  0.4610302  0.06543782 -0.116442469  0.01763433  0.13933105  0.005327110
[6,] -0.1297265 -0.07117453 -0.002400178  0.10108043  0.03344819 -0.002837749
             PC25         PC26        PC27          PC28         PC29
[1,]  0.150887294 -0.201326305 -0.25236294 -0.0338846387  0.045607590
[2,]  0.170360355 -0.041092627  0.18111081  0.0325955021 -0.005682424
```

```
[3,] -0.171007656  0.004731249  0.04952586  0.0469844833  0.003143131
[4,] -0.077427574 -0.274982822  0.18330078  0.0424469831 -0.069233868
[5,] -0.003059371  0.039219780  0.03213957 -0.0347556386  0.005033481
[6,] -0.122282765 -0.030272333 -0.08438081  0.0007296587 -0.019703996
             PC30
[1,]  0.0471277407
[2,]  0.0018662342
[3,] -0.0007498749
[4,]  0.0199198881
[5,] -0.0211951203
[6,] -0.0034564331
```

My main PC result figure

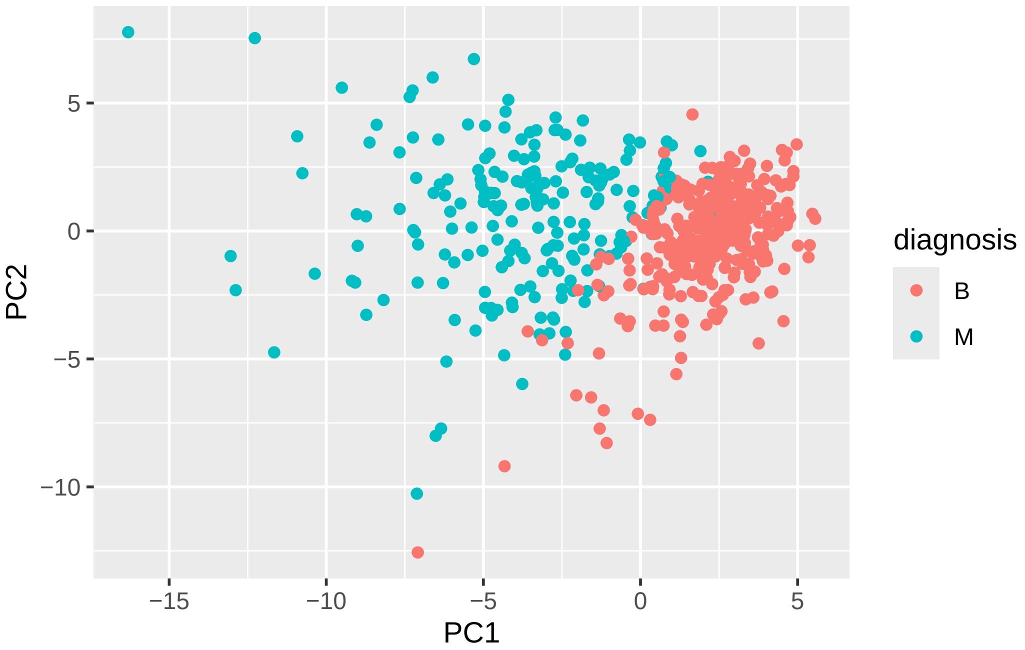
```
plot(wisc.pr$x, col=diagnosis)
```



```
# 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()
```



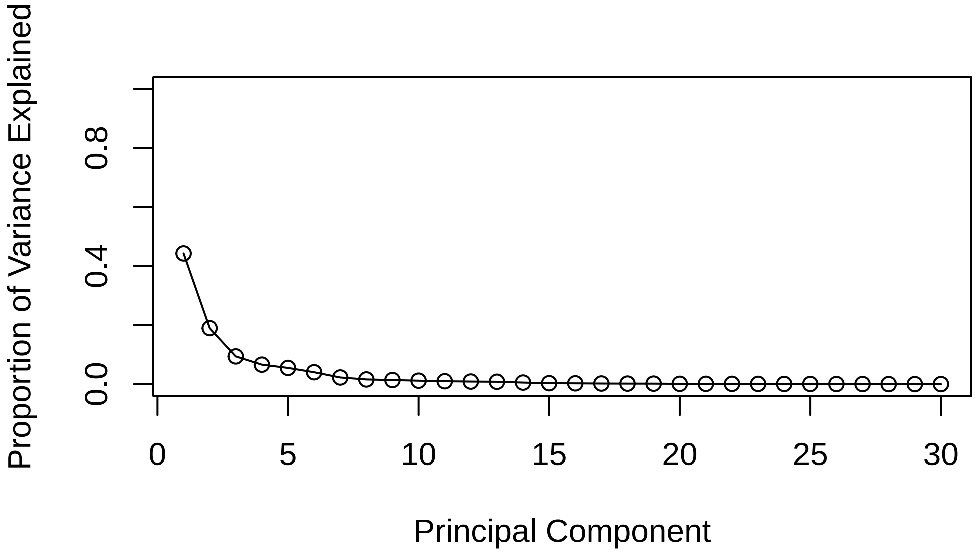
Variance explained

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

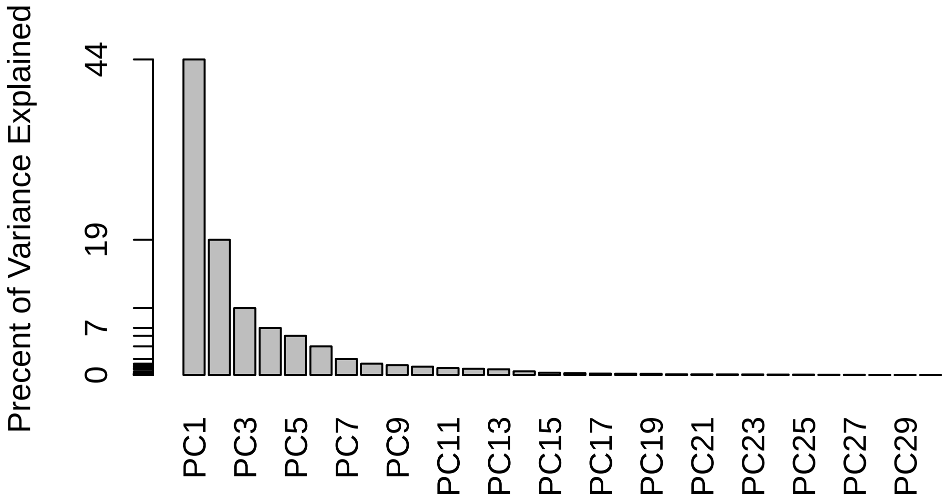
```
[1] 13.281608  5.691355  2.817949  1.980640  1.648731  1.207357
```

```
# Variance explained by each principal component: pve
pve <- 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 )
```



Communicating PCA results ## The loadings, represented as vectors, explain the mapping from the original features to the principal components. The principal components are naturally ordered from the most variance explained to the least variance explained.

> Q9. For the first principal component, what is the component of the loading vector (i.e. wisc.pr$rotation[,1]) for the feature concave.points_mean? This tells us how much this original feature contributes to the first PC

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

```
concave.points_mean 
         -0.2608538 
```

Hierarchical clustering

##Try to cluster the `wisc.data`.

```
km <- kmeans(wisc.data[,2:31], centers = 2)
table(km$cluster)
```

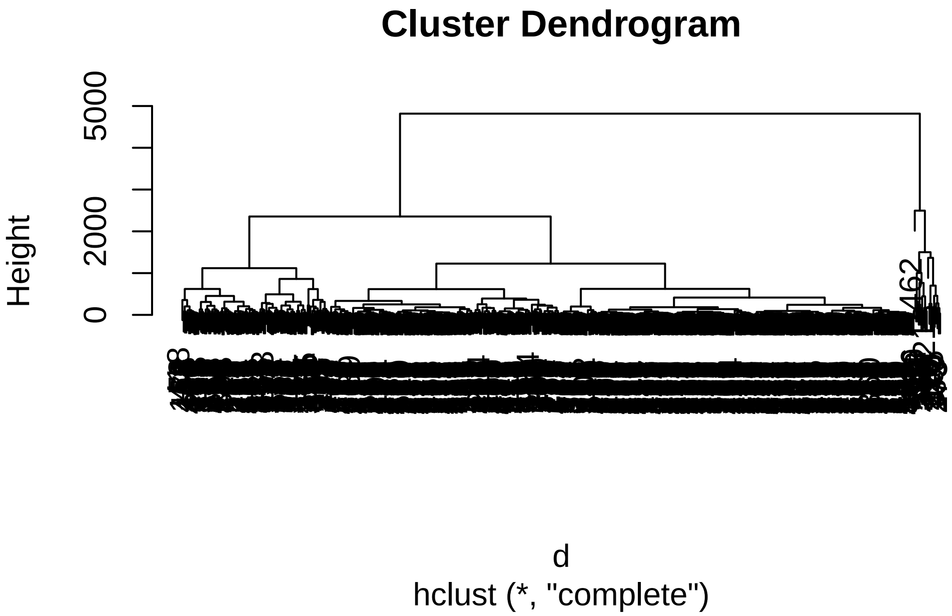
```

  1   2 
131 438 
```

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

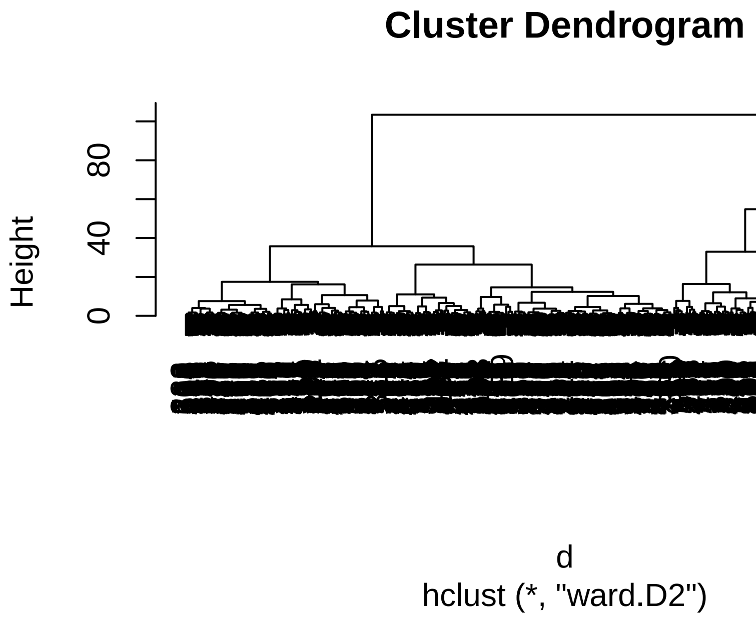
```
Warning in dist(wisc.data): NAs introduced by coercion
```

```
hc <- hclust (d)
plot(hc)
```



##Cluster in PC space In other words, use my PCA results as a basis of clustering.

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



Cut this tree to yield 2 groups / clusters

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

```
grps
  1   2 
203 366 
```

Compare to my expert M and B `diagnosis`

```
table(diagnosis)
```

```
diagnosis
  B   M 
357 212 
```

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

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

```
# Scale the wisc.data data using the "scale()" function
data.scaled <- scale(wisc.data[,2:31])
```

Calculate the (Euclidean) distances between all pairs of observations in the new scaled dataset and assign the result to data.dist.

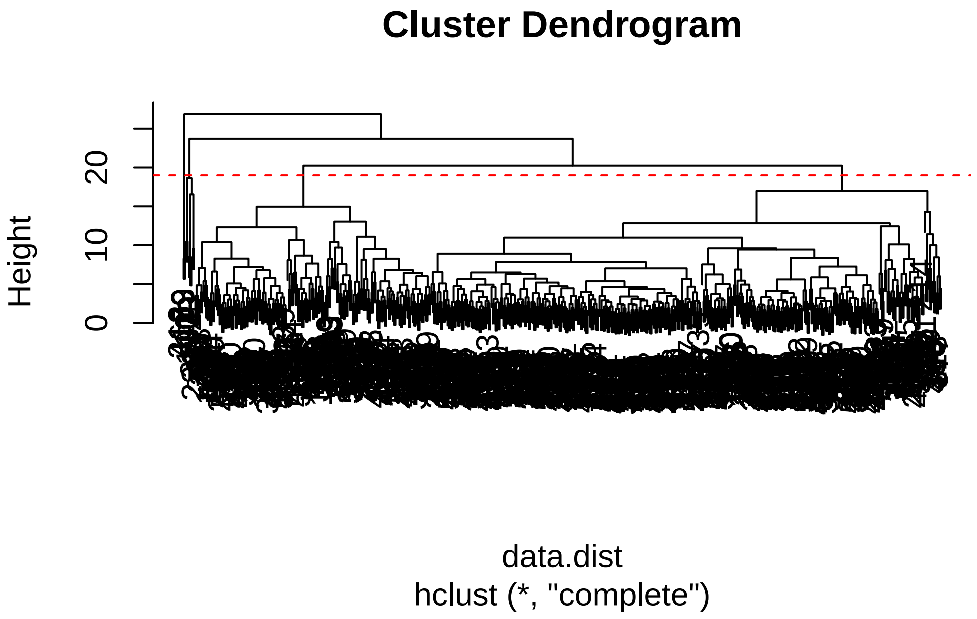
```
data.dist <- dist(data.scaled, method = "euclidean")
```

Create a hierarchical clustering model using complete linkage. Manually specify the method argument to hclust() and assign the results to wisc.hclust.

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

Results of hierarchical clustering > Q10. Using the plot() and abline() functions, what is the height at which the clustering model has 4 clusters?

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



Selecting number of clusters ## Use cutree() to cut the tree so that it has 4 clusters. Assign the output to the variable wisc.hclust.clusters.

```r
wisc.hclust.clusters <- cutree (wisc.hclust, k=4)
head(wisc.hclust.clusters)
```

```
[1] 1 1 1 2 1 1
```

##We can use the table() function to compare the cluster membership to the actual diagnoses.

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

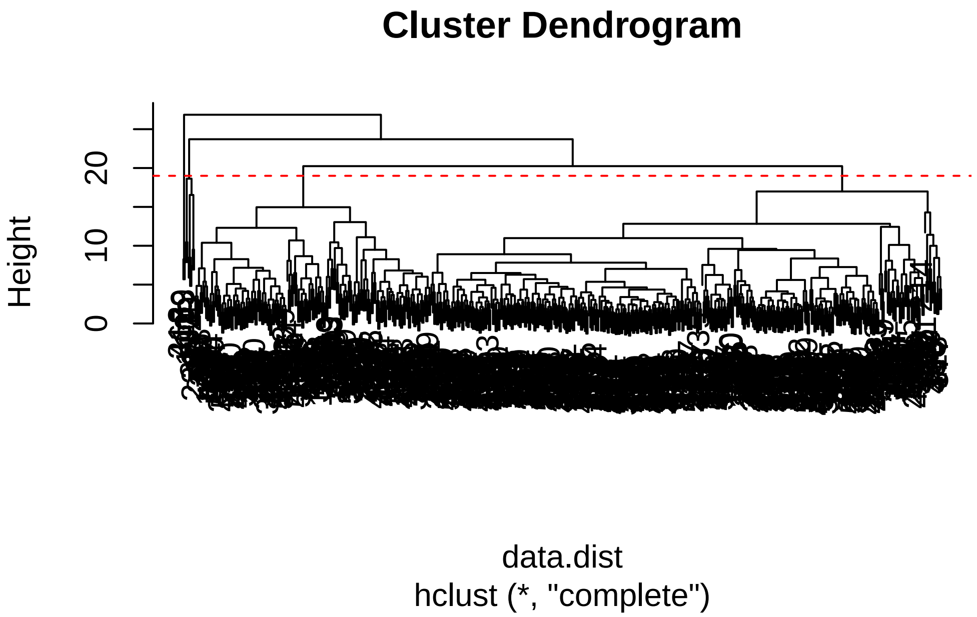
```
                    diagnosis
wisc.hclust.clusters   B   M
                   1  12 165
                   2   2   5
                   3 343  40
                   4   0   2
```

Using different methods > Q12. Which method gives your favorite results for the same data.dist dataset? Explain your reasoning.

I like the “complete” method because the height and hierarchies look more clear, but detailed.

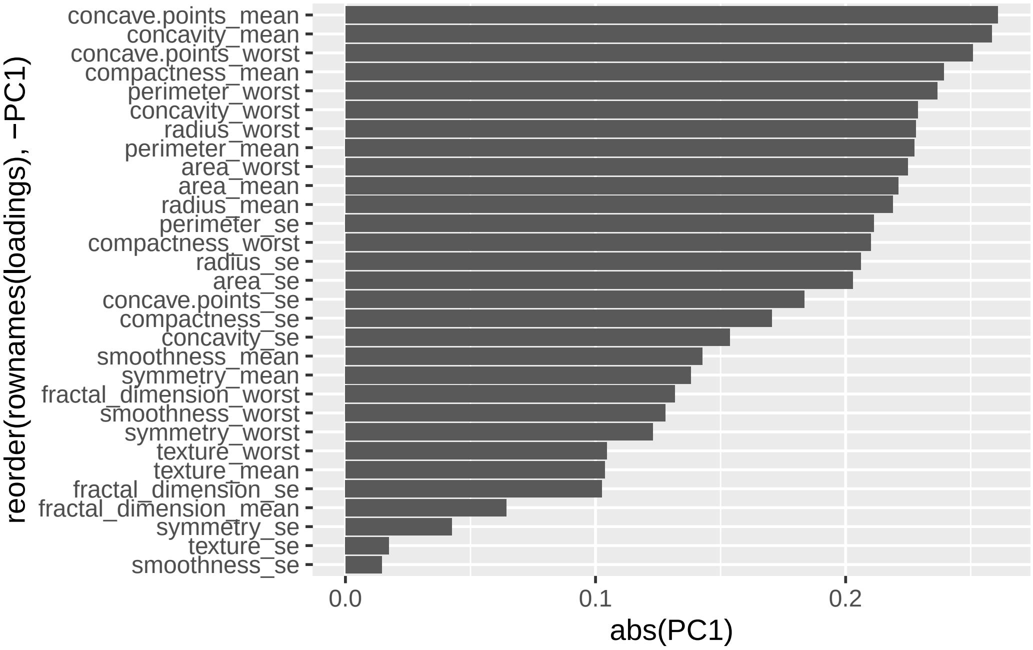
```r
wisc.hclust <- hclust(data.dist, "complete")
```

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



```
loadings <- wisc.pr$rotation

ggplot(loadings) +
  aes(abs(PC1), reorder(rownames(loadings), -PC1)) + geom_col()
```


concave.points_mean
concavity_mean
concave.points_worst
compactness_mean
perimeter_worst
concavity_worst
radius_worst
perimeter_mean
area_worst
area_mean
radius_mean
perimeter_se
compactness_worst
radius_se
area_se
concave.points_se
compactness_se
concavity_se
smoothness_mean
symmetry_mean
fractal_dimension_worst
smoothness_worst
symmetry_worst
texture_worst
texture_mean
fractal_dimension_se
fractal_dimension_mean
symmetry_se
texture_se
smoothness_se
reorder(rownames(loadings), −PC1)
0.0
0.1
0.2
abs(PC1)