Class 8: PCA Mini Project

Noel Lim (PID:A17652474)

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

```
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
```

```
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
```

```
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
```

```
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 prior 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("WisconsinCancer.csv",
                    row.names=1)

head(wisc.df)
```

	diagnosis	radius_mean	texture_mean	perimeter_mean	area_mean
842302	M	17.99	10.38	122.80	1001.0
842517	M	20.57	17.77	132.90	1326.0
84300903	M	19.69	21.25	130.00	1203.0
84348301	M	11.42	20.38	77.58	386.1
84358402	M	20.29	14.34	135.10	1297.0
843786	M	12.45	15.70	82.57	477.1

	smoothness_mean	compactness_mean	concavity_mean	concave.points_mean
842302	0.11840	0.27760	0.3001	0.14710
842517	0.08474	0.07864	0.0869	0.07017
84300903	0.10960	0.15990	0.1974	0.12790
84348301	0.14250	0.28390	0.2414	0.10520
84358402	0.10030	0.13280	0.1980	0.10430
843786	0.12780	0.17000	0.1578	0.08089

	symmetry_mean	fractal_dimension_mean	radius_se	texture_se	perimeter_se
842302	0.2419	0.07871	1.0950	0.9053	8.589
842517	0.1812	0.05667	0.5435	0.7339	3.398
84300903	0.2069	0.05999	0.7456	0.7869	4.585
84348301	0.2597	0.09744	0.4956	1.1560	3.445
84358402	0.1809	0.05883	0.7572	0.7813	5.438
843786	0.2087	0.07613	0.3345	0.8902	2.217

	area_se	smoothness_se	compactness_se	concavity_se	concave.points_se
842302	153.40	0.006399	0.04904	0.05373	0.01587
842517	74.08	0.005225	0.01308	0.01860	0.01340
84300903	94.03	0.006150	0.04006	0.03832	0.02058
84348301	27.23	0.009110	0.07458	0.05661	0.01867
84358402	94.44	0.011490	0.02461	0.05688	0.01885
843786	27.19	0.007510	0.03345	0.03672	0.01137

	symmetry_se	fractal_dimension_se	radius_worst	texture_worst
842302	0.03003	0.006193	25.38	17.33
842517	0.01389	0.003532	24.99	23.41
84300903	0.02250	0.004571	23.57	25.53
84348301	0.05963	0.009208	14.91	26.50
84358402	0.01756	0.005115	22.54	16.67
843786	0.02165	0.005082	15.47	23.75

	perimeter_worst	area_worst	smoothness_worst	compactness_worst
842302	184.60	2019.0	0.1622	0.6656
842517	158.80	1956.0	0.1238	0.1866
84300903	152.50	1709.0	0.1444	0.4245
84348301	98.87	567.7	0.2098	0.8663
84358402	152.20	1575.0	0.1374	0.2050
843786	103.40	741.6	0.1791	0.5249

	concavity_worst	concave.points_worst	symmetry_worst

```
842302              0.7119                0.2654          0.4601
842517              0.2416                0.1860          0.2750
84300903            0.4504                0.2430          0.3613
84348301            0.6869                0.2575          0.6638
84358402            0.4000                0.1625          0.2364
843786              0.5355                0.1741          0.3985
          fractal_dimension_worst
842302                    0.11890
842517                    0.08902
84300903                  0.08758
84348301                  0.17300
84358402                  0.07678
843786                    0.12440
```

```r
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 etc. It is essentially the expert "answer" that we will compare our analysis results to.

```r
# 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

Exploratory data analysis

  Q1. How many observations are in this dataset?

569 observations

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

212 observations

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

10 variables

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

```
[1] 10
```

Principal Component Analysis

```r
# 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
```

```r
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
```

```r
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
```

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

44.3%

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

3 PCs are required to describe at least 70% of the original variance in the data

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

7 PCs are required to describe at least 90% of the original variance in the data

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

```r
biplot(wisc.pr)
```
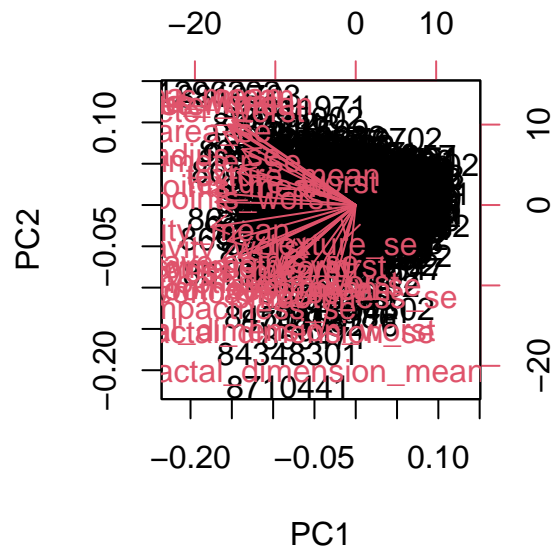
This plot is a hot mess, need to generate our own plots for better understanding.

See what is in our PCA result object:

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

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

$class
[1] "prcomp"
```

```
wisc.pr$x
```

```
                  PC1            PC2            PC3          PC4          PC5
842302    -9.18475521  -1.946870030  -1.122178766   3.630536408   1.1940594778
842517    -2.38570263   3.764859063  -0.528827374   1.117280773  -0.6212283647
84300903  -5.72885549   1.074228589  -0.551262540   0.911280840   0.1769302185
84348301  -7.11669126 -10.266555635  -3.229947535   0.152412923   2.9582754313
84358402  -3.93184247   1.946358977   1.388544953   2.938054169  -0.5462667446
843786    -2.37815462  -3.946456430  -2.932296681   0.940209586   1.0551135428
844359    -2.23691506   2.687666414  -1.638471247   0.149208600  -0.0403240371
```

9

```
84458202   -2.14141428   -2.338186649  -0.871180715  -0.126931171   1.4261817833
844981     -3.17213315   -3.388831138  -3.117243065  -0.600768440   1.5209521144
84501001   -6.34616284   -7.720380945  -4.338098744  -3.372234369  -1.7087596141
845636      0.80970132    2.656937673  -0.488400053  -1.671096176  -0.2755690974
84610002   -2.64876984   -0.066509405  -1.525113359   0.051216497  -0.3316592904
846226     -8.17783882   -2.698602007   5.725193241  -1.111278747  -1.0425531111
846381     -0.34182514    0.967428026   1.715661982  -0.594479872  -0.4675990720
84667401   -4.33856172   -4.856809832  -2.813639832  -1.453278303  -1.2889287269
84799002   -4.07207318   -2.974443983  -3.122526655  -2.455909915   0.4079831402
848406     -0.22985277    1.563382114  -0.801813642  -0.650010973   0.4942761390
84862001   -4.41412695   -1.417423150  -2.268323145  -0.186108659   1.4226094459
849014     -4.94435304    4.110716528  -0.314472408  -0.088128974   0.0566653163
8510426     1.23597583    0.188049490  -0.592761930   1.594942716   0.4417655273
8510653     1.57677384   -0.572304625  -1.799863016   1.124286473   0.3949222435
8510824     3.55420904   -1.661487969   0.450790799   2.071941593   0.4903150736
8511133    -4.72904972   -3.302058265  -1.465247427   2.039355666   0.0261970715
851509     -4.20482441    5.123858059  -0.751740573  -0.861951843   0.4705538779
852552     -4.94528075    1.542395143  -1.711687827   0.046718059   1.7377012054
852631     -7.09232236   -2.016835734  -0.028984132   2.585675482   2.0375470912
852763     -3.50717666   -2.169715994  -3.891122637  -1.294620549   0.0681580703
852781     -3.06136021    1.874902631   2.579478032   0.128371462   0.1165625639
852973     -4.00374127   -0.536769860  -2.759197831  -1.896718595   0.5252107652
853201     -1.71380176    1.522365502   0.146058578   1.909706071  -0.5356519265
853401     -6.05411853    0.756511800  -0.348932376  -1.063281958   0.7454493340
853612     -2.89968469   -4.001774373  -2.998823809  -0.325030387   0.8546038749
85382601   -4.55077848   -0.337239419  -0.753637681  -0.699714306   1.5471839770
854002     -4.98621538    1.131593223  -2.575118337  -1.216191663  -0.6693259394
854039     -2.98271631   -0.757756497  -3.490690279   0.054212589  -0.1669530505
854253     -2.76393718    0.354044421  -1.895295337  -0.533786198   0.8832432812
854268     -1.29505925   -0.912393466  -1.574383382  -1.042249570  -0.4143571251
854941      3.74601730    1.412230504   1.730784885  -0.564945456  -0.0802687991
855133      0.99719148    3.348346731   4.301788720  -0.560716245   0.4639645611
855138     -0.76459136   -0.885464837  -2.702540362  -0.274538185  -0.8097169787
855167      2.14906252    1.922300194  -1.179446370  -1.112219391  -0.4480774771
855563      0.09324934   -2.258764532  -1.903051997  -1.441039161   1.7038647386
855625     -9.08001023   -2.016898441   2.139343894  -1.068304028  -0.7972299505
856106     -0.98958304   -0.984064148  -2.308702241  -0.276582144   0.6399478981
85638502    0.29328849    0.136978564  -3.299029123  -1.008898141   0.0224910920
857010     -5.37620991    0.134758404  -1.677366657   1.506369463  -0.1518645822
85713702    4.57790860   -1.482915508   0.042037623   0.295968708   0.7132249498
85715      -1.69851237   -2.350203862  -3.075383081  -0.065962912   1.0555376469
857155      2.13456708   -0.095745364  -1.491099878   1.120077655   0.0679774156
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91979701    -0.0487762627   5.821042e-02   1.015633e-02    2.035367e-02    9.738559e-03
919812       0.0329233687  -1.804282e-02  -2.169062e-02   -2.378939e-02    8.893677e-03
921092       0.1468627182   7.253893e-02  -8.746899e-03   -1.161071e-02    9.286171e-03
921362       0.1812441331   7.132198e-03   1.665571e-03   -5.739799e-02    3.679201e-02
921385      -0.0295036155  -8.523727e-03  -8.796157e-03   -2.463757e-03    9.112497e-05
921386      -0.0987152511   2.575798e-03  -1.994940e-02    8.161193e-03   -1.262046e-02
921644      -0.0565374950   1.610918e-02  -1.295072e-02   -2.390649e-02    4.092165e-03
922296       0.0568923371  -7.840121e-02  -1.162042e-02    3.505356e-03   -6.121733e-03
922297      -0.0542291424  -8.247547e-02  -8.960736e-03    1.302883e-02    4.772981e-03
922576      -0.0678745818  -1.961314e-02  -6.487119e-03   -4.750888e-03   -3.114620e-03
922577       0.0125381679   4.498783e-02   5.470187e-03   -7.783998e-03   -4.507372e-03
922840       0.0313546289  -4.161718e-02  -2.705643e-03    9.706143e-03    3.657914e-03
923169       0.1006525985   5.511332e-02  -8.274135e-04   -2.590615e-02    8.789459e-04
923465      -0.0007909619   3.418774e-02   6.937288e-05   -2.145122e-02   -4.134624e-03
923748      -0.0163685109  -1.107701e-02   2.770954e-02    1.795767e-02    8.260042e-03
923780      -0.0014215153   5.637368e-02  -3.381745e-03    3.849594e-03   -1.779362e-03
924084      -0.1022492547  -9.323360e-03   5.913651e-04    1.263059e-02   -7.162542e-03
924342       0.0044220903   4.297202e-03  -9.650436e-03   -1.615592e-02   -1.435061e-03
```

```
924632     0.0024994349 -7.130661e-02  4.473723e-02  1.560585e-02  1.385123e-03
924934     0.0938320141  3.896512e-02 -1.164274e-02 -1.431460e-03  6.878081e-03
924964     0.0152530115 -3.226473e-03  2.268760e-03 -1.799952e-02 -4.947889e-05
925236     0.1510723322  1.702667e-01  3.413466e-02  3.102528e-02  8.728220e-03
925277     0.0407493494  3.978350e-02 -1.130892e-02  4.068695e-03 -6.920526e-03
925291     0.0599659983 -3.787753e-02  2.037519e-02 -3.413149e-04  1.269775e-02
925292     0.0968312180 -1.392626e-02  2.900866e-02  1.731854e-03  4.328273e-03
925311     0.0041827618  2.209661e-02  7.486086e-03 -3.107530e-04  5.831723e-03
925622     0.2037854413 -1.474368e-01 -1.245986e-01  9.015380e-03 -7.118296e-03
926125    -0.0729289516  1.450989e-01 -3.945551e-02  7.014761e-02  7.638391e-03
926424    -0.1227922446  1.590577e-01  9.843968e-03  7.112909e-03  1.413613e-03
926682     0.0658312978 -6.845211e-02 -2.355466e-02 -2.746212e-02  1.041027e-02
926954     0.0070890278 -2.367063e-02 -2.575490e-03  6.700316e-03 -3.767102e-03
927241    -0.1980178555 -2.738532e-02 -6.802653e-02 -8.408929e-02  2.376191e-02
92751      0.3468098821  1.272691e-01 -9.507513e-03 -6.085956e-02  1.945846e-02
```

```
#plot(wisc.pr$x)
```

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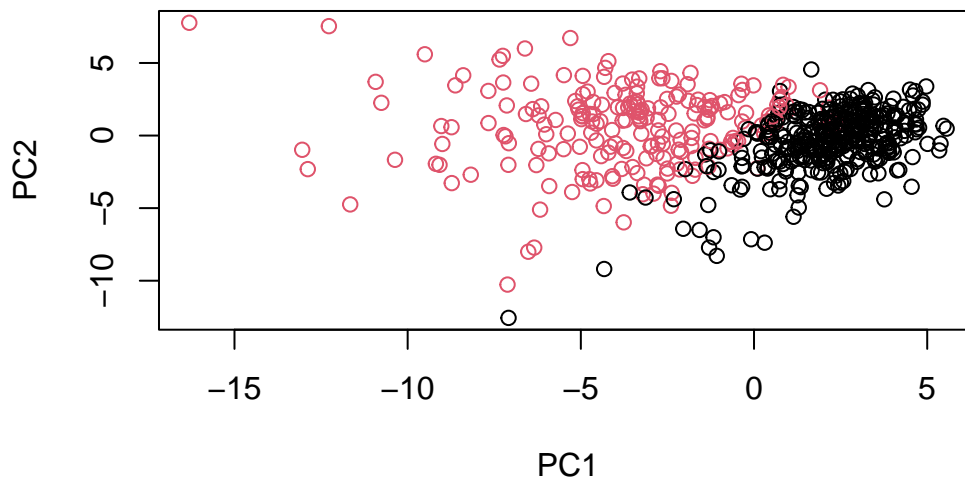

Q8. Generate a similar plot for principal components 1 and 3. What do you notice about these plots?
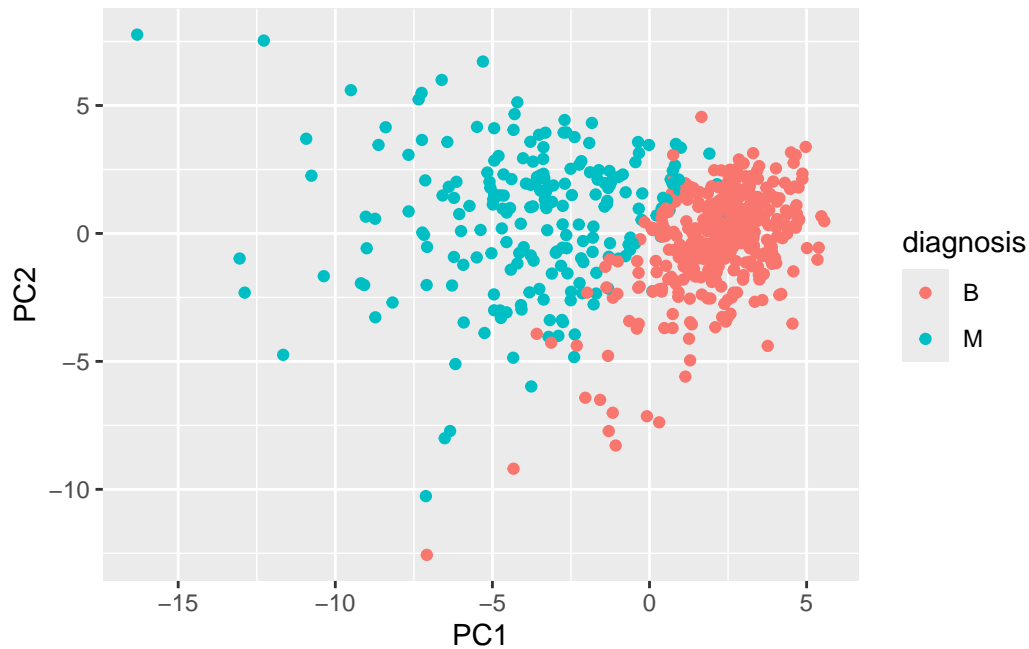
```
# Repeat for components 1 and 3
plot(wisc.pr$x[,1], wisc.pr$x[,3], col = as.factor(diagnosis), xlab = "PC1", ylab = "PC3")
```
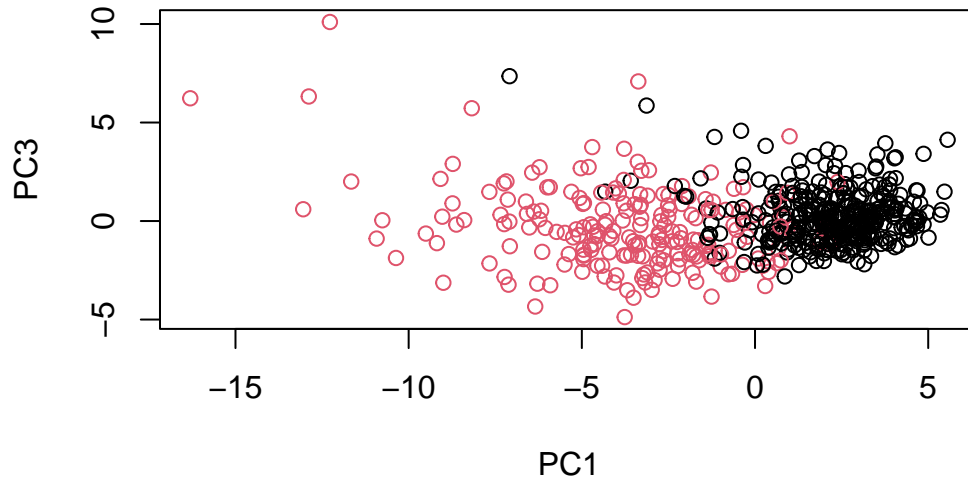


```
# Create a data.frame for ggplot
df <- as.data.frame(wisc.pr$x)
df$diagnosis <- diagnosis

# Load the ggplot2 package
library(ggplot2)

# Make a scatter plot colored by diagnosis
ggplot(df) +
  aes(PC1, PC2, col = diagnosis) +
  geom_point()
```

```
# Calculate variance of each component
pr.var <- wisc.pr$sdev^2
head(pr.var)
```
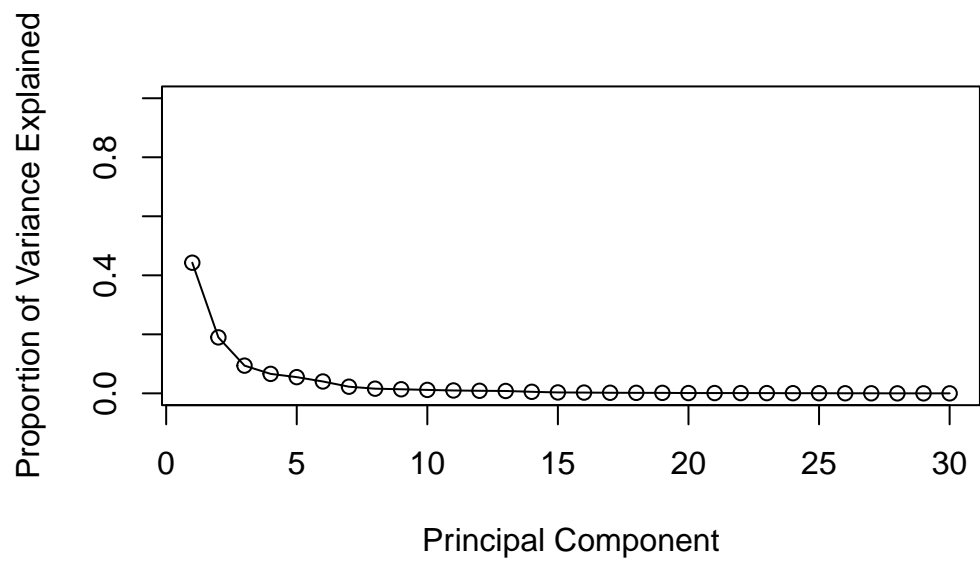
```
[1] 13.281608  5.691355  2.817949  1.980640  1.648731  1.207357
```

```
# Variance explained by each principal component: pve
pr.var <- wisc.pr$sdev^2
head(pr.var)
```

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

```
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")
```

```r
# 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 )
```
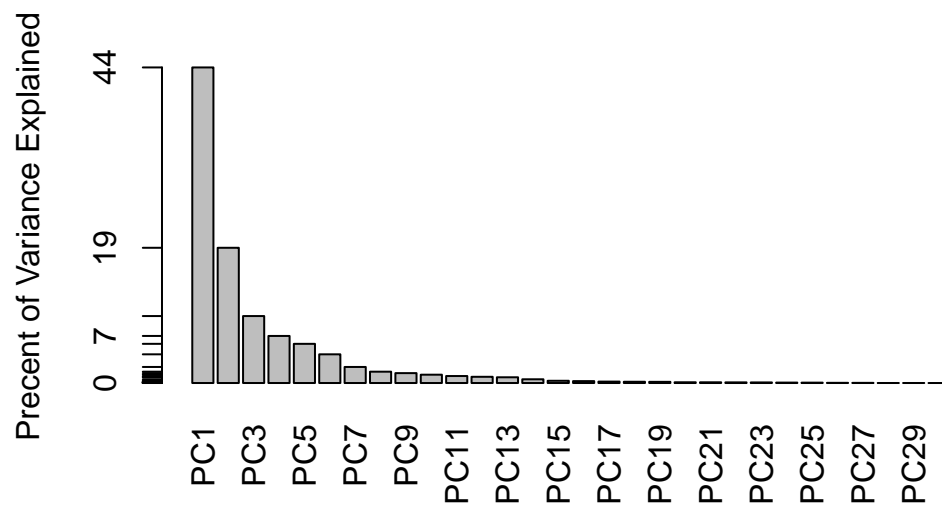
```
## ggplot based graph
#install.packages("factoextra")
library(factoextra)
```

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

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

Scree plot
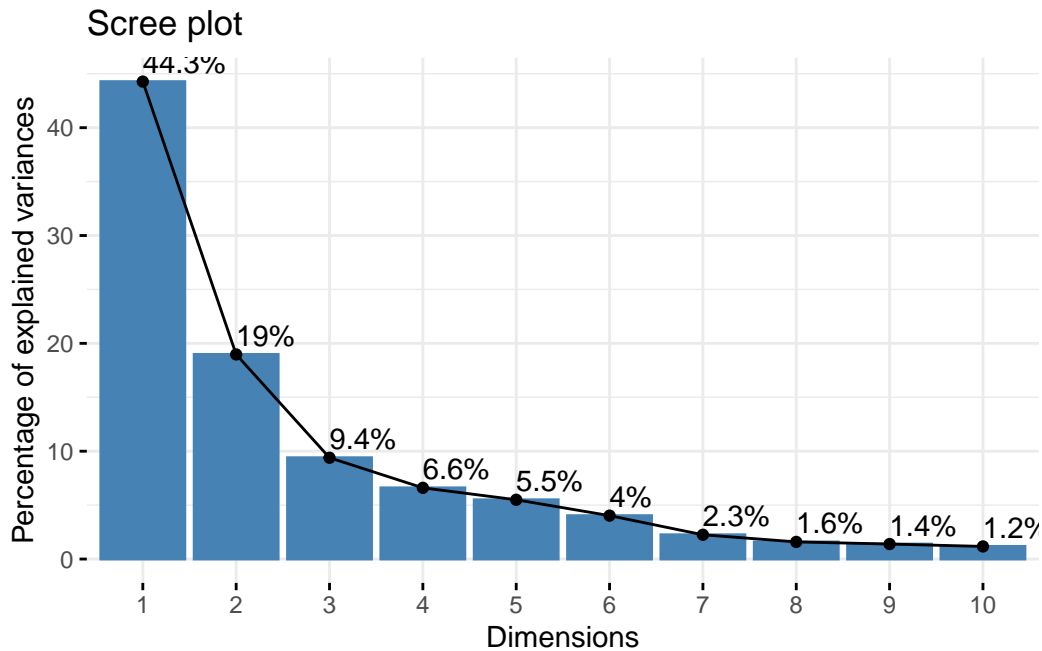
Q9. For the first principal component, what is the component of the loading vector (i.e. wisc.pr$rotation[,1]) for the feature concave.points_mean?

```
wisc.pr$rotation[,1]
```

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

```
                -0.12795256                 -0.21009588                 -0.22876753
          concave.points_worst     symmetry_worst fractal_dimension_worst
                -0.25088597                 -0.12290456                 -0.13178394
```

Concave points mean: -0.26085376

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

5 PCs required to explain 80% of the variance of the data

Hierarchical Clustering

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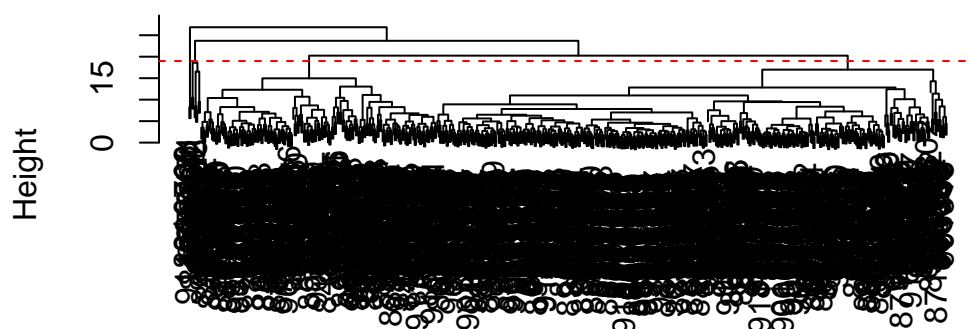
```
data.dist <- dist(data.scaled)
```

```
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?

Height = 19

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

Cluster Dendrogram

data.dist
hclust (*, "complete")

Selecting Number of Clusters

```
wisc.hclust.clusters <- cutree(wisc.hclust, h = 19)
```

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

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

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

```
wisc.hclust.clusters10 <- cutree(wisc.hclust, k=10)
table(wisc.hclust.clusters10, diagnosis)
```

```
                  diagnosis
wisc.hclust.clusters10    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
```
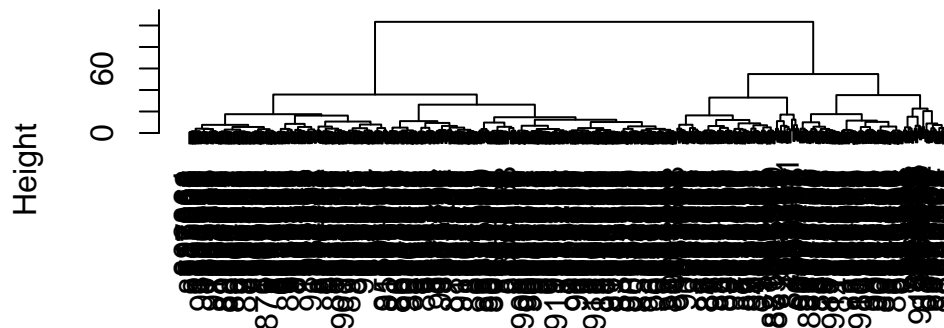
Combine PCA and Clustering

Our PCA results were in `wisc.pr$x`

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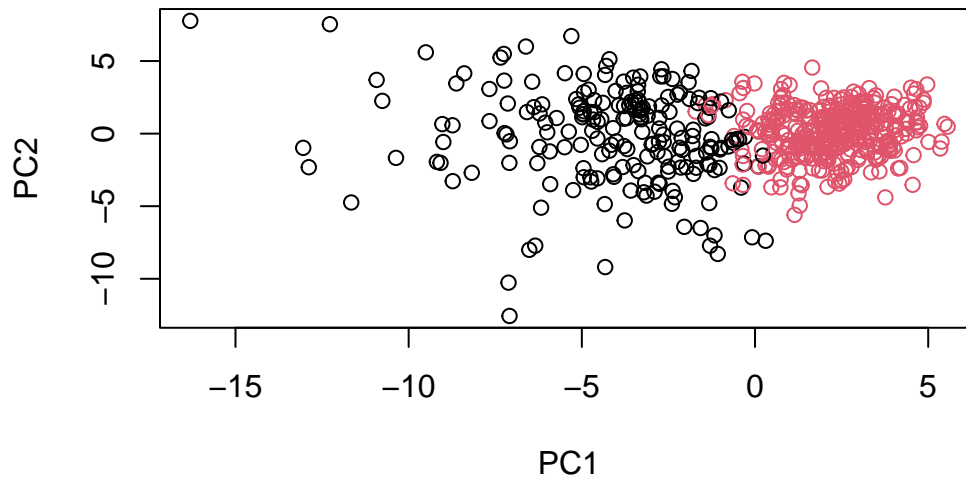

Cluster Dendrogram

d
hclust (*, "ward.D2")

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

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

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


Compare my clustering result (my `grps`) to the 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
```

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

Single

Q14. How well does k-means separate the two diagnoses? How does it compare to your hclust results?

It does a better job in separating B to M by proportion of the cluster