

# Class 08

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## Breast Cancer FNA data

```
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
842517	0.1812		0.05667	0.5435	0.7339
84300903	0.2069		0.05999	0.7456	0.7869
84348301	0.2597		0.09744	0.4956	1.1560
84358402	0.1809		0.05883	0.7572	0.7813
843786	0.2087		0.07613	0.3345	0.8902

	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				

Q1. How many rows/patients/subjects.

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

```
[1] 569
```

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

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

```
  B    M  
357 212
```

Be sure to remove this diagnosis column from our data to analyze

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

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

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

```
[1] 10
```

```
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

## Principal Component Analysis

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

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

How much variance captured in each PC?

```
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					

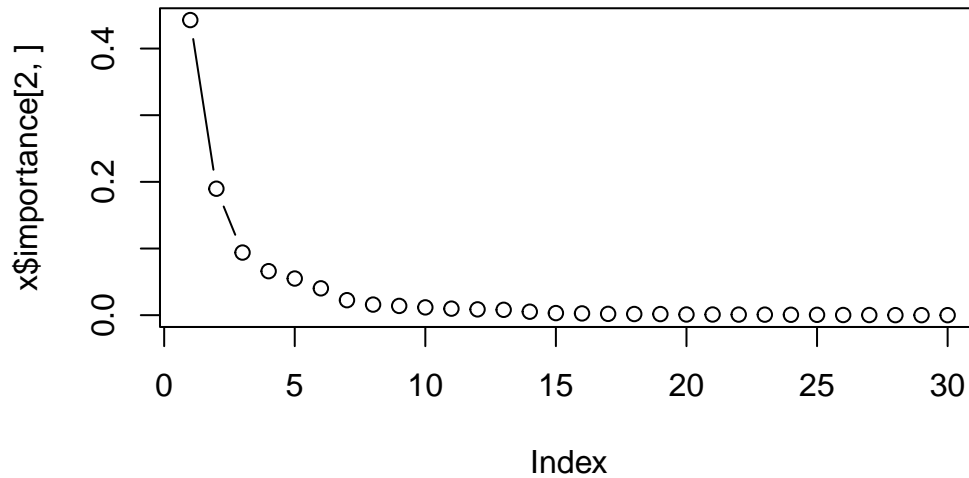
How much variance captured in each PC?

```
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

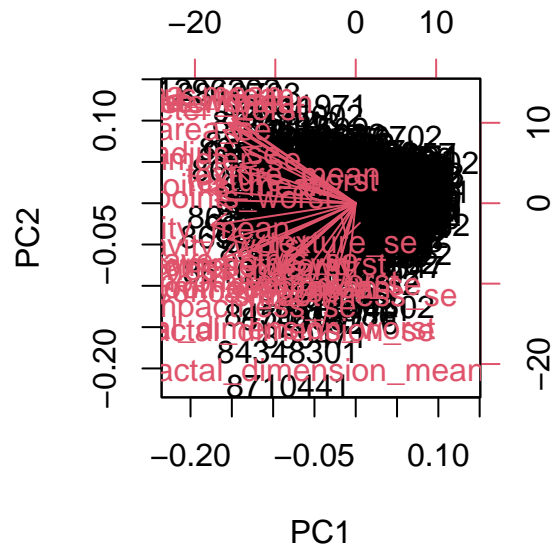
```
plot(x$importance[2,], typ="b")
```



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

The plot is very difficult to understand because there are so many factors that are overlapping making the plot difficult to read.

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



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

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

$class
[1] "prcomp"
```

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

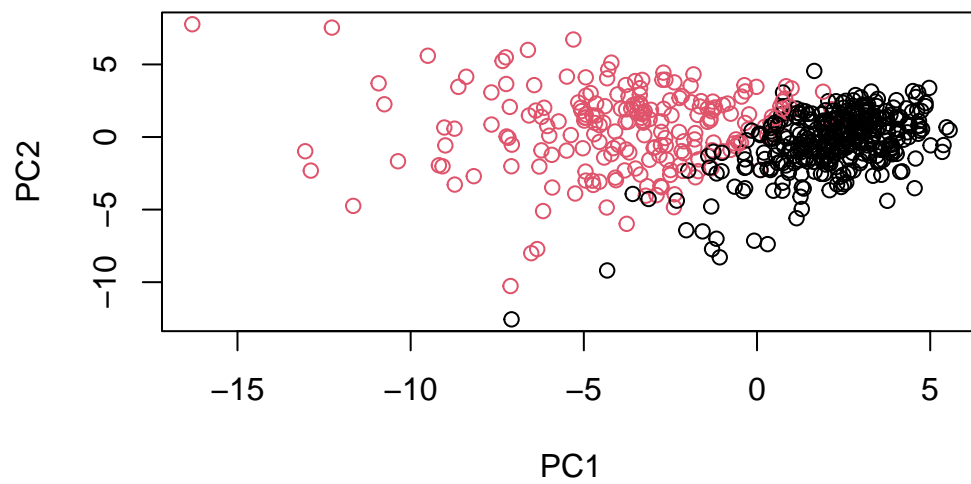
	PC1	PC2	PC3	PC4	PC5	PC6
842302	-9.184755	-1.946870	-1.1221788	3.6305364	1.1940595	1.41018364
842517	-2.385703	3.764859	-0.5288274	1.1172808	-0.6212284	0.02863116
84300903	-5.728855	1.074229	-0.5512625	0.9112808	0.1769302	0.54097615
84348301	-7.116691	-10.266556	-3.2299475	0.1524129	2.9582754	3.05073750
84358402	-3.931842	1.946359	1.3885450	2.9380542	-0.5462667	-1.22541641
843786	-2.378155	-3.946456	-2.9322967	0.9402096	1.0551135	-0.45064213
	PC7	PC8	PC9	PC10	PC11	PC12
842302	2.15747152	0.39805698	-0.15698023	-0.8766305	-0.2627243	-0.8582593

842517	0.01334635	-0.24077660	-0.71127897	1.1060218	-0.8124048	0.1577838
84300903	-0.66757908	-0.09728813	0.02404449	0.4538760	0.6050715	0.1242777
84348301	1.42865363	-1.05863376	-1.40420412	-1.1159933	1.1505012	1.0104267
84358402	-0.93538950	-0.63581661	-0.26357355	0.3773724	-0.6507870	-0.1104183
843786	0.49001396	0.16529843	-0.13335576	-0.5299649	-0.1096698	0.0813699
	PC13	PC14	PC15	PC16	PC17	
842302	0.10329677	-0.690196797	0.601264078	0.74446075	-0.26523740	
842517	-0.94269981	-0.652900844	-0.008966977	-0.64823831	-0.01719707	
84300903	-0.41026561	0.016665095	-0.482994760	0.32482472	0.19075064	
84348301	-0.93245070	-0.486988399	0.168699395	0.05132509	0.48220960	
84358402	0.38760691	-0.538706543	-0.310046684	-0.15247165	0.13302526	
843786	-0.02625135	0.003133944	-0.178447576	-0.01270566	0.19671335	
	PC18	PC19	PC20	PC21	PC22	
842302	-0.54907956	0.1336499	0.34526111	0.096430045	-0.06878939	
842517	0.31801756	-0.2473470	-0.11403274	-0.077259494	0.09449530	
84300903	-0.08789759	-0.3922812	-0.20435242	0.310793246	0.06025601	
84348301	-0.03584323	-0.0267241	-0.46432511	0.433811661	0.20308706	
84358402	-0.01869779	0.4610302	0.06543782	-0.116442469	0.01763433	
843786	-0.29727706	-0.1297265	-0.07117453	-0.002400178	0.10108043	
	PC23	PC24	PC25	PC26	PC27	
842302	0.08444429	0.175102213	0.150887294	-0.201326305	-0.25236294	
842517	-0.21752666	-0.011280193	0.170360355	-0.041092627	0.18111081	
84300903	-0.07422581	-0.102671419	-0.171007656	0.004731249	0.04952586	
84348301	-0.12399554	-0.153294780	-0.077427574	-0.274982822	0.18330078	
84358402	0.13933105	0.005327110	-0.003059371	0.039219780	0.03213957	
843786	0.03344819	-0.002837749	-0.122282765	-0.030272333	-0.08438081	
	PC28	PC29	PC30			
842302	-0.0338846387	0.045607590	0.0471277407			
842517	0.0325955021	-0.005682424	0.0018662342			
84300903	0.0469844833	0.003143131	-0.0007498749			
84348301	0.0424469831	-0.069233868	0.0199198881			
84358402	-0.0347556386	0.005033481	-0.0211951203			
843786	0.0007296587	-0.019703996	-0.0034564331			

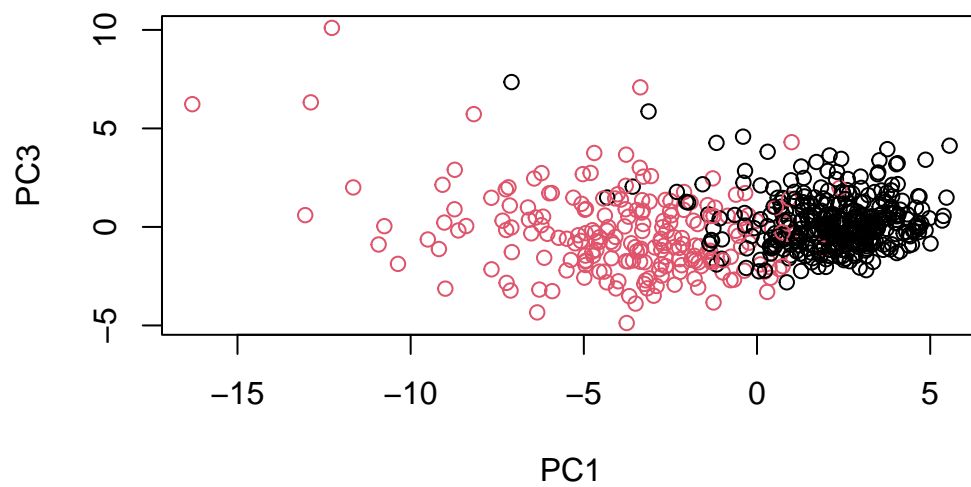
My main PC results figure

```
plot(wisc.pr$x , col = diagnosis ,
      xlab = "PC1", ylab = "PC2")
```





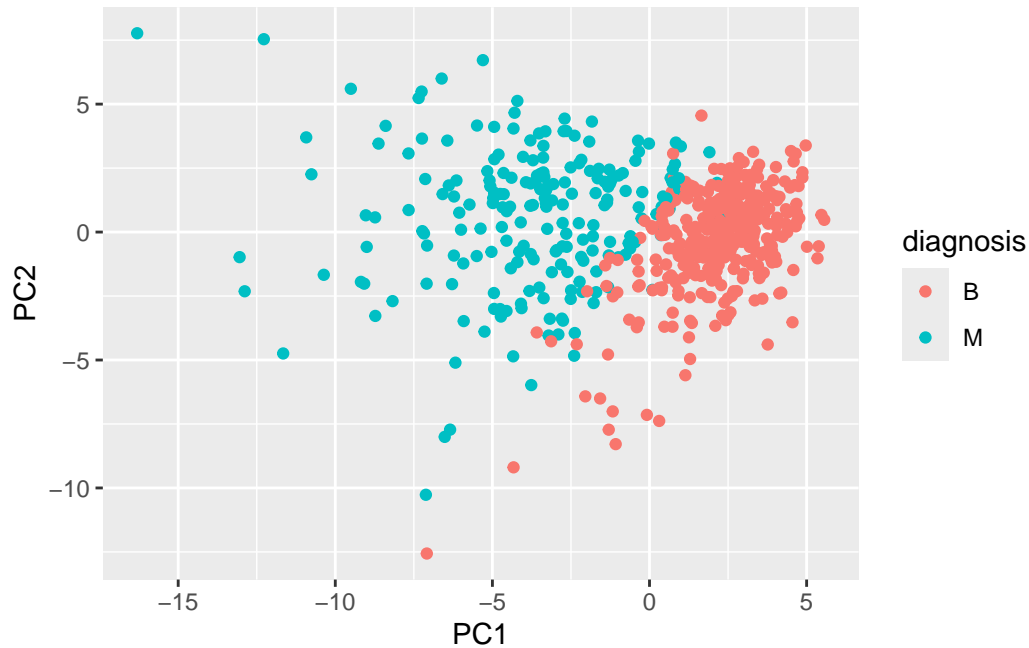
```
plot(wisc.pr$x[,c(1,3) ], col =diagnosis,  
     xlab = "PC1", ylab = "PC3")
```



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

library(ggplot2)

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



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

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

## Clustering

Try to cluster the `wisc.data`.

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

```

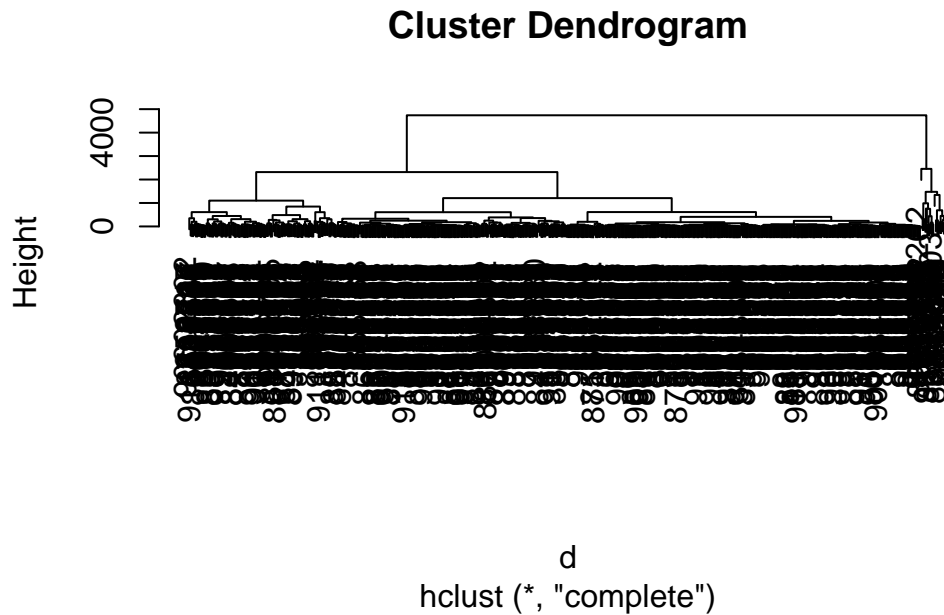
1 2
438 131

```

```

d <- dist(wisc.data)
hc <- hclust(d)
plot(hc)

```



```

grps <- cutree(hc, k=3)
table(grps)

```

```

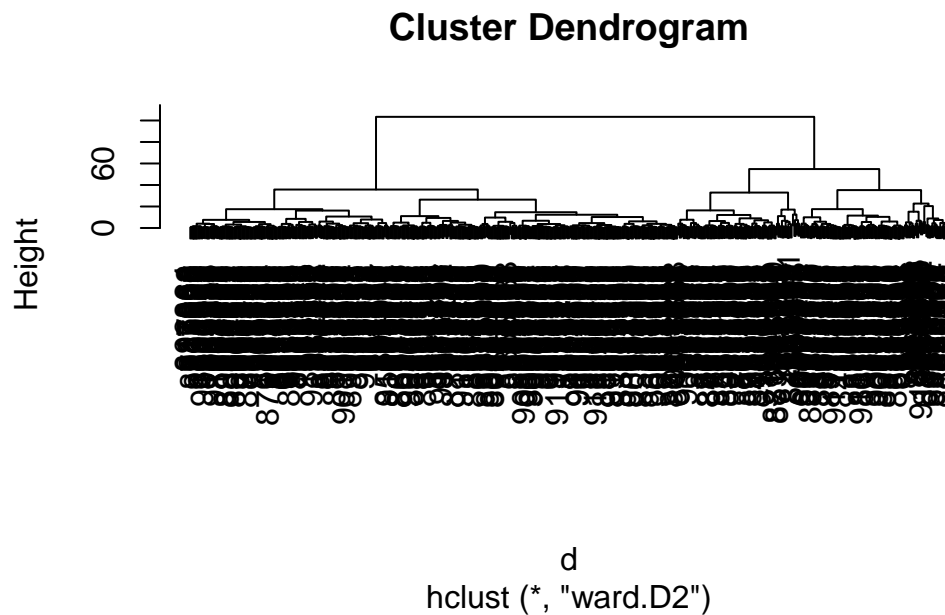
grps
1 2 3
549 19 1

```

### 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)
```

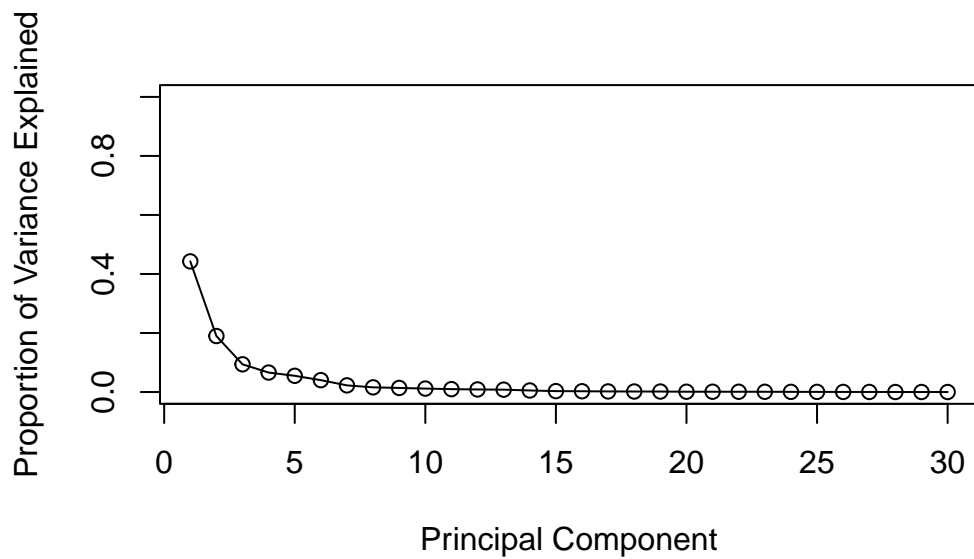
```
diagnosis
  B  M
357 212
```

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

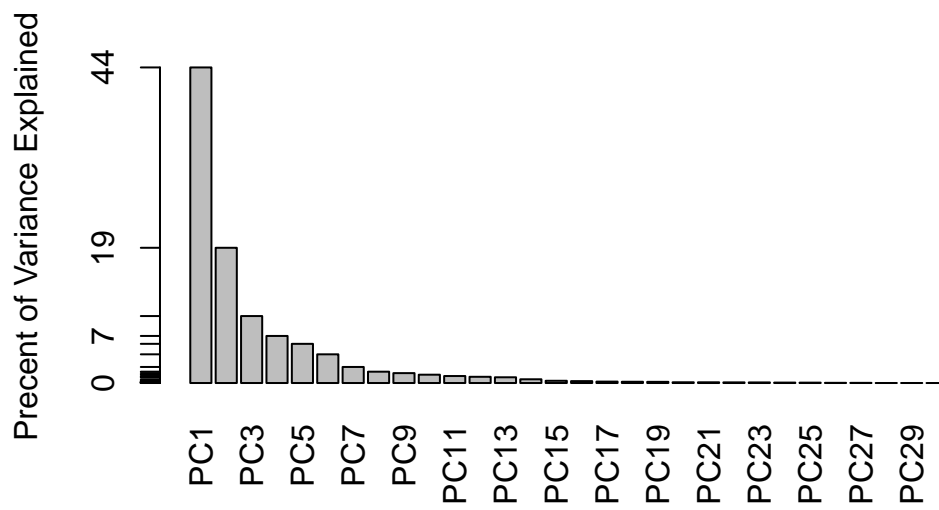
```
      grps
diagnosis 1  2
B      24 333
M     179  33
```

```
pve <- (wisc.pr$sdev^2) / sum(wisc.pr$sdev^2)
```

```
plot(pve, xlab = "Principal Component",
     ylab = "Proportion of Variance Explained",
     ylim = c(0, 1), type = "o")
```



```
barplot(pve, ylab = "Precent of Variance Explained",
       names.arg=paste0("PC",1:length(pve)), las=2, axes = FALSE)
axis(2, at=pve, labels=round(pve,2)*100 )
```



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

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

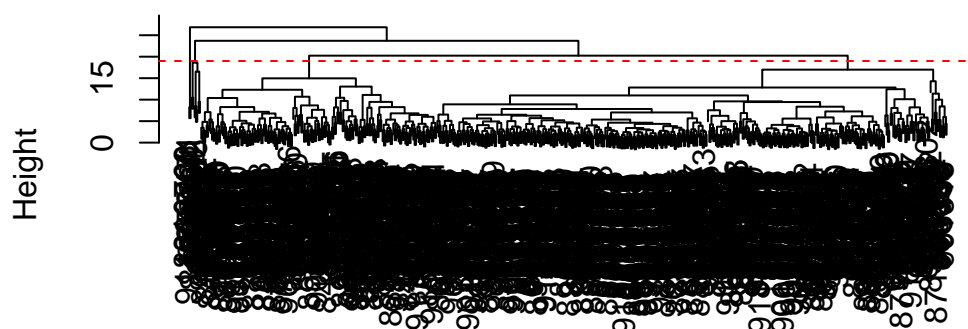
```
[1] -0.2608538
```

```
# 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)
```

## Cluster Dendrogram



data.dist  
hclust (\*, "complete")

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

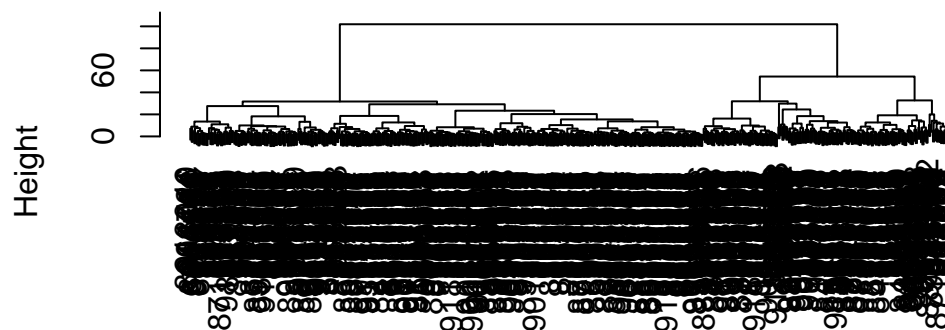
```
table(wisc.hclust.clusters, diagnosis)
```

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

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

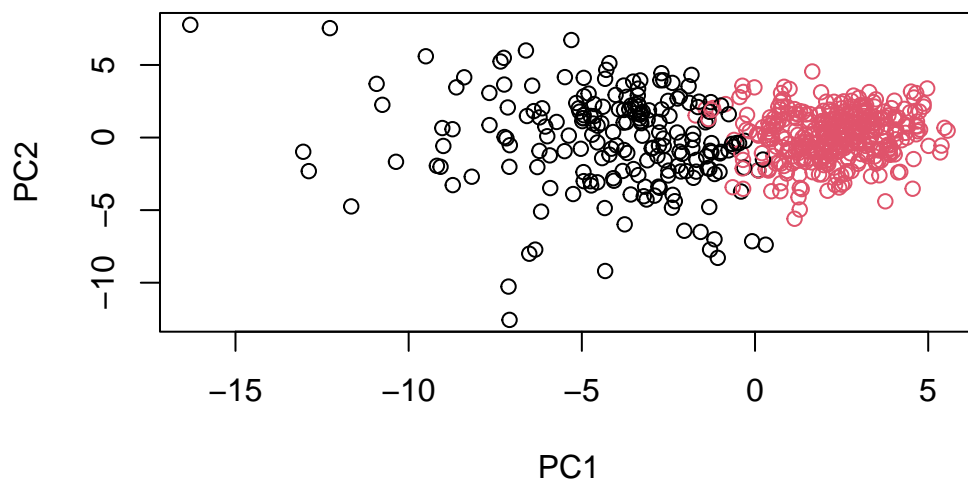
```
wisc.hclust <- hclust(data.dist, method = "ward.D2")  
plot(wisc.hclust)
```

## Cluster Dendrogram



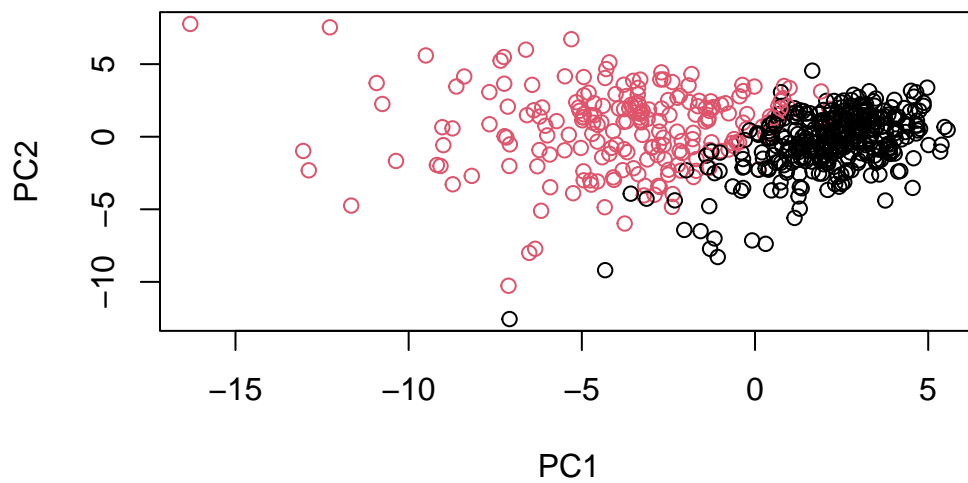
```
data.dist  
hclust (*, "ward.D2")
```

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





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



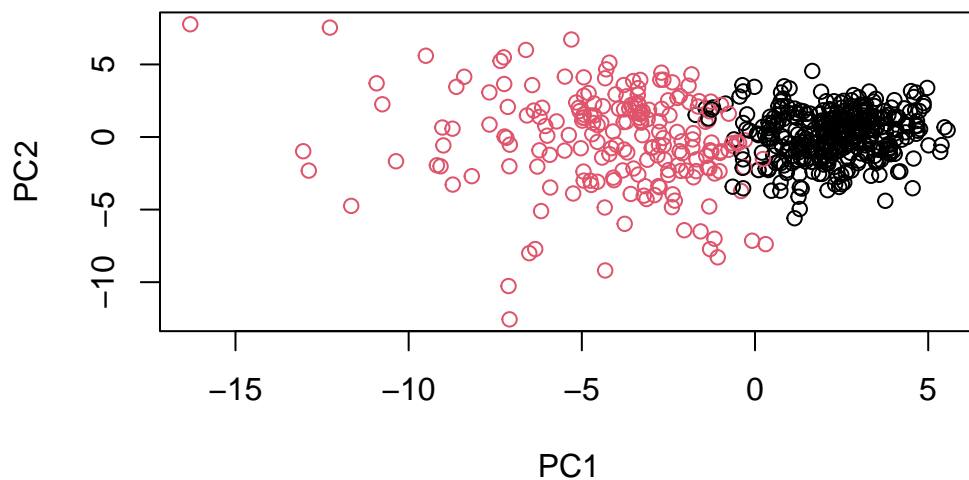
```
g <- as.factor(grps)
levels(g)
```

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

```
g <- relevel(g,2)
levels(g)
```

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

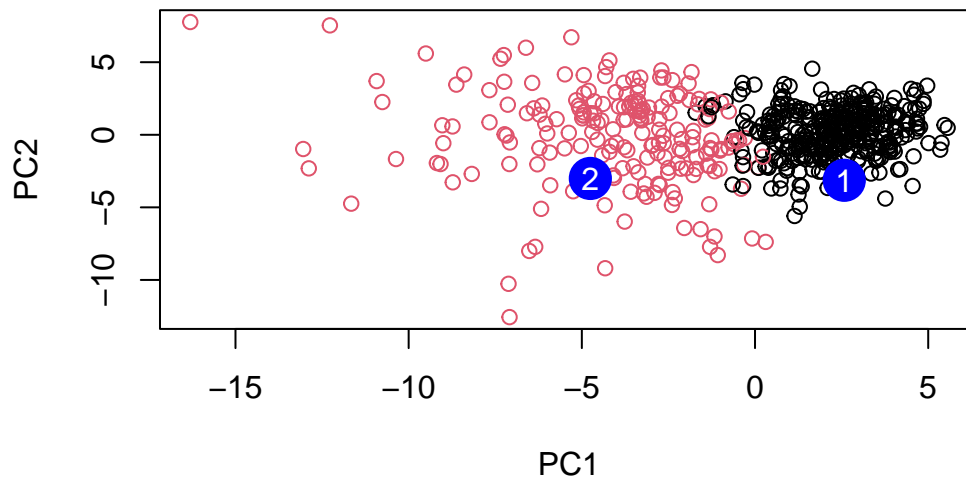
```
plot(wisc.pr$x[,1:2], col=g)
```



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

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
[1,]	2.576616	-3.135913	1.3990492	-0.7631950	2.781648	-0.8150185	-0.3959098
[2,]	-4.754928	-3.009033	-0.1660946	-0.6052952	-1.140698	-1.2189945	0.8193031
	PC8	PC9	PC10	PC11	PC12	PC13	PC14
[1,]	-0.2307350	0.1029569	-0.9272861	0.3411457	0.375921	0.1610764	1.187882
[2,]	-0.3307423	0.5281896	-0.4855301	0.7173233	-1.185917	0.5893856	0.303029
	PC15	PC16	PC17	PC18	PC19	PC20	
[1,]	0.3216974	-0.1743616	-0.07875393	-0.11207028	-0.08802955	-0.2495216	
[2,]	0.1299153	0.1448061	-0.40509706	0.06565549	0.25591230	-0.4289500	
	PC21	PC22	PC23	PC24	PC25	PC26	
[1,]	0.1228233	0.09358453	0.08347651	0.1223396	0.02124121	0.078884581	
[2,]	-0.1224776	0.01732146	0.06316631	-0.2338618	-0.20755948	-0.009833238	
	PC27	PC28	PC29	PC30			
[1,]	0.220199544	-0.02946023	-0.015620933	0.005269029			
[2,]	-0.001134152	0.09638361	0.002795349	-0.019015820			

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



Q16. Which of these new patients should we prioritize for follow up based on your results?

Patient 2 should be prioritized because they have more malignant type cells.