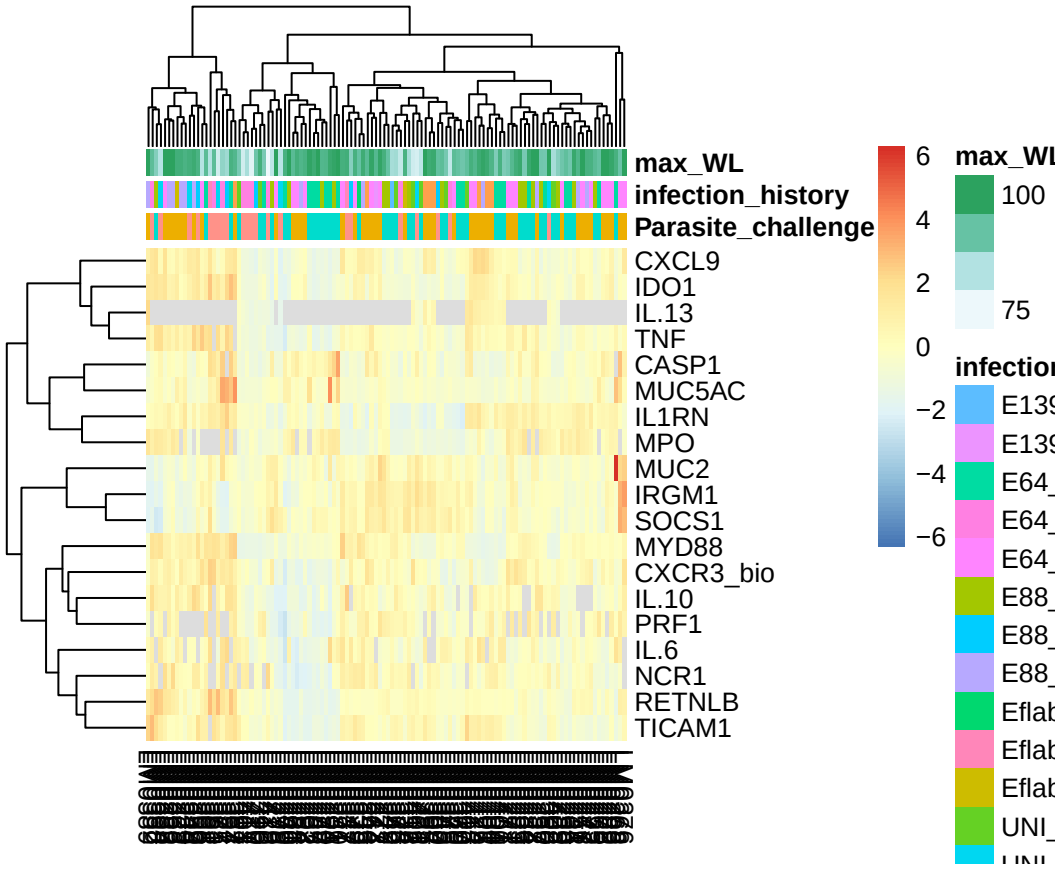
Gene_expression

Fay

09/05/2022

Gene expression - laboratory infections

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --
## v ggplot2 3.3.6     v purrr   0.3.4
## v tibble  3.1.7     v dplyr   1.0.9
## v tidyr   1.2.0     v stringr 1.4.0
## v readr   2.1.2     v forcats 0.5.1
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
##
## Attaching package: 'matrixStats'
## The following object is masked from 'package:dplyr':
##
##     count
##
## Attaching package: 'janitor'
## The following objects are masked from 'package:stats':
##
##     chisq.test, fisher.test
## corrplot 0.92 loaded
```

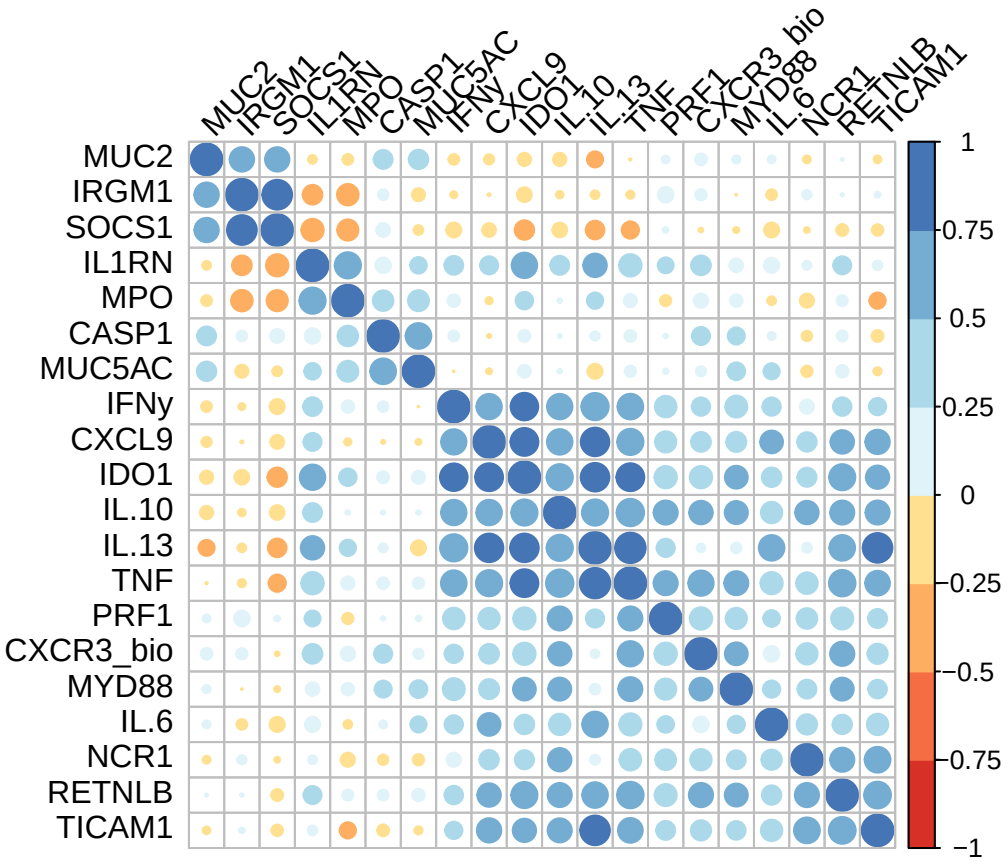


Heatmap on gene expression data:

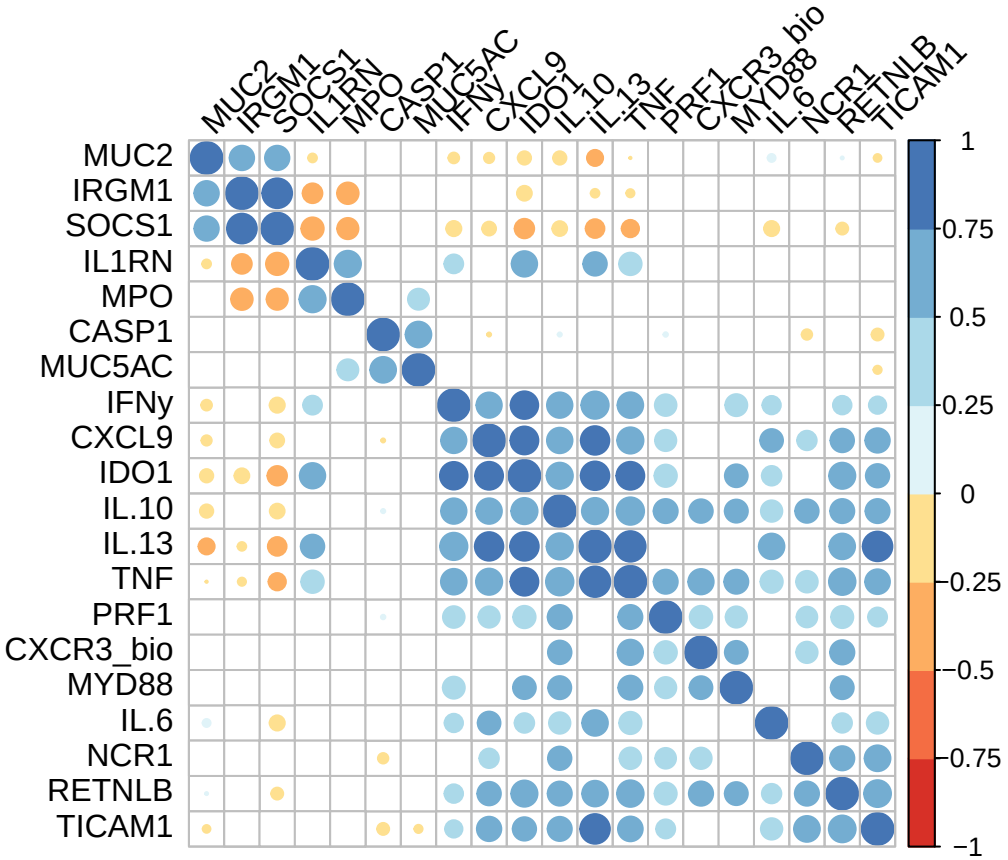
Gene correlation

Correlations between genes:

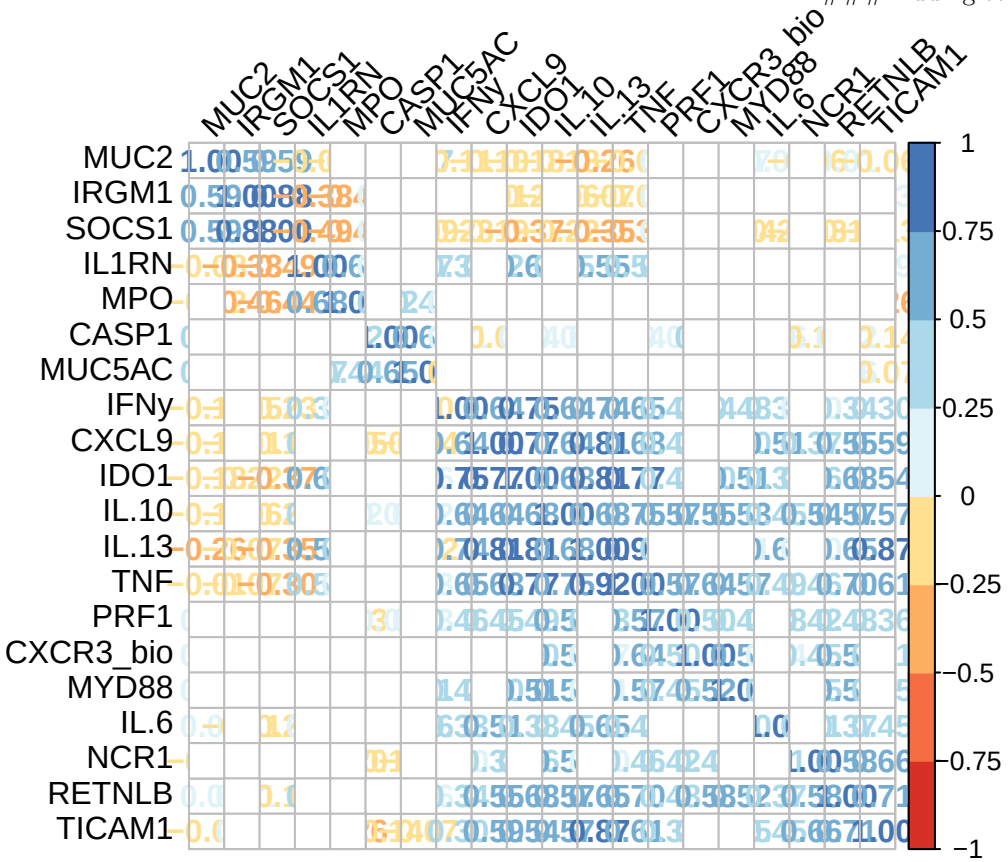
```
corrplot(gene_correlation,
         method = "circle",  #method of the plot, "color" would show colour gradient
         tl.col = "black", tl.srt=45, #colour of labels and rotation
         col = brewer.pal(n = 8, name ="RdYlBu"), #colour of matrix
         order="hclust") #hclust reordering
```

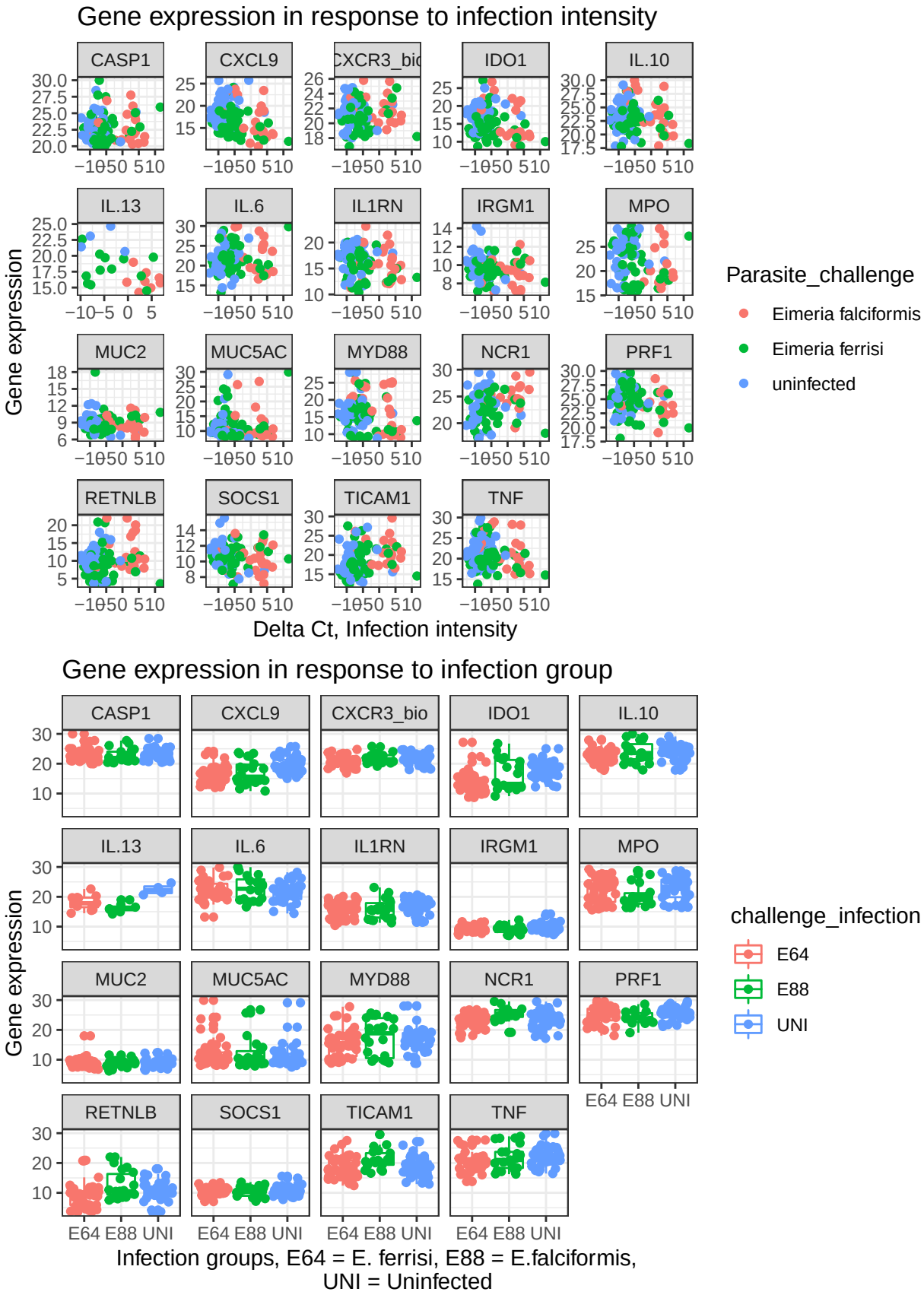

MUC2
IRGM1
SOCS1
IL1RN
MPO
CASP1
MUC5AC
IFNy
CXCL9
IDO1
IL.10
IL.13
TNF
PRF1
CXCR3_bio
MYD88
IL.6
NCR1
RETNLB
TICAM1
1
0.75
0.5
0.25
0
−0.25
−0.5
−0.75
−1

Correlations between genes, only including significant values



Adding correlation coefficients

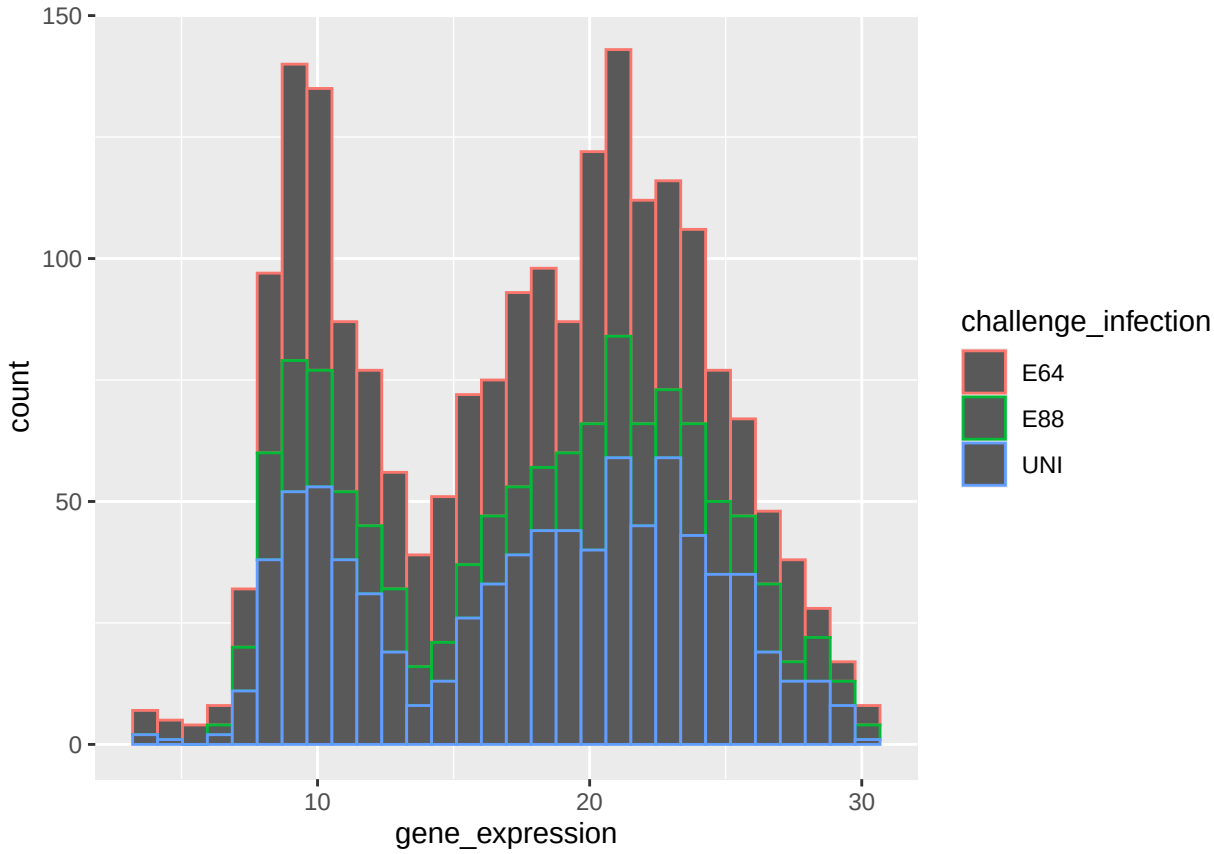



Gene expression in response to infection intensity
CASP1
CXCL9
CXCR3_bio
IDO1
IL.10
IL.13
IL.6
IL1RN
IRGM1
MPO
MUC2
MUC5AC
MYD88
NCR1
PRF1
RETNLB
SOCS1
TICAM1
TNF
Gene expression
Delta Ct, Infection intensity
Parasite_challenge
Eimeria falciformis
Eimeria ferrisi
uninfected
Gene expression in response to infection group
challenge_infection
E64
E88
UNI
E64 E88 UNI
Infection groups, E64 = E. ferrisi, E88 = E.falciformis,
UNI = Uninfected

```
gene_expr %>%
    group_by(EH_ID) %>%
  pivot_longer(cols = 8:26, names_to = "Gene", values_to = "gene_expression") %>%
  ggplot(aes(x = gene_expression, color = challenge_infection)) +
  geom_histogram()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

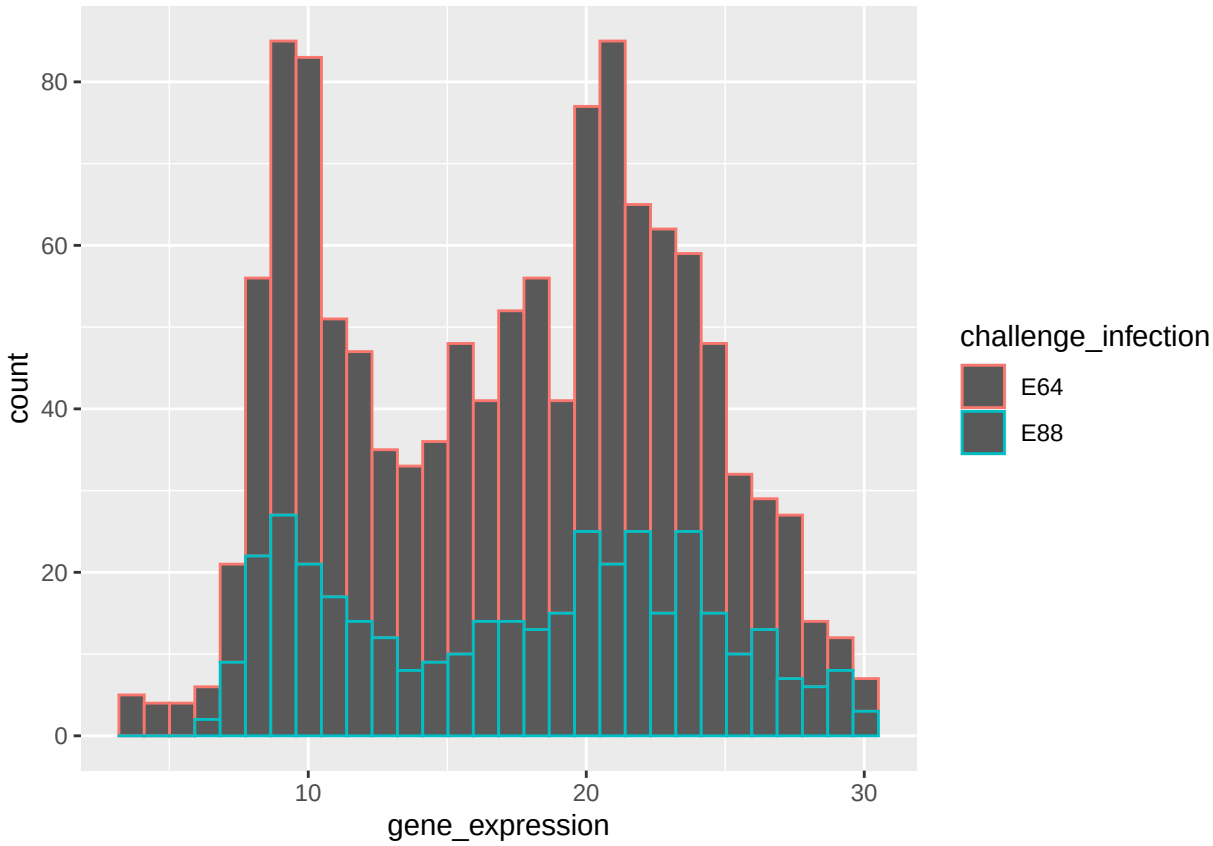
```
## Warning: Removed 159 rows containing non-finite values (stat_bin).
```




```
gene_expr %>%
    group_by(EH_ID) %>%
  filter(!challenge_infection == "UNI") %>%
  pivot_longer(cols = 8:26, names_to = "Gene", values_to = "gene_expression") %>%
  ggplot(aes(x = gene_expression, color = challenge_infection)) +
  geom_histogram()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

```
## Warning: Removed 90 rows containing non-finite values (stat_bin).
```




```
summary(gene_expr)
```

```
##     EH_ID           primary_infection  challenge_infection infection_history
##  Length:116         Length:116         Length:116          Length:116
##  Class :character   Class :character   Class :character    Class :character
##  Mode  :character   Mode  :character   Mode  :character    Mode  :character
##
##
##
##
##  mouse_strain           max_WL           delta            CXCR3_bio
##  Length:116         Min.   : 73.45   Min.   :-12.690   Min.   :16.86
##  Class :character   1st Qu.: 89.14   1st Qu.: -8.600   1st Qu.:20.08
##  Mode  :character   Median : 94.14   Median : -6.065   Median :21.15
##                     Mean   : 92.37   Mean   : -5.065   Mean   :21.25
##                     3rd Qu.: 97.28   3rd Qu.: -3.741   3rd Qu.:22.57
##                     Max.   :100.00   Max.   : 11.610   Max.   :25.80
##                                      NA's   :6
##       IL.6            IL.10            IL.13           IL1RN
##  Min.   :13.22   Min.   :17.79   Min.   :14.24   Min.   :10.39
##  1st Qu.:19.52   1st Qu.:21.48   1st Qu.:16.11   1st Qu.:14.71
##  Median :22.03   Median :23.22   Median :18.64   Median :16.91
##  Mean   :22.21   Mean   :23.24   Mean   :18.60   Mean   :16.37
##  3rd Qu.:24.97   3rd Qu.:24.85   3rd Qu.:20.56   3rd Qu.:18.21
##  Max.   :29.95   Max.   :29.99   Max.   :24.66   Max.   :23.14
##  NA's   :10      NA's   :10      NA's   :86
##      CASP1            CXCL9            IDO1            IRGM1
```

```
##  Min.   :19.96   Min.   :10.83   Min.   : 8.662   Min.   : 7.028
##  1st Qu.:21.28   1st Qu.:14.62   1st Qu.:12.506   1st Qu.: 8.838
##  Median :22.62   Median :17.65   Median :15.631   Median : 9.472
##  Mean   :22.85   Mean   :17.74   Mean   :15.815   Mean   : 9.579
##  3rd Qu.:23.81   3rd Qu.:20.04   3rd Qu.:18.434   3rd Qu.:10.301
##  Max.   :29.99   Max.   :25.74   Max.   :27.170   Max.   :14.225
##  NA's   :2
##       MPO             MUC2            MUC5AC           MYD88
##  Min.   :15.61   Min.   : 6.211   Min.   : 7.526   Min.   : 8.79
##  1st Qu.:17.66   1st Qu.: 7.942   1st Qu.: 9.053   1st Qu.:11.32
##  Median :21.50   Median : 8.570   Median :10.101   Median :16.16
##  Mean   :21.82   Mean   : 8.786   Mean   :11.598   Mean   :16.17
##  3rd Qu.:25.42   3rd Qu.: 9.357   3rd Qu.:12.309   3rd Qu.:19.00
##  Max.   :29.21   Max.   :17.991   Max.   :29.918   Max.   :28.08
##  NA's   :15
##       NCR1            PRF1            RETNLB           SOCS1
##  Min.   :17.17   Min.   :18.08   Min.   : 3.437   Min.   : 7.087
##  1st Qu.:21.69   1st Qu.:23.49   1st Qu.: 8.444   1st Qu.: 9.675
##  Median :23.71   Median :25.39   Median : 9.915   Median :10.466
##  Mean   :23.50   Mean   :25.08   Mean   :10.247   Mean   :10.606
##  3rd Qu.:25.43   3rd Qu.:27.10   3rd Qu.:11.533   3rd Qu.:11.518
##  Max.   :29.55   Max.   :29.79   Max.   :22.021   Max.   :15.561
##  NA's   :10      NA's   :23
##      TICAM1           TNF        Parasite_challenge
##  Min.   :12.41   Min.   :13.79   Length:116
##  1st Qu.:16.51   1st Qu.:19.37   Class :character
##  Median :19.12   Median :21.17   Mode  :character
##  Mean   :19.13   Mean   :21.43
##  3rd Qu.:21.48   3rd Qu.:23.07
##  Max.   :29.58   Max.   :29.87
##  NA's   :1       NA's   :2
```

```
g <- gene_expr
```

It is possible to compute a pca with missing data using the package missMDA. The missMDA package is dedicated to missing values in exploratory multivariate data analysis: single imputation/multiple imputation, etc.

Following the tutorial of the package author: Francois Husson: https://www.youtube.com/watch?v=OOM8_FH6_8o

Handling missing data in a pca: Bad methods: removing individuals with missing data or replacing missing data with the mean (default setting in many packages).

```
## Loading required package: xts
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
##
## Attaching package: 'xts'
```

```
## The following objects are masked from 'package:dplyr':
##
##     first, last
##
## Attaching package: 'PerformanceAnalytics'
## The following object is masked from 'package:graphics':
##
##     legend
## Warning in par(usr): argument 1 does not name a graphical parameter

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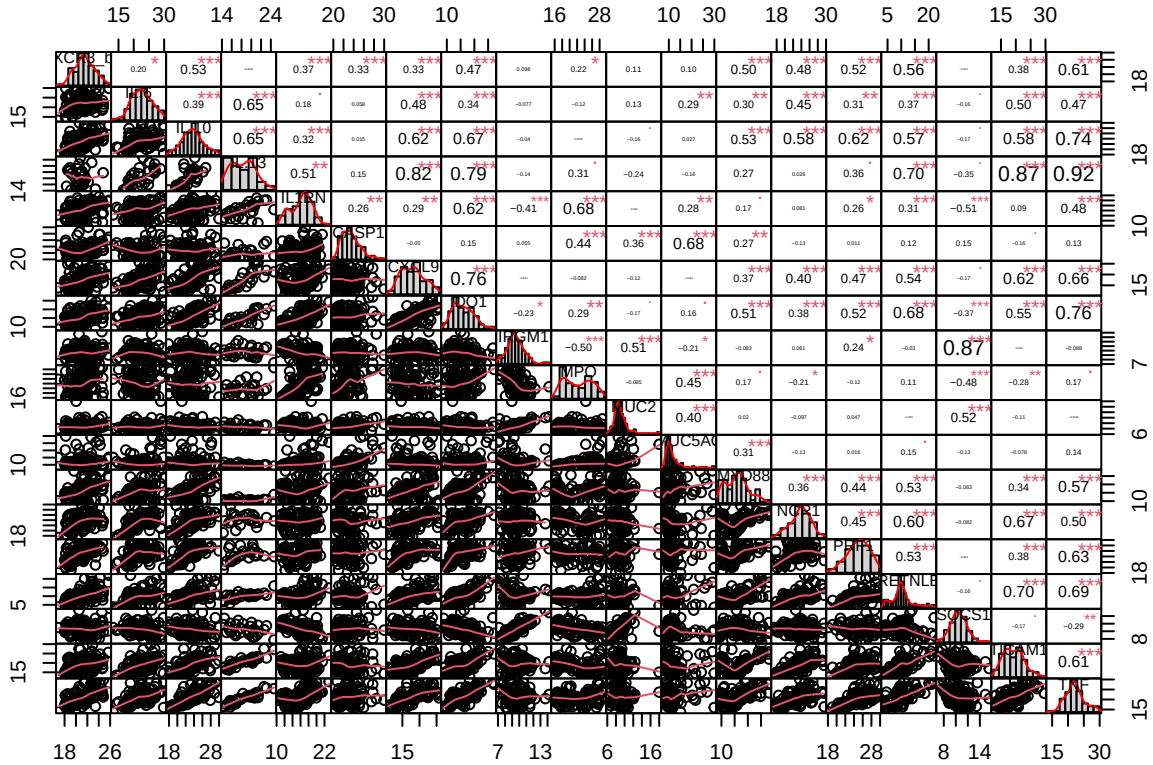
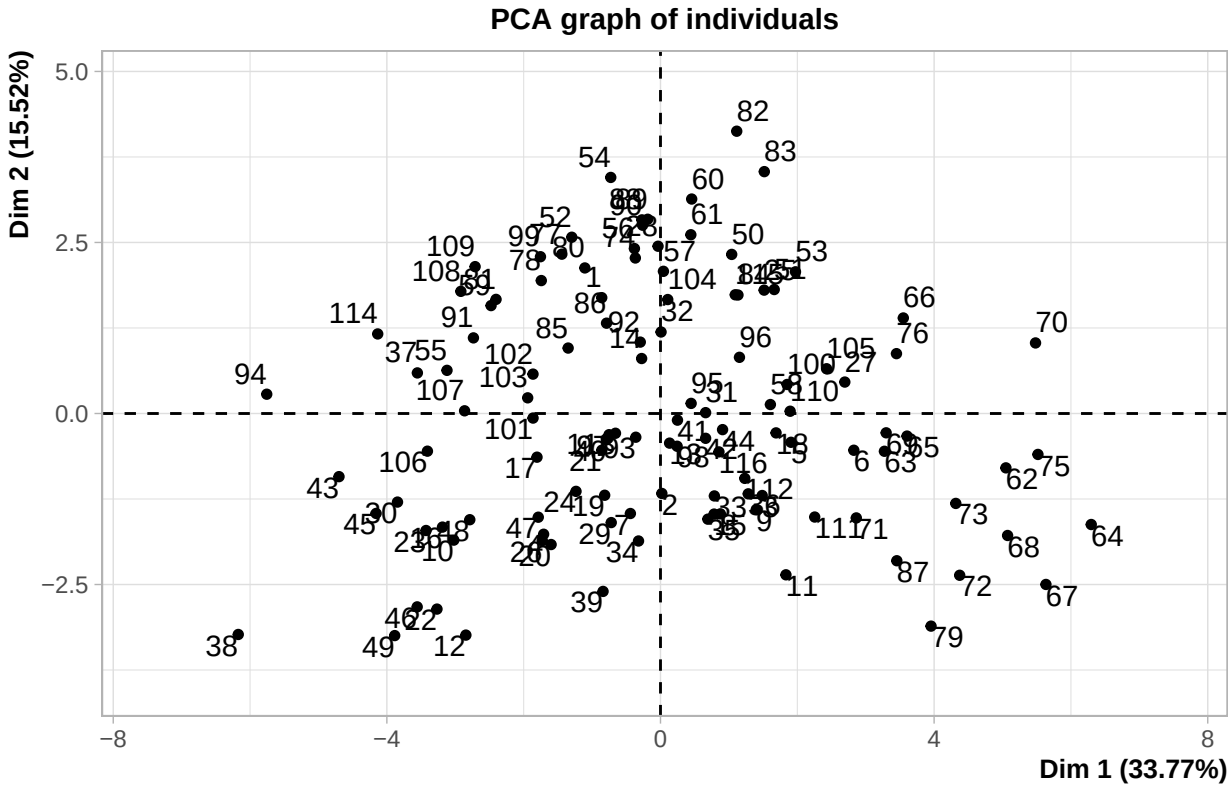
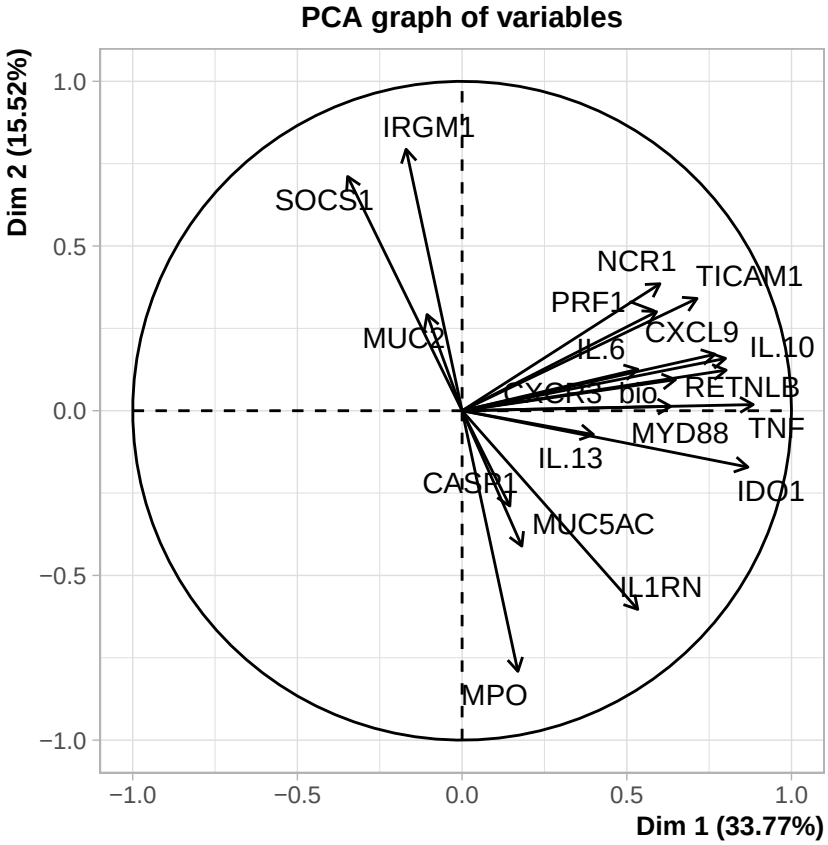
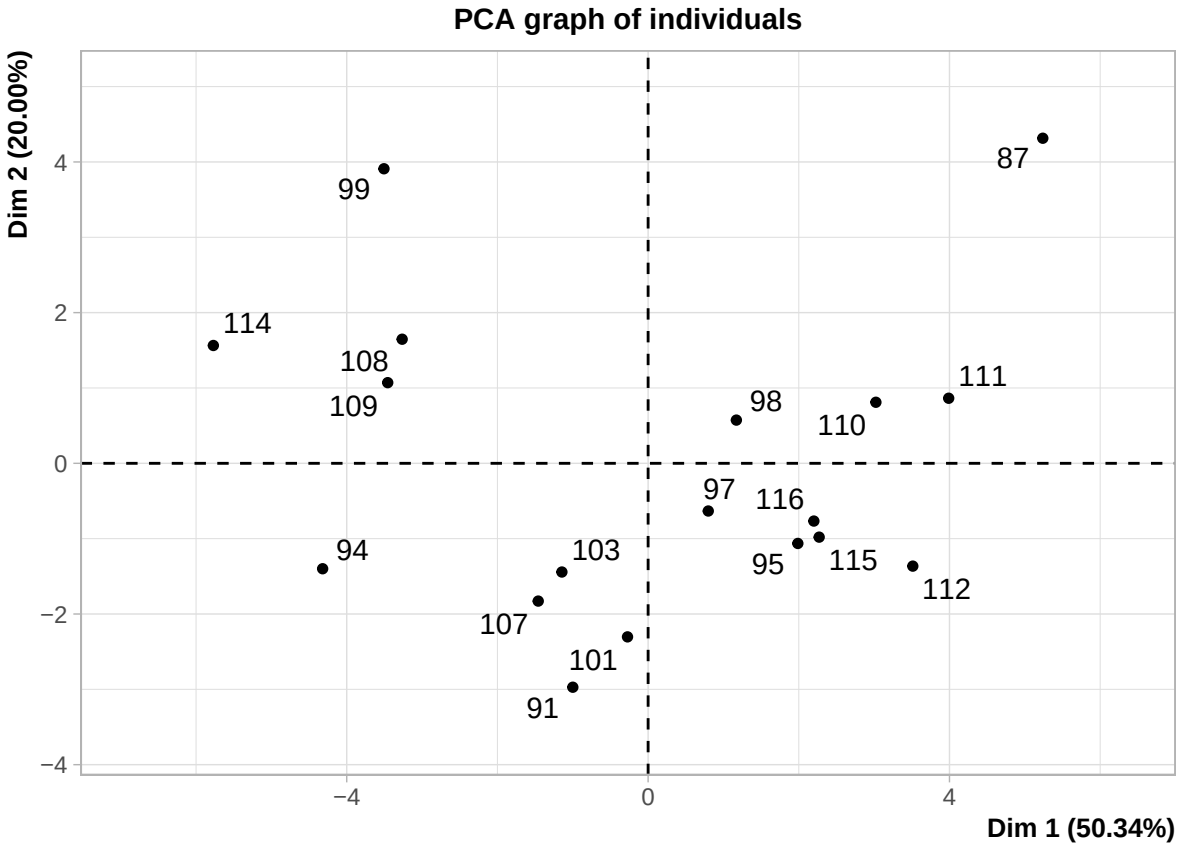


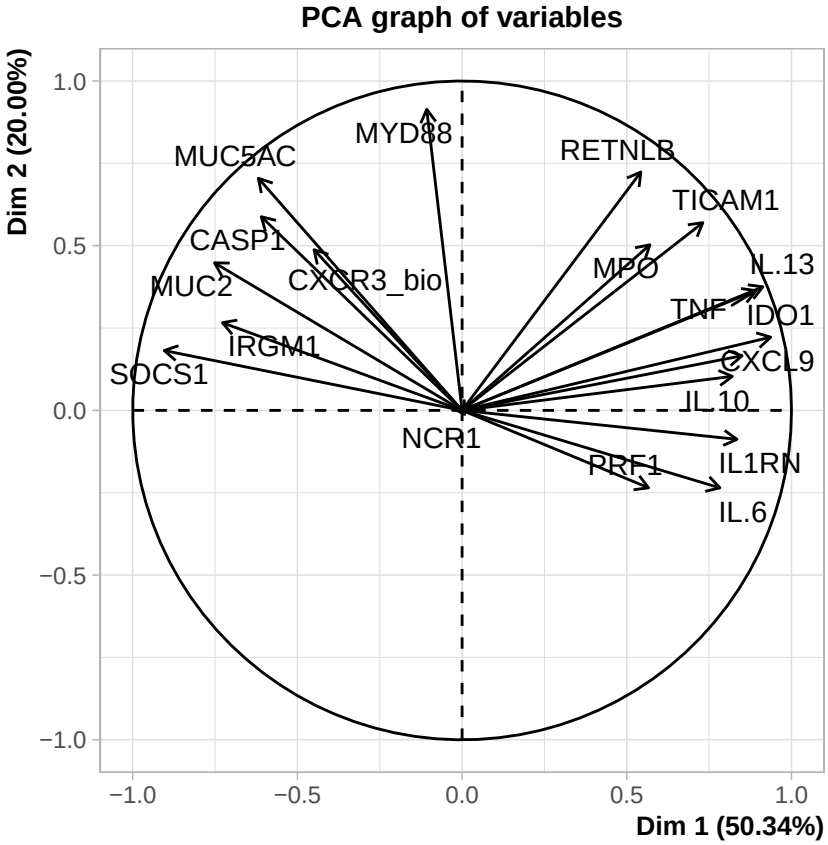

```
## Warning in PCA(g[8:26]): Missing values are imputed by the mean of the variable:
## you should use the imputePCA function of the missMDA package
```






```
#let's do a pca while removing ALL NA values
res.NA.remove <- PCA(g[8:26] %>% na.omit())
```


PCA graph of individuals
Dim 2 (20.00%)
Dim 1 (50.34%)
87
99
114
108
109
98
110
111
97
116
95
115
112
94
103
107
101
91
4
2
0
−2
−4
−4
0
4

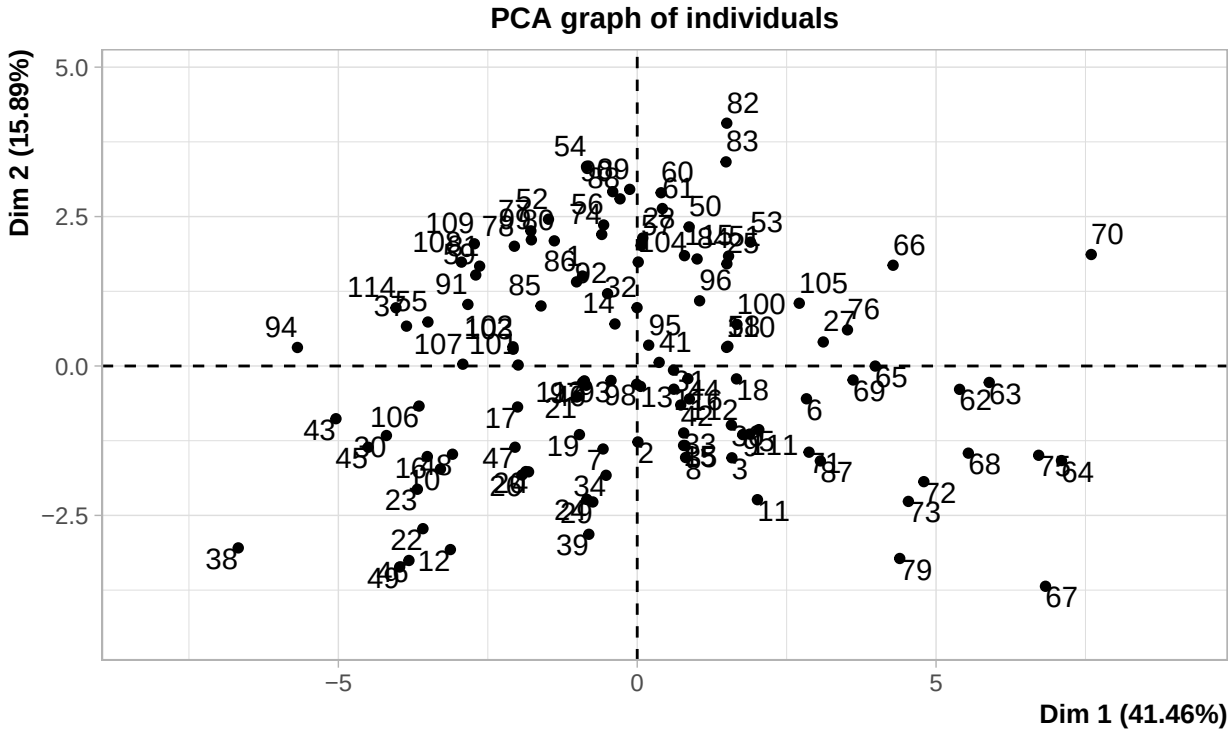

PCA graph of variables
Dim 2 (20.00%)
Dim 1 (50.34%)
MYD88
MUC5AC
RETNLB
TICAM1
CASP1
MPO
IL.13
MUC2
CXCR3_bio
TNF
IDO1
IRGM1
CXCL9
SOCS1
IL.10
NCR1
PRF1
IL1RN
IL.6
1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0

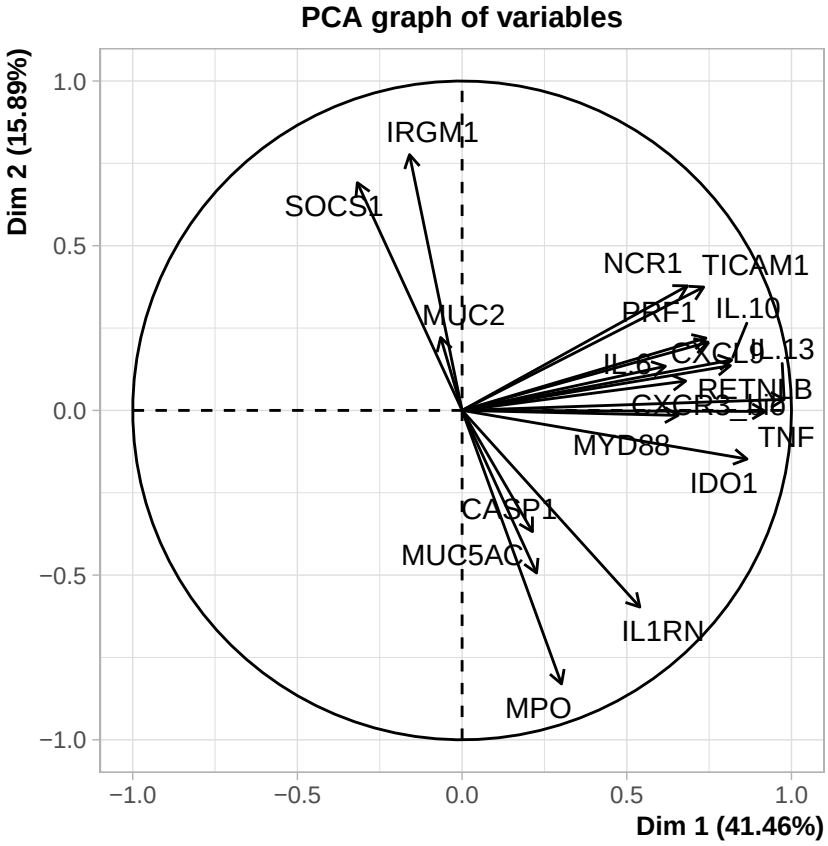
```
# These are rather unsophisticated ways to solve the problem
```

We will now continue by using an iterative pca to impute missing data A. Initialization: impute using the mean B. Step lampda: # a. do pca on imputed data table S dimensions retained # b. missing data imputed using pca # c. means (and standard deviations) updated C. Iterate the estimation and imputation steps (until convergence) (convergence: the act of converging and especially moving toward union or uniformity)

Overfitting is a common problem due to believing too much in links between variables. –> regularized iterative PCA (This version is what is being implented in missMDA) This is a way of taking less risk when imputing the missing data. The algorithm estimates the missing data values with values that have no influence on the PCA results, i.e., no influence on the coordinates of the individuals or variables.

```
##      CXCR3_bio     IL.6    IL.10    IL.13    IL1RN    CASP1    CXCL9     IDO1
## [1,]  20.92666 21.09045 21.78837 18.20471 16.42338 22.02920 13.60226 13.68551
## [2,]  21.62075 25.32600 22.92255 19.01956 20.13510 24.25054 14.53048 12.34782
## [3,]  23.66537 24.18021 24.90025 20.31376 18.14916 22.55511 18.99093 15.90241
## [4,]  20.21312 23.90781 22.31029 17.23688 16.79377 27.50341 14.03929 12.78334
## [5,]  23.02829 23.19571 27.67319 20.87536 18.98532 25.45624 19.20542 18.25427
## [6,]  23.18574 22.59572 25.82543 21.46693 19.45825 23.14097 19.07817 18.48888
##          IRGM1      MPO      MUC2   MUC5AC    MYD88     NCR1     PRF1    RETNLB
## [1,] 11.625516 23.16109 11.394231 12.36831 16.85699 23.33234 27.53290 11.389996
## [2,] 10.033986 26.67972  9.724516 14.59914 18.01044 22.89312 26.26383  7.857130
## [3,]  7.810604 25.81143  7.749293 12.87121 20.05994 23.96486 25.98379  9.184355
## [4,] 10.157602 27.67628  7.183272 14.04150 15.61895 23.45405 23.24062  3.920192
## [5,]  9.241544 26.30798  9.869590 14.37152 17.53845 24.12714 27.09015  8.711133
## [6,]  9.197374 24.94612  8.225922 11.58353 20.05389 25.43377 27.84301 15.803676
##          SOCS1   TICAM1      TNF
## [1,] 13.025961 19.82281 21.01065
## [2,] 10.292493 17.66099 22.36282
## [3,]  9.205008 19.11736 22.81213
## [4,] 10.692568 15.46167 18.96024
## [5,] 10.586118 17.03506 24.77639
## [6,] 10.037031 18.92915 25.01909
```






```
##
## Call:
## PCA(X = comp$completeObs)
##
```

```
##
## Eigenvalues
##                        Dim.1   Dim.2   Dim.3   Dim.4   Dim.5   Dim.6   Dim.7
## Variance               7.878   3.020   2.506   1.180   0.858   0.671   0.526
## % of var.             41.461  15.893  13.187   6.212   4.515   3.531   2.768
## Cumulative % of var.  41.461  57.354  70.541  76.753  81.268  84.799  87.567
##                        Dim.8   Dim.9  Dim.10  Dim.11  Dim.12  Dim.13  Dim.14
## Variance               0.396   0.327   0.309   0.288   0.227   0.200   0.167
## % of var.              2.086   1.723   1.628   1.515   1.195   1.052   0.879
## Cumulative % of var.  89.653  91.377  93.005  94.520  95.715  96.767  97.646
##                       Dim.15  Dim.16  Dim.17  Dim.18  Dim.19
## Variance               0.141   0.130   0.081   0.070   0.025
## % of var.              0.740   0.685   0.429   0.370   0.131
## Cumulative % of var.  98.385  99.070  99.499  99.869 100.000
##
## Individuals
##                Dist    Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3
## 1          |  3.463 | -0.916  0.092  0.070 |  1.505  0.647  0.189 |  2.048
## 2          |  2.751 |  0.012  0.000  0.000 | -1.271  0.461  0.213 |  1.537
## 3          |  2.852 |  1.584  0.275  0.309 | -1.536  0.673  0.290 | -0.683
## 4          |  3.998 | -1.818  0.362  0.207 | -1.771  0.895  0.196 |  1.249
## 5          |  3.312 |  2.035  0.453  0.377 | -1.065  0.324  0.103 |  1.424
## 6          |  3.229 |  2.832  0.878  0.769 | -0.549  0.086  0.029 | -0.121
## 7          |  2.184 | -0.571  0.036  0.068 | -1.389  0.551  0.405 | -0.021
## 8          |  2.870 |  0.810  0.072  0.080 | -1.531  0.669  0.284 |  0.409
## 9          |  3.157 |  1.766  0.341  0.313 | -1.148  0.376  0.132 | -0.379
## 10         |  4.222 | -3.292  1.186  0.608 | -1.723  0.848  0.167 |  0.207
## 11         |  3.312 |  2.011  0.443  0.369 | -2.237  1.428  0.456 |  0.102
## 12         |  5.013 | -3.126  1.069  0.389 | -3.072  2.693  0.375 | -0.841
## 13         |  1.827 |  0.055  0.000  0.001 | -0.341  0.033  0.035 | -0.326
## 14         |  2.113 | -0.372  0.015  0.031 |  0.703  0.141  0.111 |  1.063
## 15         |  2.321 |  0.776  0.066  0.112 | -1.329  0.505  0.328 | -0.453
## 16         |  4.372 | -3.512  1.350  0.645 | -1.515  0.655  0.120 | -0.406
## 17         |  2.588 | -2.001  0.438  0.598 | -0.686  0.134  0.070 |  0.206
## 18         |  3.217 |  1.661  0.302  0.267 | -0.216  0.013  0.005 | -0.464
## 19         |  3.337 | -0.967  0.102  0.084 | -1.148  0.376  0.118 | -0.230
## 20         |  3.033 | -1.865  0.381  0.378 | -1.767  0.891  0.339 | -1.026
## 21         |  1.893 | -1.007  0.111  0.283 | -0.514  0.075  0.074 | -0.034
## 22         |  4.927 | -3.585  1.406  0.529 | -2.722  2.115  0.305 |  0.021
## 23         |  5.131 | -3.678  1.481  0.514 | -2.062  1.214  0.162 |  0.842
## 24         |  8.480 | -0.842  0.077  0.010 | -2.231  1.421  0.069 |  6.426
## 25         |  3.220 |  1.500  0.246  0.217 |  1.709  0.834  0.282 |  1.404
## 26         |  3.059 | -1.926  0.406  0.397 | -1.823  0.949  0.355 | -0.234
## 27         |  4.129 |  3.113  1.061  0.568 |  0.402  0.046  0.009 |  0.117
## 28         |  6.571 |  0.092  0.001  0.000 |  2.141  1.309  0.106 |  5.559
## 29         |  3.450 | -0.743  0.060  0.046 | -2.275  1.478  0.435 |  0.285
## 30         |  4.788 | -4.196  1.927  0.768 | -1.163  0.386  0.059 | -0.133
## 31         |  3.240 |  0.607  0.040  0.035 | -0.070  0.001  0.000 |  1.148
## 32         |  4.094 | -0.003  0.000  0.000 |  0.976  0.272  0.057 |  2.500
## 33         |  2.375 |  0.778  0.066  0.107 | -1.120  0.358  0.223 | -0.278
## 34         |  2.948 | -0.521  0.030  0.031 | -1.829  0.955  0.385 | -0.133
## 35         |  2.435 |  0.800  0.070  0.108 | -1.331  0.506  0.299 | -0.805
## 36         |  3.733 |  1.576  0.272  0.178 | -0.988  0.279  0.070 |  1.005
## 37         |  4.920 | -3.860  1.631  0.616 |  0.666  0.127  0.018 |  0.879
```

```
## 38       |  7.731 | -6.675  4.876  0.745 | -3.044  2.645  0.155 | -0.156
## 39       |  5.076 | -0.809  0.072  0.025 | -2.816  2.264  0.308 |  3.401
## 40       |  2.639 | -0.853  0.080  0.105 | -0.322  0.030  0.015 |  0.926
## 41       |  2.858 |  0.368  0.015  0.017 |  0.060  0.001  0.000 |  0.477
## 42       |  2.448 |  0.728  0.058  0.088 | -0.653  0.122  0.071 | -0.861
## 43       |  5.402 | -5.040  2.780  0.871 | -0.882  0.222  0.027 |  1.160
## 44       |  2.324 |  0.848  0.079  0.133 | -0.212  0.013  0.008 |  0.049
## 45       |  4.871 | -4.501  2.217  0.854 | -1.360  0.528  0.078 |  0.385
## 46       |  5.568 | -3.819  1.596  0.471 | -3.254  3.023  0.342 | -0.301
## 47       |  3.332 | -2.044  0.457  0.376 | -1.359  0.527  0.166 | -0.649
## 48       |  4.478 | -3.090  1.045  0.476 | -1.476  0.622  0.109 | -0.284
## 49       |  7.648 | -3.974  1.729  0.270 | -3.363  3.229  0.193 |  3.278
## 50       |  3.791 |  0.868  0.082  0.052 |  2.327  1.546  0.377 | -1.200
## 51       |  3.528 |  1.528  0.256  0.188 |  1.839  0.965  0.272 | -1.472
## 52       |  3.367 | -1.484  0.241  0.194 |  2.455  1.721  0.532 |  0.541
## 53       |  3.709 |  1.896  0.393  0.261 |  2.072  1.226  0.312 | -1.205
## 54       |  3.913 | -0.848  0.079  0.047 |  3.334  3.174  0.726 |  0.799
## 55       |  4.093 | -3.501  1.341  0.732 |  0.736  0.155  0.032 | -0.776
## 56       |  2.949 | -0.561  0.034  0.036 |  2.360  1.589  0.640 | -0.427
## 57       |  2.849 |  0.066  0.000  0.001 |  2.016  1.161  0.501 |  0.930
## 58       |  3.565 |  1.517  0.252  0.181 |  0.329  0.031  0.009 | -2.190
## 59       |  3.723 | -2.701  0.799  0.527 |  1.522  0.662  0.167 |  0.210
## 60       |  4.369 |  0.400  0.017  0.008 |  2.898  2.398  0.440 |  1.959
## 61       |  3.623 |  0.422  0.019  0.014 |  2.634  1.981  0.529 |  0.000
## 62       |  6.556 |  5.393  3.183  0.677 | -0.391  0.044  0.004 | -2.686
## 63       |  6.230 |  5.890  3.796  0.894 | -0.275  0.022  0.002 |  1.234
## 64       |  7.930 |  7.099  5.514  0.801 | -1.582  0.715  0.040 |  2.089
## 65       |  4.613 |  3.983  1.736  0.745 | -0.002  0.000  0.000 | -1.389
## 66       |  5.116 |  4.281  2.006  0.700 |  1.686  0.811  0.109 |  0.022
## 67       |  8.121 |  6.831  5.106  0.708 | -3.686  3.878  0.206 |  1.567
## 68       |  6.486 |  5.541  3.359  0.730 | -1.458  0.607  0.051 | -1.691
## 69       |  4.773 |  3.611  1.427  0.572 | -0.234  0.016  0.002 | -2.108
## 70       |  8.550 |  7.597  6.316  0.790 |  1.865  0.993  0.048 |  2.787
## 71       |  3.833 |  2.875  0.904  0.562 | -1.443  0.594  0.142 | -1.236
## 72       |  6.069 |  4.796  2.517  0.624 | -1.935  1.069  0.102 | -1.522
## 73       |  6.042 |  4.537  2.253  0.564 | -2.266  1.466  0.141 |  0.271
## 74       |  3.375 | -0.593  0.038  0.031 |  2.200  1.382  0.425 | -0.268
## 75       |  7.746 |  6.717  4.937  0.752 | -1.494  0.637  0.037 |  1.874
## 76       |  4.195 |  3.518  1.354  0.703 |  0.605  0.104  0.021 | -0.162
## 77       |  3.226 | -1.779  0.346  0.304 |  2.261  1.459  0.491 | -0.027
## 78       |  3.620 | -2.055  0.462  0.322 |  2.004  1.146  0.306 | -1.143
## 79       |  7.008 |  4.392  2.111  0.393 | -3.221  2.961  0.211 |  2.891
## 80       |  3.307 | -1.387  0.210  0.176 |  2.094  1.252  0.401 | -0.864
## 81       |  3.699 | -2.637  0.761  0.508 |  1.670  0.796  0.204 |  0.405
## 82       |  6.178 |  1.498  0.246  0.059 |  4.062  4.711  0.432 |  3.827
## 83       |  4.871 |  1.486  0.242  0.093 |  3.415  3.330  0.492 |  0.179
## 84       |  2.892 |  1.003  0.110  0.120 |  1.790  0.915  0.383 | -0.620
## 85       |  2.418 | -1.609  0.283  0.443 |  1.004  0.288  0.173 | -0.662
## 86       |  2.959 | -1.015  0.113  0.118 |  1.407  0.565  0.226 | -0.929
## 87       |  5.471 |  3.064  1.028  0.314 | -1.588  0.720  0.084 | -3.198
## 88       |  3.475 | -0.287  0.009  0.007 |  2.796  2.232  0.648 |  0.432
## 89       |  3.632 | -0.126  0.002  0.001 |  2.955  2.493  0.662 |  0.207
## 90       |  4.071 | -0.410  0.018  0.010 |  2.917  2.429  0.513 | -0.705
## 91       |  3.910 | -2.833  0.878  0.525 |  1.030  0.303  0.069 | -1.513
```

```
## 92        |  2.738 | -0.496  0.027  0.033 |  1.210  0.418  0.195 | -1.544
## 93        |  2.539 | -0.438  0.021  0.030 | -0.243  0.017  0.009 | -0.722
## 94        |  6.097 | -5.685  3.537  0.869 |  0.310  0.027  0.003 | -0.503
## 95        |  2.940 |  0.192  0.004  0.004 |  0.348  0.035  0.014 | -2.118
## 96        |  3.785 |  1.044  0.119  0.076 |  1.091  0.340  0.083 | -1.934
## 97        |  2.947 | -0.913  0.091  0.096 | -0.275  0.022  0.009 | -1.568
## 98        |  3.008 | -0.008  0.000  0.000 | -0.306  0.027  0.010 | -1.597
## 99        |  4.096 | -1.771  0.343  0.187 |  2.110  1.272  0.265 |  2.247
## 100       |  4.138 |  1.669  0.305  0.163 |  0.696  0.138  0.028 |  0.104
## 101       |  3.649 | -1.992  0.434  0.298 |  0.016  0.000  0.000 | -2.161
## 102       |  3.155 | -2.079  0.473  0.434 |  0.321  0.029  0.010 | -0.586
## 103       |  3.747 | -2.076  0.471  0.307 |  0.280  0.022  0.006 | -1.442
## 104       |  3.044 |  0.017  0.000  0.000 |  1.739  0.864  0.326 |  0.460
## 105       |  4.133 |  2.712  0.805  0.430 |  1.050  0.315  0.065 |  0.748
## 106       |  4.318 | -3.650  1.458  0.715 | -0.671  0.128  0.024 | -1.444
## 107       |  3.601 | -2.918  0.932  0.657 |  0.030  0.000  0.000 | -1.232
## 108       |  4.012 | -2.941  0.946  0.537 |  1.738  0.862  0.188 |  0.808
## 109       |  4.707 | -2.725  0.813  0.335 |  2.045  1.193  0.189 |  0.150
## 110       |  4.129 |  1.495  0.245  0.131 |  0.311  0.028  0.006 | -2.071
## 111       |  4.583 |  1.879  0.387  0.168 | -1.140  0.371  0.062 | -2.115
## 112       |  4.500 |  0.873  0.083  0.038 | -0.551  0.087  0.015 | -3.195
## 113       |  2.859 | -0.884  0.086  0.096 | -0.249  0.018  0.008 | -1.657
## 114       |  5.395 | -4.036  1.782  0.559 |  0.974  0.271  0.033 |  2.010
## 115       |  3.724 |  0.791  0.068  0.045 |  1.846  0.973  0.246 | -2.165
## 116       |  3.115 |  0.613  0.041  0.039 | -0.389  0.043  0.016 | -1.994
##             ctr   cos2
## 1         1.443  0.350 |
## 2         0.813  0.312 |
## 3         0.161  0.057 |
## 4         0.537  0.098 |
## 5         0.698  0.185 |
## 6         0.005  0.001 |
## 7         0.000  0.000 |
## 8         0.058  0.020 |
## 9         0.049  0.014 |
## 10        0.015  0.002 |
## 11        0.004  0.001 |
## 12        0.243  0.028 |
## 13        0.037  0.032 |
## 14        0.389  0.253 |
## 15        0.071  0.038 |
## 16        0.057  0.009 |
## 17        0.015  0.006 |
## 18        0.074  0.021 |
## 19        0.018  0.005 |
## 20        0.362  0.114 |
## 21        0.000  0.000 |
## 22        0.000  0.000 |
## 23        0.244  0.027 |
## 24       14.207  0.574 |
## 25        0.678  0.190 |
## 26        0.019  0.006 |
## 27        0.005  0.001 |
## 28       10.633  0.716 |
```

```
## 29         0.028  0.007 |
## 30         0.006  0.001 |
## 31         0.453  0.125 |
## 32         2.150  0.373 |
## 33         0.027  0.014 |
## 34         0.006  0.002 |
## 35         0.223  0.109 |
## 36         0.347  0.072 |
## 37         0.266  0.032 |
## 38         0.008  0.000 |
## 39         3.979  0.449 |
## 40         0.295  0.123 |
## 41         0.078  0.028 |
## 42         0.255  0.124 |
## 43         0.463  0.046 |
## 44         0.001  0.000 |
## 45         0.051  0.006 |
## 46         0.031  0.003 |
## 47         0.145  0.038 |
## 48         0.028  0.004 |
## 49         3.697  0.184 |
## 50         0.496  0.100 |
## 51         0.746  0.174 |
## 52         0.101  0.026 |
## 53         0.499  0.105 |
## 54         0.220  0.042 |
## 55         0.207  0.036 |
## 56         0.063  0.021 |
## 57         0.297  0.106 |
## 58         1.650  0.377 |
## 59         0.015  0.003 |
## 60         1.320  0.201 |
## 61         0.000  0.000 |
## 62         2.482  0.168 |
## 63         0.524  0.039 |
## 64         1.502  0.069 |
## 65         0.664  0.091 |
## 66         0.000  0.000 |
## 67         0.845  0.037 |
## 68         0.983  0.068 |
## 69         1.530  0.195 |
## 70         2.672  0.106 |
## 71         0.526  0.104 |
## 72         0.797  0.063 |
## 73         0.025  0.002 |
## 74         0.025  0.006 |
## 75         1.209  0.059 |
## 76         0.009  0.001 |
## 77         0.000  0.000 |
## 78         0.449  0.100 |
## 79         2.876  0.170 |
## 80         0.257  0.068 |
## 81         0.056  0.012 |
## 82         5.039  0.384 |
```

```
## 83         0.011  0.001 |
## 84         0.132  0.046 |
## 85         0.151  0.075 |
## 86         0.297  0.099 |
## 87         3.518  0.342 |
## 88         0.064  0.015 |
## 89         0.015  0.003 |
## 90         0.171  0.030 |
## 91         0.788  0.150 |
## 92         0.820  0.318 |
## 93         0.179  0.081 |
## 94         0.087  0.007 |
## 95         1.543  0.519 |
## 96         1.287  0.261 |
## 97         0.846  0.283 |
## 98         0.877  0.282 |
## 99         1.736  0.301 |
## 100        0.004  0.001 |
## 101        1.606  0.351 |
## 102        0.118  0.034 |
## 103        0.715  0.148 |
## 104        0.073  0.023 |
## 105        0.192  0.033 |
## 106        0.718  0.112 |
## 107        0.522  0.117 |
## 108        0.225  0.041 |
## 109        0.008  0.001 |
## 110        1.476  0.252 |
## 111        1.539  0.213 |
## 112        3.512  0.504 |
## 113        0.945  0.336 |
## 114        1.390  0.139 |
## 115        1.612  0.338 |
## 116        1.369  0.410 |
##
## Variables
##              Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3    ctr   cos2
## CXCR3_bio |  0.679  5.848  0.461 |  0.089  0.263  0.008 |  0.253  2.559  0.064
## IL.6      |  0.617  4.836  0.381 |  0.134  0.595  0.018 |  0.103  0.427  0.011
## IL.10     |  0.818  8.503  0.670 |  0.153  0.774  0.023 | -0.111  0.488  0.012
## IL.13     |  0.978 12.133  0.956 |  0.033  0.037  0.001 | -0.004  0.001  0.000
## IL1RN     |  0.540  3.696  0.291 | -0.597 11.804  0.356 |  0.036  0.053  0.001
## CASP1     |  0.214  0.579  0.046 | -0.368  4.485  0.135 |  0.788 24.790  0.621
## CXCL9     |  0.747  7.075  0.557 |  0.207  1.417  0.043 | -0.199  1.586  0.040
## IDO1      |  0.865  9.497  0.748 | -0.148  0.722  0.022 | -0.113  0.510  0.013
## IRGM1     | -0.160  0.323  0.025 |  0.776 19.961  0.603 |  0.448  8.027  0.201
## MPO       |  0.302  1.156  0.091 | -0.830 22.832  0.689 |  0.177  1.254  0.031
## MUC2      | -0.065  0.054  0.004 |  0.221  1.622  0.049 |  0.829 27.410  0.687
## MUC5AC    |  0.226  0.649  0.051 | -0.494  8.066  0.244 |  0.652 16.984  0.426
## MYD88     |  0.656  5.459  0.430 | -0.015  0.008  0.000 |  0.214  1.830  0.046
## NCR1      |  0.684  5.939  0.468 |  0.378  4.733  0.143 | -0.115  0.525  0.013
## PRF1      |  0.740  6.957  0.548 |  0.220  1.596  0.048 |  0.102  0.417  0.010
## RETNLB    |  0.815  8.422  0.663 |  0.136  0.612  0.018 | -0.006  0.002  0.000
## SOCS1     | -0.318  1.284  0.101 |  0.691 15.830  0.478 |  0.526 11.043  0.277
```

```
## TICAM1    |  0.733  6.827  0.538 |  0.374  4.644  0.140 | -0.224  2.011  0.050
## TNF       |  0.921 10.760  0.848 | -0.003  0.000  0.000 |  0.045  0.082  0.002
##
## CXCR3_bio |
## IL.6      |
## IL.10     |
## IL.13     |
## IL1RN     |
## CASP1     |
## CXCL9     |
## IDO1      |
## IRGM1     |
## MPO       |
## MUC2      |
## MUC5AC    |
## MYD88     |
## NCR1      |
## PRF1      |
## RETNLB    |
## SOCS1     |
## TICAM1    |
## TNF       |
```

```
## NULL
```

```
## $Dim.1
## $quanti
##           correlation      p.value
## IL.13       0.9776601 4.575076e-79
## TNF         0.9206774 2.139356e-48
## IDO1        0.8649672 6.274569e-36
## IL.10       0.8184320 3.355024e-29
## RETNLB      0.8145332 1.001197e-28
## CXCL9       0.7465281 6.676802e-22
## PRF1        0.7402907 2.194441e-21
## TICAM1      0.7333679 7.903732e-21
## NCR1        0.6839699 2.623696e-17
## CXCR3_bio   0.6787540 5.630664e-17
## MYD88       0.6558009 1.356908e-15
## IL.6        0.6172165 1.600776e-13
## IL1RN       0.5396153 4.094022e-10
## MPO         0.3017989 9.933861e-04
## MUC5AC      0.2260973 1.466854e-02
## CASP1       0.2136150 2.131084e-02
## SOCS1      -0.3180971 5.018860e-04
##
## attr(,"class")
## [1] "condes" "list"
##
## $Dim.2
## $quanti
##        correlation      p.value
## IRGM1    0.7763684 1.339074e-24
## SOCS1    0.6913736 8.632991e-18
## NCR1     0.3780309 2.867164e-05
```

```
## TICAM1   0.3744576 3.457090e-05
## MUC2     0.2213188 1.696110e-02
## PRF1     0.2195441 1.788836e-02
## CXCL9    0.2068282 2.590529e-02
## CASP1   -0.3680234 4.815534e-05
## MUC5AC  -0.4935210 1.812712e-08
## IL1RN   -0.5970273 1.511949e-12
## MPO     -0.8303219 1.010067e-30
##
## attr(,"class")
## [1] "condes" "list"
##
## $Dim.3
## $quanti
##           correlation      p.value
## MUC2        0.8287201 1.644715e-30
## CASP1       0.7881238 8.851803e-26
## MUC5AC      0.6523399 2.141080e-15
## SOCS1       0.5260068 1.330377e-09
## IRGM1       0.4484578 4.452910e-07
## CXCR3_bio   0.2532317 6.093521e-03
## MYD88       0.2141508 2.097999e-02
## CXCL9      -0.1993732 3.190083e-02
## TICAM1     -0.2244631 1.542027e-02
##
## attr(,"class")
## [1] "condes" "list"
##
## $call
## $call$num.var
## [1] 1
##
## $call$proba
## [1] 0.05
##
## $call$weights
##   [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
##  [38] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
##  [75] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [112] 1 1 1 1 1
##
## $call$X
##            Dim.1 CXCR3_bio     IL.6    IL.10    IL.13    IL1RN    CASP1
## 1   -0.915545774  20.92666 21.09045 21.78837 18.20471 16.42338 22.02920
## 2    0.011780083  21.62075 25.32600 22.92255 19.01956 20.13510 24.25054
## 3    1.584363191  23.66537 24.18021 24.90025 20.31376 18.14916 22.55511
## 4   -1.818030087  20.21312 23.90781 22.31029 17.23688 16.79377 27.50341
## 5    2.034804392  23.02829 23.19571 27.67319 20.87536 18.98532 25.45624
## 6    2.832029262  23.18574 22.59572 25.82543 21.46693 19.45825 23.14097
## 7   -0.570846800  20.19632 23.91450 21.62915 18.46942 18.55582 23.11127
## 8    0.809533133  23.73105 21.14346 23.61026 19.35098 17.67666 25.06357
## 9    1.765621773  23.18462 22.02135 24.86233 20.33561 19.31653 22.45011
## 10  -3.291836424  19.21698 19.62519 22.94861 15.86227 17.29027 23.55407
## 11   2.011495300  22.52077 23.46206 23.85751 20.85859 20.58918 23.81598
```

```
## 12  -3.125533593  19.12177 25.26331 20.62422 16.15499 17.38254 22.70095
## 13   0.054794456  22.45032 22.69335 23.62850 18.93492 17.74972 22.49518
## 14  -0.372270923  22.51152 20.95665 23.01596 18.52967 16.69397 22.84267
## 15   0.775923951  21.26747 21.85538 23.82383 19.73429 19.67336 22.04784
## 16  -3.512223468  18.00746 18.38914 18.74826 15.90985 15.10803 23.38067
## 17  -2.001392829  19.10121 20.98553 22.42743 17.18706 16.44270 23.42149
## 18   1.660922890  22.41295 20.25383 23.03015 20.32417 17.63167 22.85872
## 19  -0.966654087  21.44775 18.45020 27.89777 17.76739 17.32784 23.05298
## 20  -1.864788567  21.07130 20.03526 21.08242 17.11006 17.43922 22.51961
## 21  -1.007482453  20.92691 21.09167 24.07971 17.98829 17.14403 22.76425
## 22  -3.584868773  19.36417 15.07182 20.66591 15.58336 16.54046 24.16598
## 23  -3.678212445  18.14328 17.39709 21.31080 15.58911 12.63218 23.57993
## 24  -0.841502706  20.03795 28.89199 21.07542 18.86096 18.66006 29.94250
## 25   1.500264009  23.44335 23.78059 24.23830 20.61809 16.75777 23.76993
## 26  -1.926479521  20.31368 19.93494 21.62254 17.14027 17.64324 22.86814
## 27   3.113068945  24.81556 21.68421 25.12770 21.75416 18.20610 22.86023
## 28   0.092018252  20.53629 25.89126 23.68561 19.46835 16.66748 28.45142
## 29  -0.742775277  20.53802 20.02823 20.76649 18.13779 17.42489 22.69451
## 30  -4.195983201  18.97607 19.07150 21.15728 14.99924 13.40232 24.16373
## 31   0.607274587  23.27692 19.71861 23.52992 19.56396 19.58139 21.79801
## 32  -0.002842419  21.66393 20.33407 20.44784 19.29409 17.72250 23.41526
## 33   0.778082720  23.07634 22.39279 23.94323 19.60995 19.91583 23.28426
## 34  -0.520873430  22.53733 18.60527 22.20044 18.41209 17.97018 25.19149
## 35   0.799691732  22.10287 20.06929 24.09205 19.58568 19.46909 21.63034
## 36   1.575786400  24.60278 18.46774 26.19512 20.22045 19.76563 23.74273
## 37  -3.860247890  18.58505 19.05836 17.86940 15.74421 14.97143 20.93711
## 38  -6.674900348  16.86408 13.21835 17.79117 12.78276 14.25306 24.43256
## 39  -0.809016843  22.15447 25.41724 22.04275 18.16404 17.18358 29.98603
## 40  -0.853391090  21.16552 18.10097 22.65766 18.21368 17.71976 24.28977
## 41   0.367541349  24.69742 19.05980 23.16757 19.17256 18.98606 22.78772
## 42   0.728066595  21.32868 21.65526 24.18590 19.50128 17.83004 22.53197
## 43  -5.040384134  18.70600 17.79219 18.49236 14.33358 14.68719 24.20202
## 44   0.848172054  22.12217 21.87536 23.32834 19.85906 18.26465 23.79661
## 45  -4.500887228  19.16785 17.97426 19.89393 14.81195 15.60916 23.59150
## 46  -3.819212366  18.19756 14.40759 20.83681 15.46550 17.24873 25.16027
## 47  -2.043532059  21.64540 17.73381 20.98086 16.94110 17.40872 20.43007
## 48  -3.090244335  20.18662 16.57967 19.05747 16.20012 16.32045 22.82450
## 49  -3.974399445  18.21390 29.81903 18.33959 15.70261 13.28305 25.93133
## 50   0.868149879  20.61515 23.03621 29.98877 19.87497 12.75221 20.43024
## 51   1.528209216  21.00294 23.67766 24.20689 20.54626 15.08824 20.90917
## 52  -1.484400934  20.65725 21.54047 23.25961 17.66527 11.65156 22.92319
## 53   1.895868415  21.31698 26.71171 25.52867 20.96153 13.83283 21.43852
## 54  -0.847813440  20.20715 24.37765 22.34004 18.42687 11.97324 21.03117
## 55  -3.501222446  18.40655 21.07280 21.44767 15.95547 11.82725 21.70017
## 56  -0.561376714  20.89049 23.48067 22.36207 18.55236 11.85427 21.44578
## 57   0.066074387  21.14188 24.07659 23.60720 19.22818 13.10425 25.34167
## 58   1.517001465  21.95768 22.34438 26.11948 20.51676 15.37061 21.28205
## 59  -2.701493670  18.21933 25.24031 20.51353 16.79688 12.28923 22.26009
## 60   0.399702758  24.65157 23.53264 23.43752 19.37199 11.43627 25.73564
## 61   0.421502299  23.52242 27.13311 24.12098 19.47855 11.27634 21.92730
## 62   5.393204085  22.91576 25.39795 28.87344 23.88989 16.75650 22.16068
## 63   5.889680025  25.66519 26.11602 27.58330 24.25735 19.70521 26.08998
## 64   7.098575665  24.22064 29.76292 28.05381 25.62352 19.23186 27.75083
## 65   3.982560186  22.86653 23.56129 25.01750 22.69070 18.03112 21.69953
```

```
## 66   4.281134917  22.76071 26.78894 27.95595 23.15535 15.84708 23.58463
## 67   6.831011961  23.52785 29.95433 28.18004 25.45059 23.13962 27.11709
## 68   5.540614286  22.75096 27.96307 25.69999 24.20575 17.58811 23.01611
## 69   3.611356503  21.48844 22.60560 29.13131 22.36904 18.63039 20.75492
## 70   7.596823857  25.80037 29.77186 29.09962 26.17544 20.02498 26.91510
## 71   2.874537418  21.03955 26.23716 26.44454 21.73347 16.61041 22.30920
## 72   4.795566060  21.52073 27.46334 24.91564 23.29033 17.10527 24.02626
## 73   4.537132227  22.66652 18.92939 25.56209 22.76709 18.86001 24.83386
## 74  -0.593108710  21.81679 20.56615 26.30993 18.24177 12.25711 21.65407
## 75   6.716558268  22.67323 26.18491 27.22396 25.27947 20.08638 25.34344
## 76   3.517995949  23.46890 22.68031 23.16663 22.11858 18.06204 22.36512
## 77  -1.779229385  19.91255 22.64689 22.45926 17.54585 11.27495 21.54675
## 78  -2.054941315  20.08603 21.31040 22.15091 17.23761 10.39335 20.70334
## 79   4.392302673  24.06576 28.75247 23.54490 23.10769 21.42000 27.75544
## 80  -1.386659442  21.27995 18.29274 24.38039 17.57979 12.06338 20.29093
## 81  -2.636669055  20.22281 24.09667 19.95704 16.75355 12.45559 21.84692
## 82   1.498389308  24.54876 23.94933 25.98836 20.62077 14.72332 24.56166
## 83   1.486028669  19.66524 28.21305 25.28405 20.68618 12.24016 21.28489
## 84   1.002576368  21.37939 22.23118 24.59390 20.11525 17.24273 21.67512
## 85  -1.609344620  20.76001 22.04766 22.25595 17.53079 15.60735 20.92126
## 86  -1.014946561  18.55728 25.20569 24.22079 18.42338 15.59951 19.99790
## 87   3.064475490  20.76581 23.12287 24.20175 24.65534 16.35892 21.11699
## 88  -0.287117840  19.80003 24.82849 24.68163 18.29073 12.63565 23.09224
## 89  -0.125845513  20.95861 24.47956 26.12950 20.04791 11.69210 22.80543
## 90  -0.409897637  21.59717 26.58406 21.70019 21.35713 11.07716 20.93479
## 91  -2.832695773  18.34869 21.28534 21.67449 15.43664 14.73684 19.96002
## 92  -0.496023933  21.69704 25.01886 23.22688 17.92247 15.92684 21.19813
## 93  -0.437785486  21.45424 19.31163 23.59355 18.98706 18.17187 22.41502
## 94  -5.684911320  19.13856 16.59937 17.90145 14.23954 12.16899 21.02919
## 95   0.192036635  20.68170 26.84019 24.26723 19.69519 17.50911 20.48537
## 96   1.043987030  18.54700 25.63743 23.37539 20.64206 17.68361 21.37431
## 97  -0.913418070  20.46746 18.96176 24.76140 17.74507 17.02771 20.42448
## 98  -0.008433619  19.20522 21.60006 22.75786 19.52374 19.51251 20.75696
## 99  -1.770740100  21.53098 18.24249 22.16032 17.34487 13.69251 24.61451
## 100  1.668914450  20.54109 26.92355 21.56791 22.61048 20.05260 24.82729
## 101 -1.991726509  20.32615 23.60529 21.83610 16.52889 15.60828 20.62177
## 102 -2.078620987  20.58743 22.64934 21.05282 15.64012 15.78011 21.04427
## 103 -2.075698591  21.30977 24.81393 20.53981 15.96387 15.62994 22.11439
## 104  0.017283801  24.78347 20.20337 23.52439 19.78487 14.97696 22.93029
## 105  2.711804234  22.77867 25.05195 25.24735 23.10120 20.21300 25.57550
## 106 -3.650027373  20.05828 17.73281 19.67574 14.96183 14.91150 20.39827
## 107 -2.917951946  20.06144 19.48198 22.33842 15.84020 15.91221 20.98834
## 108 -2.940622156  21.33039 19.22344 21.16372 16.83008 12.50428 22.24713
## 109 -2.725183539  21.08006 18.49392 19.74151 15.73607 12.83904 21.46682
## 110  1.495490699  18.95654 21.82732 26.77299 21.41995 19.69194 20.78469
## 111  1.879367204  20.24860 28.76398 23.93211 21.10862 20.95269 21.23007
## 112  0.873089477  19.01495 26.92797 23.32124 20.67509 18.21358 20.67898
## 113 -0.884056174  22.14929 22.09470 24.41267 16.81424 17.08754 20.84055
## 114 -4.035682818  23.41073 17.46569 19.79551 14.49658 13.13472 25.08039
## 115  0.791002902  18.84797 25.09494 24.87735 20.31023 15.62935 20.16156
## 116  0.612760349  21.05519 27.11805 23.21401 20.25871 18.40590 21.07134
##        CXCL9      IDO1     IRGM1      MPO      MUC2    MUC5AC     MYD88
## 1   13.60226 13.685507 11.625516 23.16109 11.394231 12.368312 16.856985
## 2   14.53048 12.347823 10.033986 26.67972  9.724516 14.599135 18.010443
```

```
## 3   18.99093 15.902410  7.810604 25.81143  7.749293 12.871210 20.059938
## 4   14.03929 12.783337 10.157602 27.67628  7.183272 14.041496 15.618948
## 5   19.20542 18.254268  9.241544 26.30798  9.869590 14.371520 17.538455
## 6   19.07817 18.488880  9.197374 24.94612  8.225922 11.583533 20.053889
## 7   14.67773 14.430931  8.600942 24.90775  8.730690 11.900492 18.177256
## 8   14.21946 15.666291  8.297135 25.61896  7.522414 13.148207 19.038180
## 9   16.20309 14.952342  8.997360 29.21133  8.156661  8.684992 20.392755
## 10  12.88829 11.663551  9.052160 27.46451  8.642571 10.342714 14.618691
## 11  20.30617 16.930006  8.162201 25.54124  8.859693 15.460500 19.281729
## 12  13.01806 10.705361  7.565302 24.91439  6.904949 15.359870 14.612337
## 13  17.39209 15.675249  9.841508 25.19862  7.871219  8.678551 16.285136
## 14  15.54217 13.079090 10.548003 23.12428  9.808142 10.449504 16.981842
## 15  19.29231 18.558979  9.218357 28.14862  8.669347 10.198480 16.960683
## 16  17.12064 15.731242  9.193427 23.38627  8.394537 10.196126 14.609839
## 17  13.68531 12.914861  9.322633 21.87048  8.714876 12.295662 15.888646
## 18  18.63569 19.069602  9.447187 27.92150  8.040773  9.121950 17.378285
## 19  12.95849 14.508282  9.598510 27.07087  7.807939 10.415893 15.854892
## 20  14.61636 13.138920  8.335187 24.66545  7.790361  9.038129 16.616529
## 21  16.18053 13.646650  9.565223 25.42206  8.771323  9.468288 15.065539
## 22  15.03703 16.004009  8.438642 27.97673  8.473955 10.951688 12.671592
## 23  14.00879 11.186614  9.439790 24.48003  8.613752 20.293679 13.916375
## 24  14.61884 12.098614  8.954314 24.31267 17.990707 24.237810 15.120134
## 25  21.33524 18.017771 11.480787 19.99031 10.255215 10.923709 17.310957
## 26  16.94201 12.246575  8.748695 26.20443  7.940369 12.292991 15.518893
## 27  18.99404 18.253549 10.577026 24.31717  8.761090  9.023115 19.547397
## 28  16.56531 16.273956 13.691213 20.56654 12.038068 20.929919 15.678849
## 29  15.85200 12.968113  8.203141 26.76613  8.233775 17.425917 17.354687
## 30  13.93241 11.229936  9.725386 24.64733  6.814177 11.003653 13.408224
## 31  18.71677 17.629490 10.881357 25.72409 10.267396 11.219287 15.989496
## 32  19.96504 19.114217 11.739965 21.94526 12.198908 12.960735 16.747558
## 33  18.19233 16.734890  8.942380 24.38990  8.418066  9.847442 16.538393
## 34  18.54367 17.279974  9.036738 22.05586  7.435172 13.026381 16.057834
## 35  17.56039 18.416046  8.848435 25.72081  8.204233  9.882749 18.079438
## 36  18.40169 19.753084  9.752966 28.66910  9.577180 10.404196 17.139011
## 37  16.51682 16.471883 11.495214 20.75777 10.413618 11.989536 14.774482
## 38  13.82651  8.661838  7.154126 23.86028  7.951477 15.116064 10.230339
## 39  13.24525 13.915862  8.987010 27.49619  9.597302 21.741745 16.270490
## 40  17.31654 17.871126 10.481867 23.27109  9.326657  9.908069 15.881726
## 41  18.82635 17.110750 10.481346 24.32100  8.573053  9.253118 16.642453
## 42  17.26648 15.929076  8.958850 24.41816  7.632720  8.440455 19.807910
## 43  12.21244  9.754557  9.836893 23.37686  9.851718 11.585622 14.407068
## 44  20.24753 19.708596  9.977461 24.92838  8.415812  8.076470 17.337172
## 45  13.56512  9.842353  9.029007 24.40325  9.316026  9.889951 13.850419
## 46  16.38290 15.927925  8.049613 26.94072  7.563250 12.350998 11.128010
## 47  16.55790 15.251946  9.385581 27.61566  8.563067  9.972695 15.725963
## 48  17.97308 18.265865  9.486106 23.34994  7.878306 10.787435 12.493822
## 49  11.98283 10.025161  8.136754 27.16886 10.834516 29.918079 13.929742
## 50  18.32872 16.717158 10.030781 16.37685  8.541946  8.852514 20.404963
## 51  21.96734 18.171699  9.531294 15.92918  7.957801  8.211709 24.785884
## 52  16.90758 12.292333 11.168791 17.07884  8.345124 10.313463 15.319679
## 53  22.16466 18.373123  9.563630 16.38449  8.132526  8.572920 23.240718
## 54  16.66383 11.993194 11.576390 17.15236 10.280913 10.532018 18.139879
## 55  15.42738 12.523361  9.928879 16.55492  8.291121  9.120236 13.839477
## 56  16.72246 13.721075 10.479662 16.32184  8.641474  8.817069 19.929199
```

```
## 57  18.64811 15.843818 10.788702 17.07038  9.428260  9.364003 18.078884
## 58  22.49707 18.930756  8.050492 16.71614  7.611355  7.888725 20.995390
## 59  15.25164 11.803676 10.108555 16.57170  9.364101  9.848285 15.544608
## 60  20.65578 12.237259 11.398526 16.60661  9.628627  9.639826 19.190942
## 61  18.51135 13.708155 10.256888 16.39160  9.063478  9.058345 20.478204
## 62  23.45426 21.459525  7.149357 25.63594  6.211322 10.154484 24.906656
## 63  19.96006 20.724537  9.016223 26.44495  9.246984 14.123916 24.948713
## 64  23.07473 27.169505  8.986193 27.97227  8.883982 23.694956 27.782637
## 65  24.18800 22.517576  8.747040 26.39468  7.865111  9.540464 19.913584
## 66  23.33492 22.130637  9.505613 20.34651  9.117813 10.210623 25.644537
## 67  22.51919 24.362430  7.028294 31.62038  9.249620 25.681823 23.705403
## 68  24.12845 22.364820  7.679259 28.01318  7.529806 12.495365 24.056632
## 69  22.14808 21.229097  8.823074 24.08935  7.071763  8.979468 18.841489
## 70  23.73669 26.746953 10.566932 23.76439 10.301982 15.246147 24.071985
## 71  20.71644 20.531902  8.015308 26.53156  6.875894 15.616582 18.824360
## 72  18.86451 21.448918  7.324264 27.47612  6.626930 13.267206 25.219254
## 73  16.34429 22.097978  7.796770 29.42759  8.052046 18.066238 24.484515
## 74  13.14677 13.300336 10.259382 16.46249  8.504597  8.874519 20.875416
## 75  23.74179 25.029717  9.255368 27.99719  8.579815 29.113148 28.078962
## 76  19.88270 20.563533 10.008556 23.69222  8.371019  9.336553 24.674035
## 77  18.09229 12.713460 10.729052 16.12279  9.020236  9.326122 17.670409
## 78  18.47461 11.083212  9.706705 15.60862  8.225850  8.669181 17.396433
## 79  18.54329 18.841289  7.212158 28.72646 11.580169 26.744894 20.536848
## 80  14.49042 12.360175 10.292874 16.43850  8.630854  8.630570 17.291781
## 81  14.45594 11.304476  9.925298 17.66268  9.721816 10.491249 15.854700
## 82  22.72566 15.063209 14.224817 20.66631 12.365167 12.636119 18.984608
## 83  23.29208 13.730573 11.186153 16.54841  9.411632  9.773155 28.008621
## 84  19.01887 18.925460 10.323671 17.42215  8.655927  9.526401 18.953311
## 85  14.94362 12.729950  9.898791 17.78050  8.541098  8.728032 16.724469
## 86  18.02023 16.255302 10.261519 17.17013  8.567059  8.840712 17.923550
## 87  21.25767 21.997595  7.290380 28.70681  6.445662  9.138264 13.951069
## 88  20.79058 13.061516 11.602668 17.49598  9.719942 10.305993 10.797975
## 89  21.78558 12.274416 11.183381 17.01788  9.354890  9.778690 10.666151
## 90  22.47699 11.437480 10.668408 16.28529  8.850896  9.096841 10.200785
## 91  15.04185 13.407077  9.601861 16.79333  7.966876  8.117302  9.107979
## 92  18.33013 15.595453  9.425018 16.97132  7.794905  8.401166  9.336994
## 93  14.38687 12.455074  9.436140 24.79474  8.197041  9.244237  9.956077
## 94  10.82695  9.136530  9.375088 17.69353  8.866534  9.777502 10.271472
## 95  18.70781 14.946433  8.839694 19.82217  7.487277  8.125193  8.844189
## 96  24.86841 19.502043  9.457993 18.28340  8.071410  8.206934  9.252441
## 97  15.35375 14.252057  9.304423 23.43023  7.997043  9.088218  9.269372
## 98  18.79592 16.970430  8.739251 20.15552  9.256436 10.444694 10.814310
## 99  14.09206 12.763815 12.235026 19.78562 11.179115 11.697763 12.527439
## 100 18.86993 17.037959 10.412347 19.15029  9.342203  9.990472 11.061339
## 101 13.72277 12.100585  8.635025 19.64736  7.290007  8.052774  8.988102
## 102 14.14905 14.815813  9.722631 18.87126  8.935368 10.212263 10.256080
## 103 14.05901 11.611228  8.832139 17.72639  7.722895  8.278575  9.471053
## 104 16.14029 14.976568 10.745571 18.11004  9.538819 10.048293 10.673092
## 105 21.90772 20.337306 10.781881 19.84596  9.299197  9.821379 10.803154
## 106 12.87900 11.674964  8.890484 21.49815  8.237312  8.762589  9.752521
## 107 11.55303 11.659147  9.496184 20.05410  7.969417  8.572635  9.429172
## 108 15.30404 11.142649 11.492399 18.39825 10.125236 10.724162 11.321831
## 109 13.54572 11.447434 10.481360 18.73255  9.916628 10.691091 11.307609
## 110 25.69238 20.921377  9.314263 19.02520  8.686559  9.464939 10.506455
```

```
## 111 25.34770 20.689122  8.418992 24.76759  7.942093  9.095062  9.772552
## 112 25.74388 20.553644  8.419839 21.41300  6.748056  7.525599  8.790171
## 113 15.14489 15.490731  9.344918 21.30055  7.847138  8.507111  9.580745
## 114 12.26390  8.769283 10.113600 19.62256 10.336654 11.690665 10.798740
## 115 20.93232 18.051913  9.677846 16.56573  7.916451  8.172702  9.524207
## 116 17.73318 16.366598  8.701905 20.94546  7.665722  8.340444  9.444841
##         NCR1     PRF1    RETNLB     SOCS1   TICAM1      TNF
## 1   23.33234 27.53290 11.389996 13.025961 19.82281 21.01065
## 2   22.89312 26.26383  7.857130 10.292493 17.66099 22.36282
## 3   23.96486 25.98379  9.184355  9.205008 19.11736 22.81213
## 4   23.45405 23.24062  3.920192 10.692568 15.46167 18.96024
## 5   24.12714 27.09015  8.711133 10.586118 17.03506 24.77639
## 6   25.43377 27.84301 15.803676 10.037031 18.92915 25.01909
## 7   23.25482 23.54348 11.930951 10.137282 17.89026 20.40686
## 8   23.69673 28.00436 10.795116 10.187464 17.98634 21.91510
## 9   23.81112 27.02770 11.763447  9.833251 20.04689 25.99834
## 10  21.39968 20.45141  4.079604 11.242170 15.12650 18.21831
## 11  23.66060 26.21540 12.512554  8.390115 17.00279 24.39284
## 12  20.06957 21.01384  3.598778  8.892853 14.34632 18.18376
## 13  24.37670 25.10224 11.645965 10.674034 15.64940 20.93638
## 14  23.76296 27.17679 12.534258 11.718299 17.56715 20.51972
## 15  23.89841 24.64252 11.212956 10.034478 16.84957 22.49043
## 16  18.00615 22.71284  6.937463 10.044808 15.08446 17.05868
## 17  21.33841 26.20900  5.973854 10.589004 17.65482 19.35511
## 18  29.49340 25.66098 14.362461 10.790189 18.71333 23.10196
## 19  23.12706 25.41527  5.662282 10.323638 15.91257 19.63243
## 20  22.28476 23.09671  6.708141  9.097796 16.83769 19.32845
## 21  24.36829 25.16968  8.373846 10.727382 15.39051 19.76802
## 22  18.33988 22.09717  3.437346 10.438836 13.27494 18.82194
## 23  18.49862 22.59840  4.203089  9.684278 13.27406 22.08087
## 24  20.80061 24.78750  4.605416 10.017204 15.04402 23.69131
## 25  25.28210 25.69449  9.644582 12.041930 19.34746 26.10923
## 26  20.79229 26.11614  6.063100  9.980612 14.75829 18.44981
## 27  23.63638 28.71855 12.795983  9.838008 22.32244 29.87482
## 28  22.63025 28.71924 13.919183 15.560557 16.95622 20.43844
## 29  21.23689 29.16415  9.982388  9.482890 14.86344 21.08135
## 30  20.03371 21.10798  5.917482 11.194286 13.04953 16.84558
## 31  20.77055 28.50238 10.511800 11.429176 16.45653 24.00758
## 32  20.53246 29.53929 10.842803 12.155859 17.76277 21.50840
## 33  25.24495 25.38933 11.824440  9.660671 15.41369 20.83225
## 34  21.49756 25.56295  7.036342  8.830993 15.62009 20.40643
## 35  22.91124 26.37404 12.132540  9.535813 16.56348 22.45497
## 36  21.85548 28.15420  9.879838 11.097173 16.94929 24.08582
## 37  19.67674 21.14482  8.466972 12.429422 15.73371 16.46384
## 38  17.36359 18.08027  3.785109 10.974022 12.41300 13.78664
## 39  23.07639 24.78306  5.259263 10.307205 14.37050 19.70445
## 40  19.59789 26.08224 11.495341 11.487913 16.29785 20.60002
## 41  22.90715 27.33195  7.758496 11.493739 17.45863 22.01304
## 42  24.18657 29.51591  9.225770  9.632405 17.44476 21.63822
## 43  19.93898 20.38618  4.346449 11.657992 15.33566 15.86004
## 44  21.63473 28.11725  9.187486 10.970666 19.30253 21.39020
## 45  18.81508 21.15985  4.867295 11.106637 15.25927 16.16250
## 46  17.17266 21.54708  3.690941 10.228503 13.47368 18.09514
## 47  21.39350 23.41759  8.189116 10.139407 15.24493 17.65270
```

```
## 48  17.79122 25.89262  4.204721 10.569843 12.91764 17.50383
## 49  18.11990 19.92611  3.577107 10.324091 14.54200 16.01331
## 50  25.36659 26.01465 10.749170 11.024760 21.19794 21.01304
## 51  26.75319 27.09819  9.755923 10.478270 22.50241 21.56508
## 52  24.26265 27.12899 10.841208 12.989070 16.99448 20.03119
## 53  27.48604 27.18535  9.478791 10.607035 21.82549 21.98348
## 54  26.70705 25.41207 12.030827 13.123553 21.09282 21.07389
## 55  20.19892 21.79024  9.145387 10.833533 15.29784 19.01250
## 56  25.53460 26.41866  9.278296 11.303618 21.34152 21.31616
## 57  26.75811 25.29939  9.923647 11.828319 19.06670 21.78523
## 58  23.38357 26.14829  8.262385  8.890513 20.80948 23.70044
## 59  22.93460 25.11673  9.047844 11.867247 16.30778 18.36694
## 60  23.87387 28.88317  9.635853 12.837053 19.15818 22.89580
## 61  26.26590 23.85662  9.703631 11.627023 21.52452 22.65241
## 62  27.00035 27.90638 18.572389  8.318661 29.57724 23.13135
## 63  27.56776 29.56682 17.913556 10.084373 25.58661 27.81593
## 64  25.83862 27.59474 20.897073  9.482244 24.73153 27.59754
## 65  29.07498 28.19561 16.332964  9.665532 21.42768 23.91542
## 66  26.89351 28.51895  9.493187 11.330597 26.12898 26.67485
## 67  25.96444 28.22388 14.714598  8.041715 24.10520 28.93255
## 68  25.88560 25.43324 20.720319  7.087203 26.26861 27.69078
## 69  26.76586 28.06315 10.975465  9.162248 19.60484 29.13404
## 70  28.71996 31.76473 22.021335 13.581984 25.64584 28.37664
## 71  24.66802 26.78273 13.342864  8.919463 19.84097 25.19713
## 72  27.21686 26.69613 20.083060  7.158283 23.30618 28.17372
## 73  24.82501 28.62742 22.004654  8.871887 23.74250 28.31769
## 74  24.39808 26.19344  9.526062 11.755902 21.52548 20.79691
## 75  27.33835 28.89657 18.031914  9.895583 25.98677 28.62975
## 76  25.71248 29.79103 15.178442 10.393341 22.46358 27.50077
## 77  22.21427 25.55363  9.661429 12.013956 18.22035 19.84642
## 78  22.32535 24.21456  8.805372 11.222371 20.81727 19.51511
## 79  28.81700 26.48781 16.855267  8.065261 20.60755 23.72752
## 80  24.59491 26.21215  9.441200 11.032251 20.47256 20.23849
## 81  22.79706 23.15837  9.722345 12.451737 20.65242 17.12110
## 82  25.50603 26.79236 13.220426 14.919748 20.57782 22.50920
## 83  26.55833 27.50508 10.058471 12.308402 22.04861 23.31357
## 84  27.12947 24.06304 10.004453 11.728596 24.10621 21.72844
## 85  24.81094 23.62678  9.365788 11.073955 17.51909 19.97281
## 86  22.33892 23.77440  9.192797 11.689073 18.09591 20.75239
## 87  23.72726 23.93945 15.923781  7.757090 27.17214 25.43076
## 88  25.57028 25.88464 11.281775 12.009186 21.10553 22.98131
## 89  24.28717 25.98337 10.982572 12.330284 20.82249 21.80276
## 90  23.38032 25.16243 10.944685 11.589537 23.26258 20.96380
## 91  22.97322 27.10505  8.885230 11.076750 16.22269 18.16059
## 92  24.09515 24.29967 10.008384 10.705349 22.69601 20.23189
## 93  26.18841 25.49433 10.995071 10.401308 20.49431 21.47300
## 94  19.15281 19.06725  7.547668 11.758377 17.68614 16.26408
## 95  23.92244 25.49845  9.999622  9.756697 21.55859 21.56077
## 96  25.46251 26.64396  9.906633 10.453336 22.37117 22.84888
## 97  22.09169 28.07379  9.665312  9.605007 20.07661 20.12716
## 98  26.34456 23.49281  9.661908  9.225406 21.56845 22.03168
## 99  24.33736 23.94627 12.576263 12.867410 20.08692 20.32090
## 100 24.35790 24.18033 11.724569 10.427714 27.52816 26.40631
## 101 26.30723 23.92448  7.985537  9.284697 19.19948 18.33022
```

```
## 102 22.18252 28.09646  5.846103 10.089456 18.04099 19.42994
## 103 26.67078 22.17432  8.544338  9.708748 19.40001 18.85483
## 104 24.40765 25.97794 11.387807 11.285548 22.13123 21.26313
## 105 24.99690 28.24536 10.488427 11.445105 22.62902 25.72357
## 106 21.39041 22.26847 10.541307  9.678177 16.57747 17.42194
## 107 23.67079 24.50357  8.477857 10.166476 17.26136 17.46136
## 108 19.99873 23.04488 10.740533 11.861010 20.43164 17.80555
## 109 29.54948 22.51975 10.484425 12.108359 20.85134 16.34527
## 110 23.17187 25.18772 11.220518  9.548208 22.43535 22.25967
## 111 21.21622 24.28532 10.960531  8.968065 23.16068 23.48999
## 112 22.99591 24.24964 10.019037  8.531568 21.37614 20.82249
## 113 25.42788 24.87718  8.590075  8.871211 17.57769 19.73392
## 114 23.75737 20.88617  6.927890 13.408973 17.53509 16.57800
## 115 26.10599 28.46406 10.098975 10.393635 23.04097 22.15808
## 116 24.42321 27.33021 10.388094  8.474758 19.93831 21.28205
```

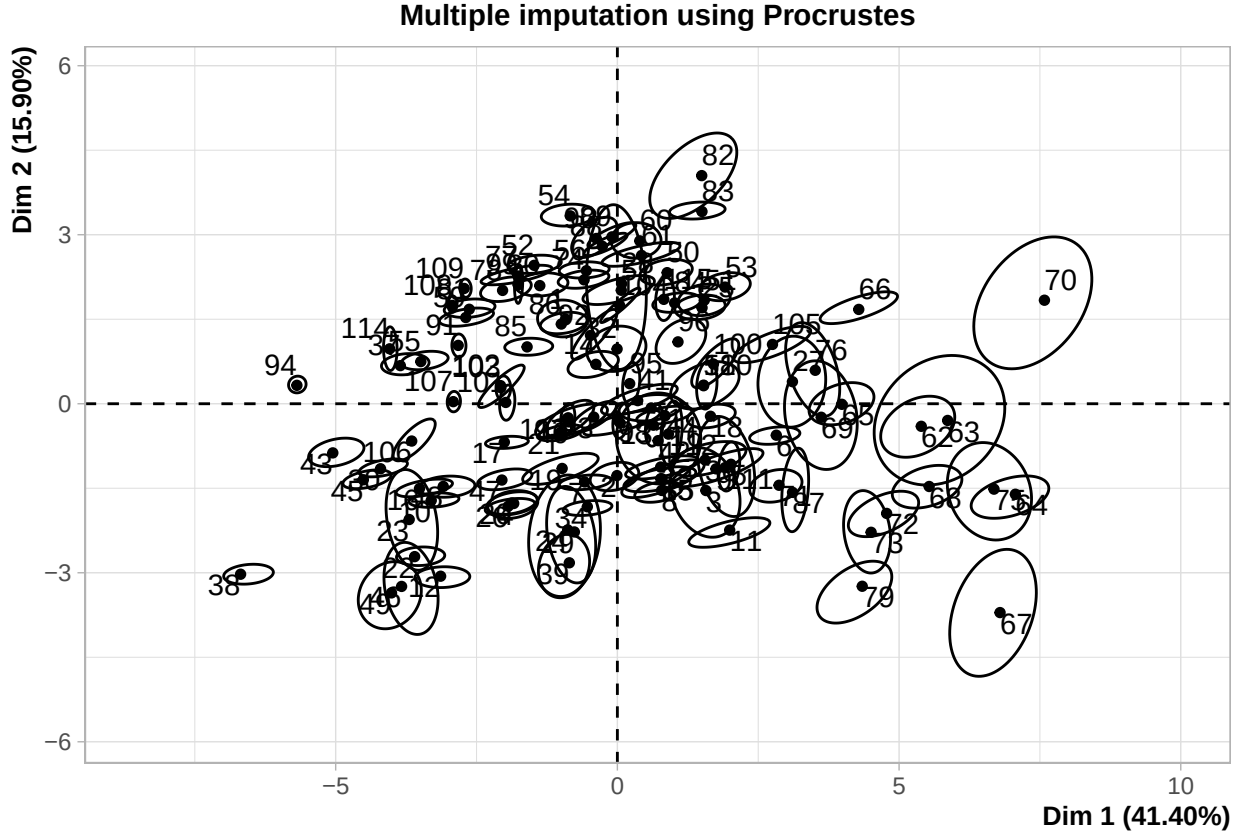
Caution: When imputing data, the percentages of inertia associated with the first dimensions will be overestimated.

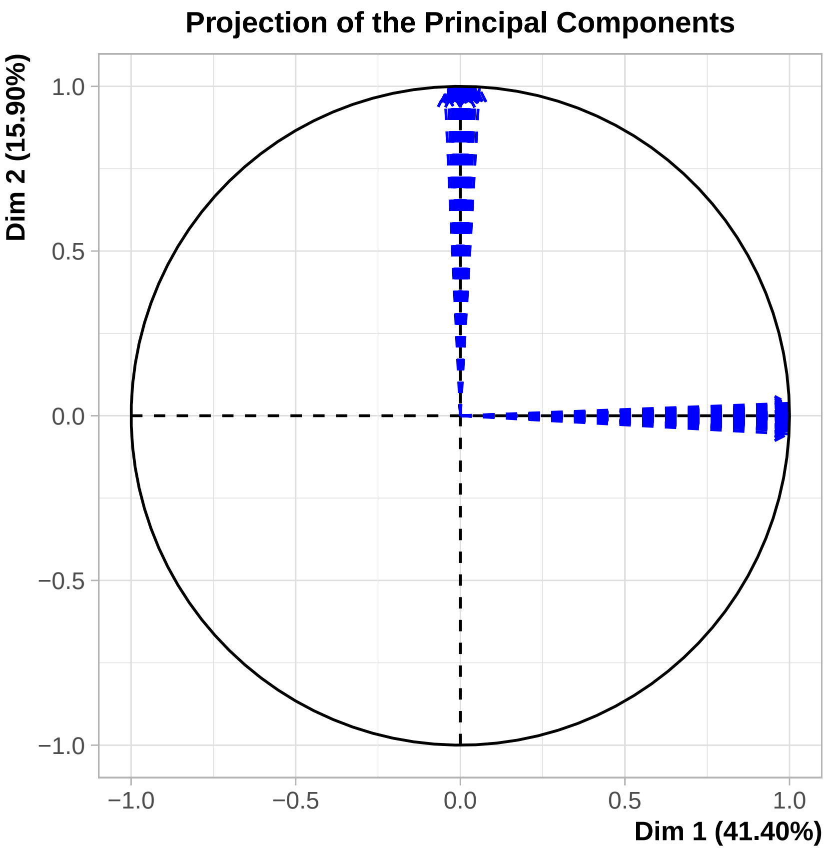
Another problem: the imputed data are, when the pca is performed considered like real observations. But they are estimations!!

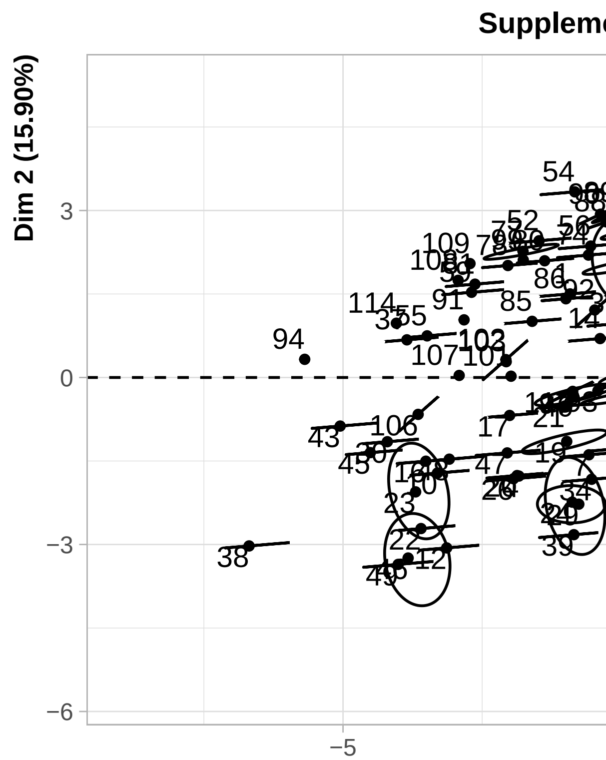
Visualizing uncertainty due to issing data:

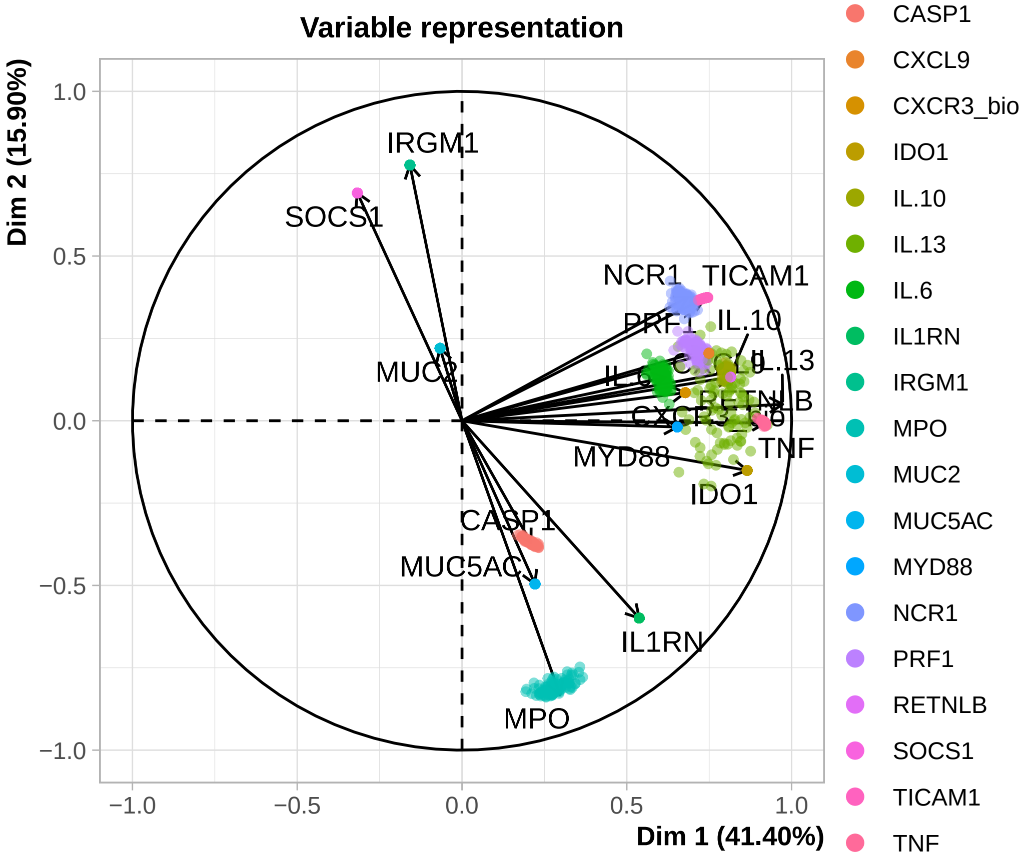
–> mulrimple imputation: generate several plausible values for each missing data point

We here visualize the variability, that is uncertainty on the plane defined by two pca axes.

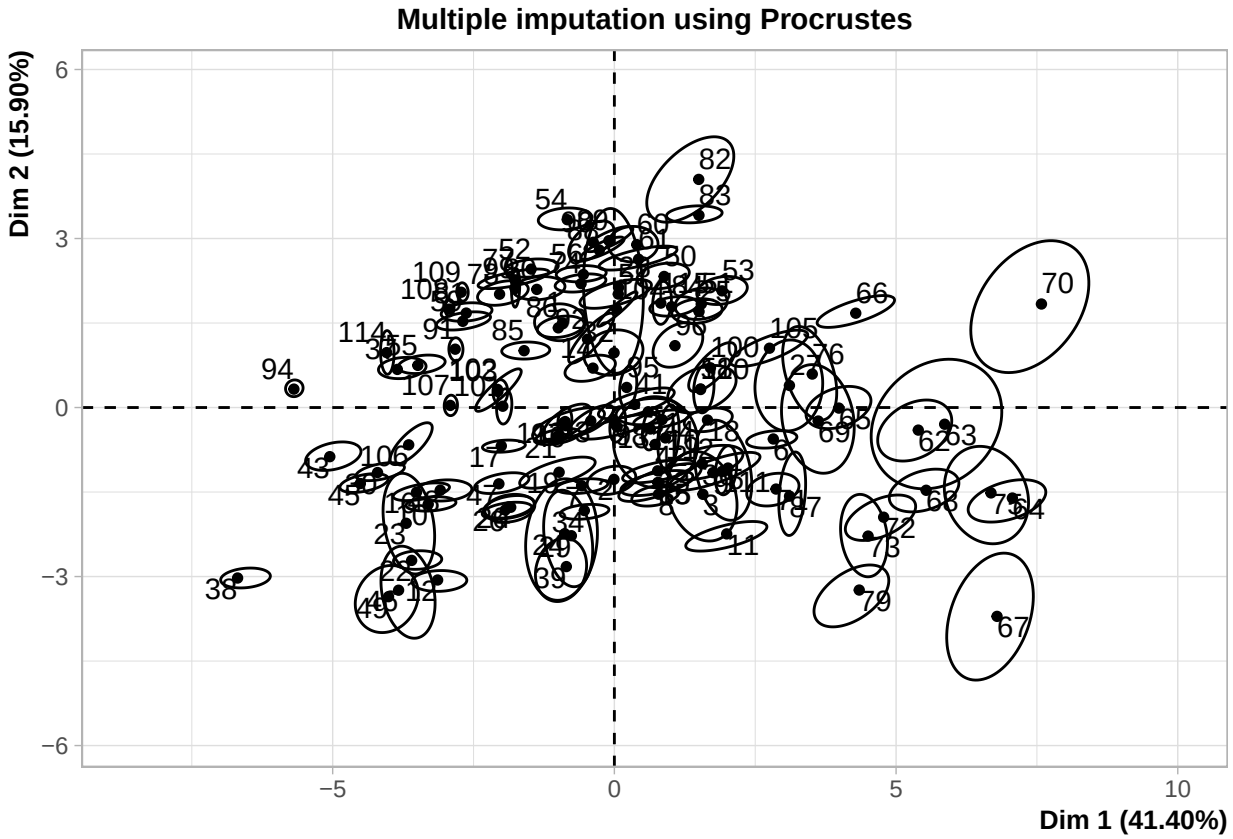



Projection of the Principal Components
Dim 2 (15.90%)
Dim 1 (41.40%)

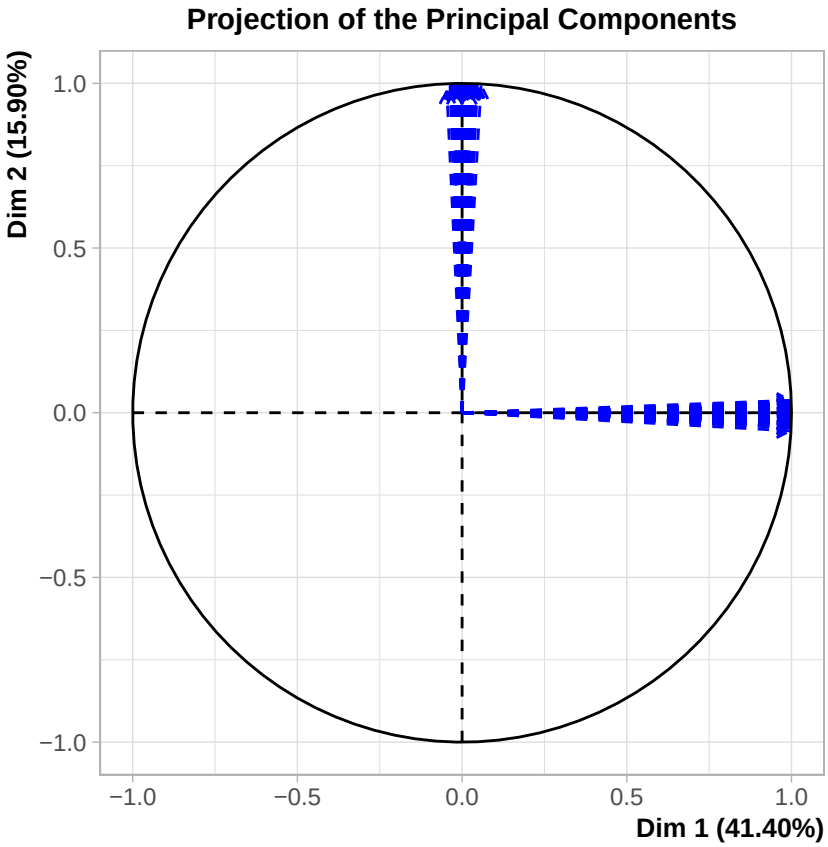

Suppleme
Dim 2 (15.90%)


Variable representation
Dim 2 (15.90%)
Dim 1 (41.40%)
IRGM1
SOCS1
MUC2
NCR1
TICAM1
PRF1
IL.10
IL.13
RETNLB
TNF
MYD88
IDO1
CASP1
MUC5AC
IL1RN
MPO
CASP1
CXCL9
CXCR3_bio
IDO1
IL.10
IL.13
IL.6
IL1RN
IRGM1
MPO
MUC2
MUC5AC
MYD88
NCR1
PRF1
RETNLB
SOCS1
TICAM1
TNF

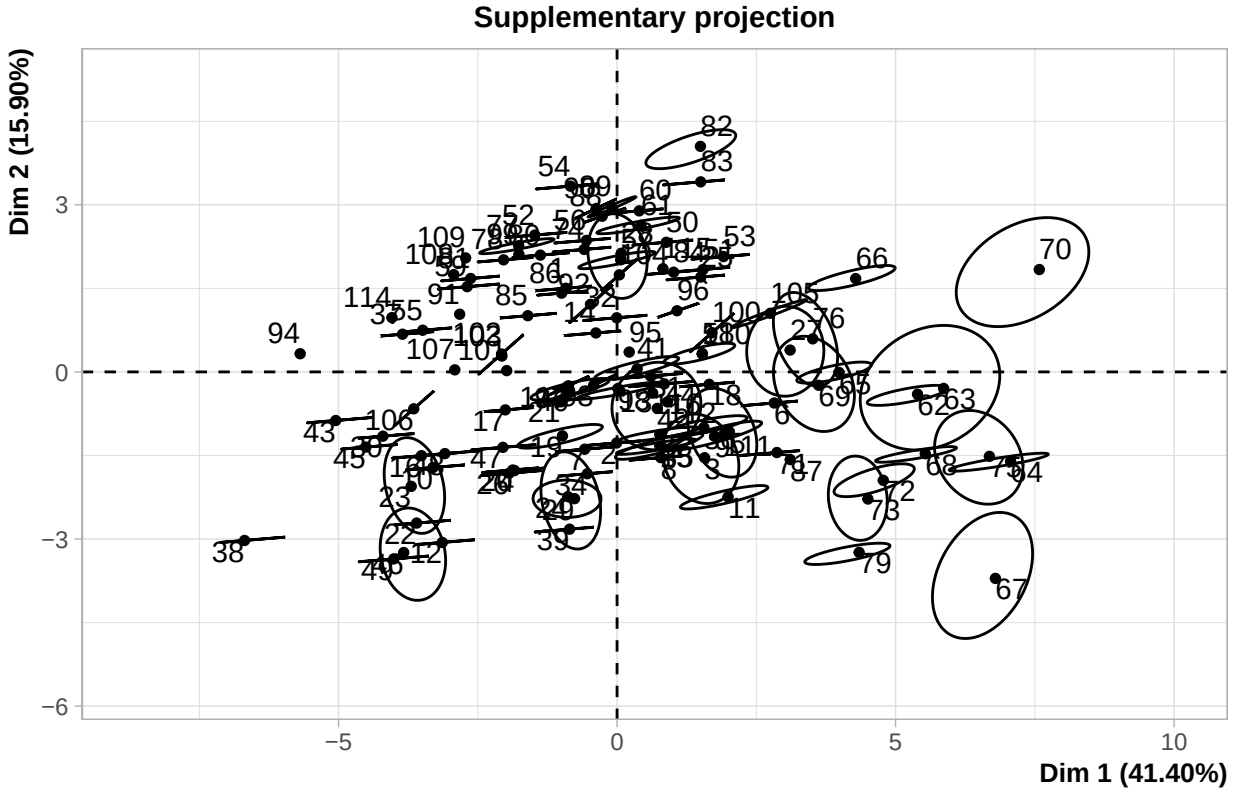
```
## $PlotIndProc
```



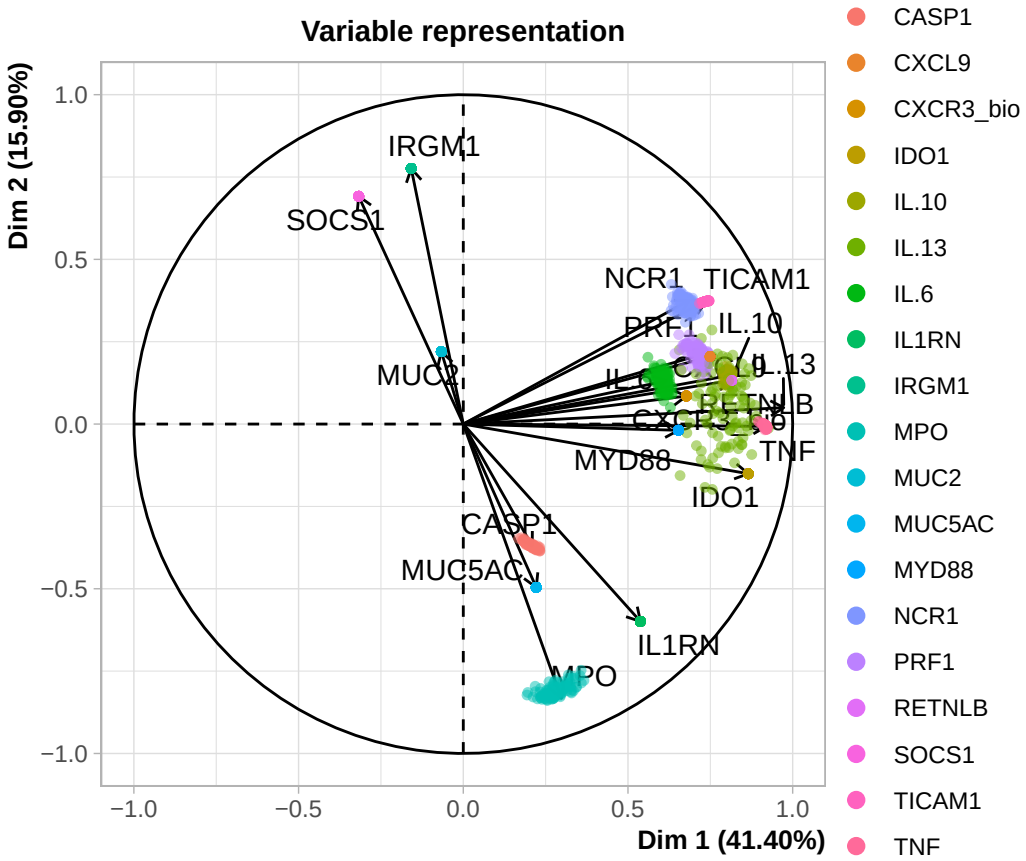

```
##
## $PlotDim
```




```
##
## $PlotIndSupp
```




```
##
## $PlotVar
```



Individuals lying on the axis have no missing data, but individuals that far away have many missing data. big ellipse = big uncertainty tight elipse (line) = low uncertainty

Variable representation: Poins tight together)look like one) - have no missing variables –> low uncertainty Points spread – > higher variability – > higher uncertainty

High uncertainty–> we should interpret the result with care

The individuals with many missing data values make the axes move, and thus the positions of all individuals

Therefore in the last plots every individual is getting an eclipse as they are as well influenced by the missing data of the others.

THe plot with the dimensions shows the projections of the pca dimensions of each imputed table on the pca plane obtained using the original imputed data table

As all of the arrows are close to either the first or second axes, this means that the axes are stable with respect to the set of imputed tables –> we don't have evidence of instability here.

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

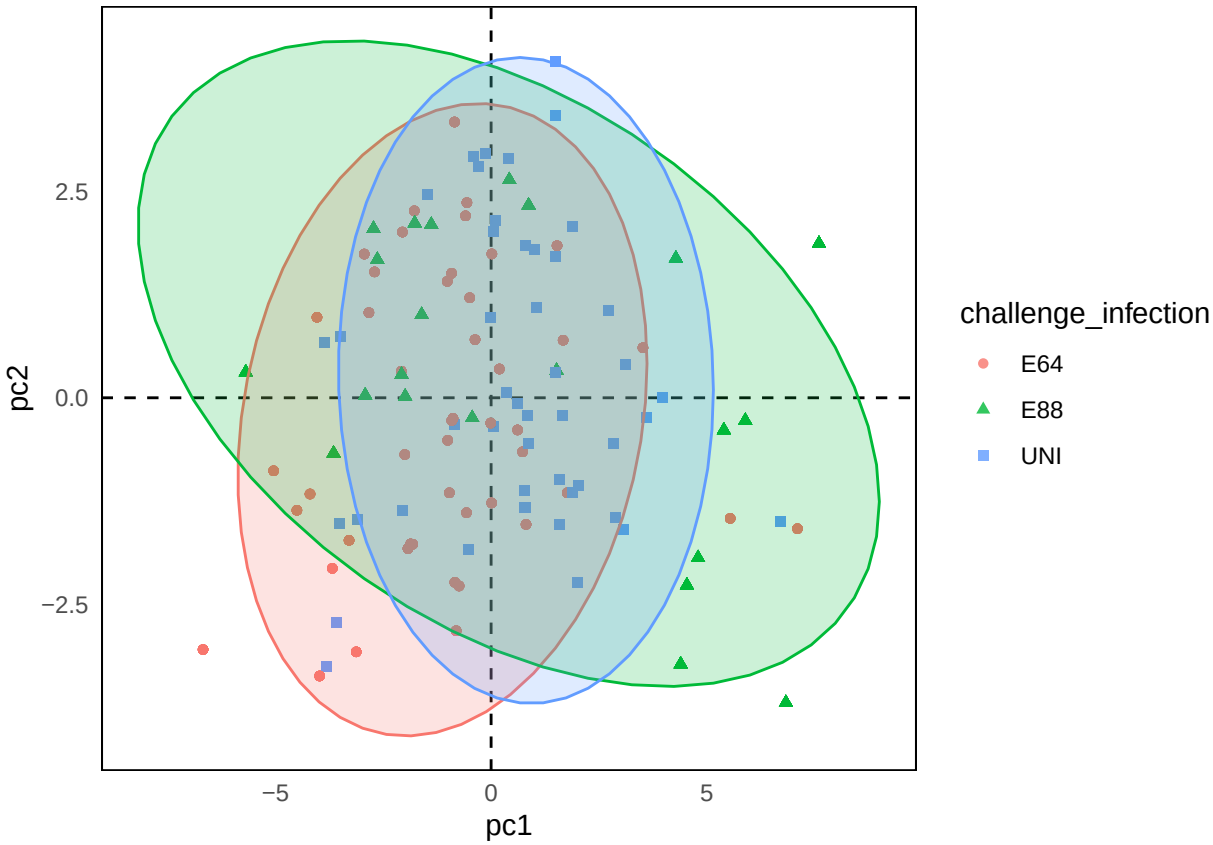
```
##
## Attaching package: 'MASS'
```

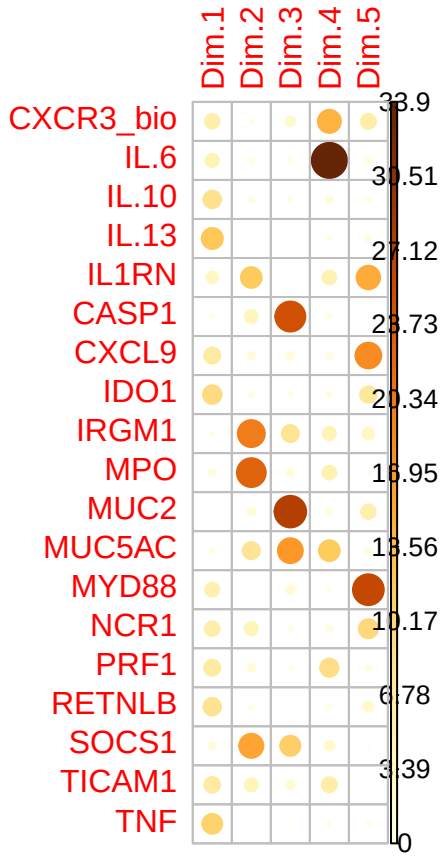
```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
##
## Attaching package: 'reshape2'
```

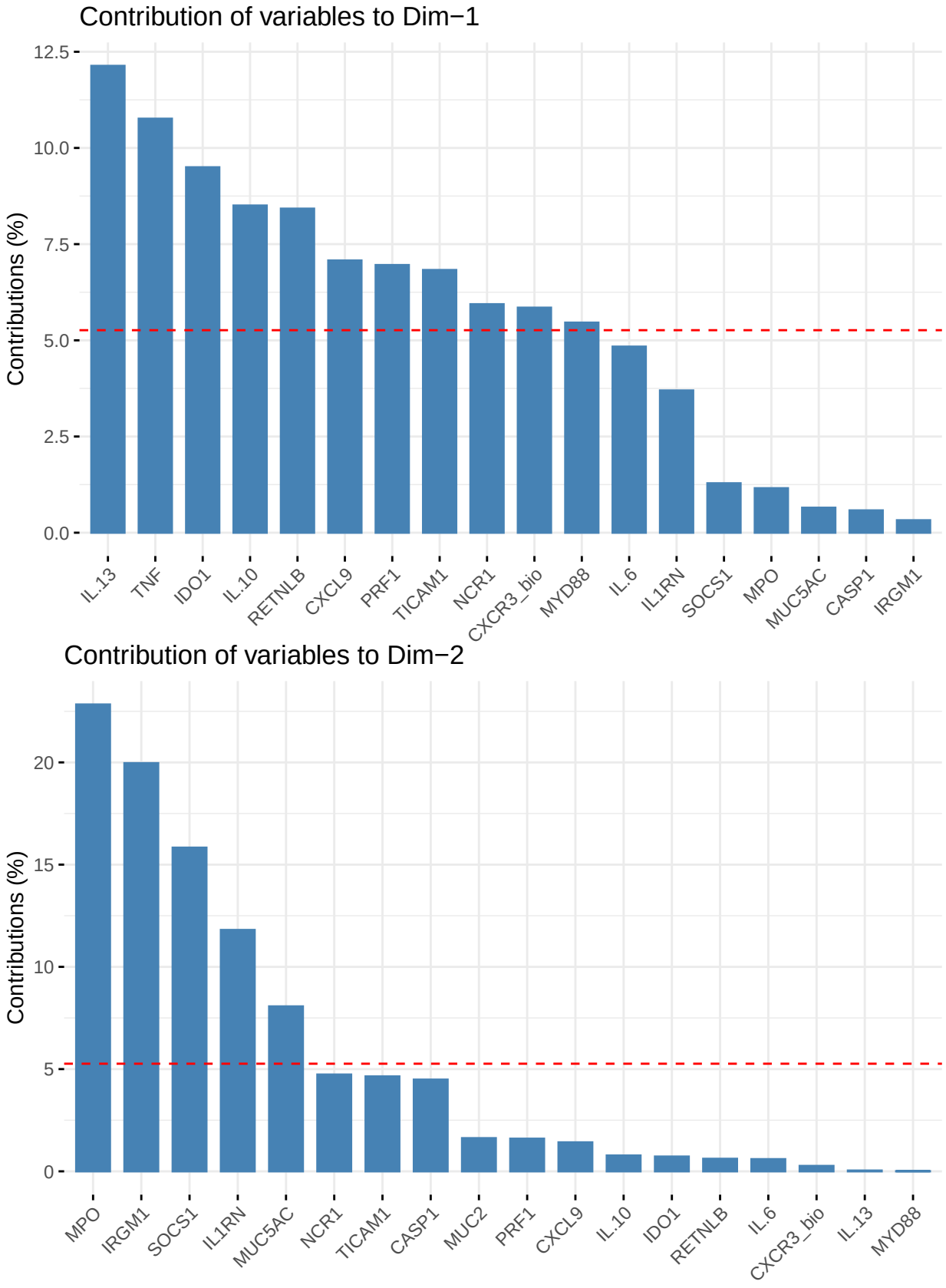
```
## The following object is masked from 'package:tidyr':
```

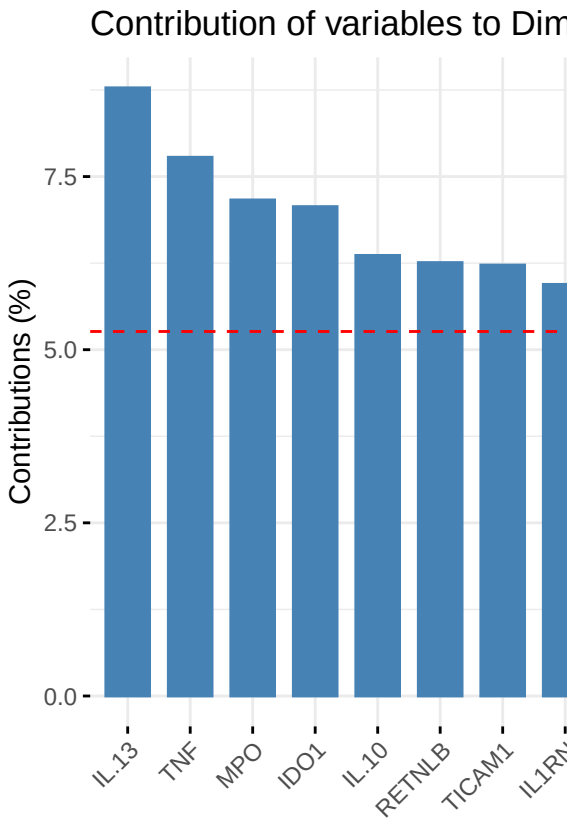
```
##
##      smiths
```





The function fviz_contrib() [factoextra package] can be used to draw a bar plot of variable contributions. If your data contains many variables, you can decide to show only the top contributing variables. The R code below shows the top 10 variables contributing to the principal components:

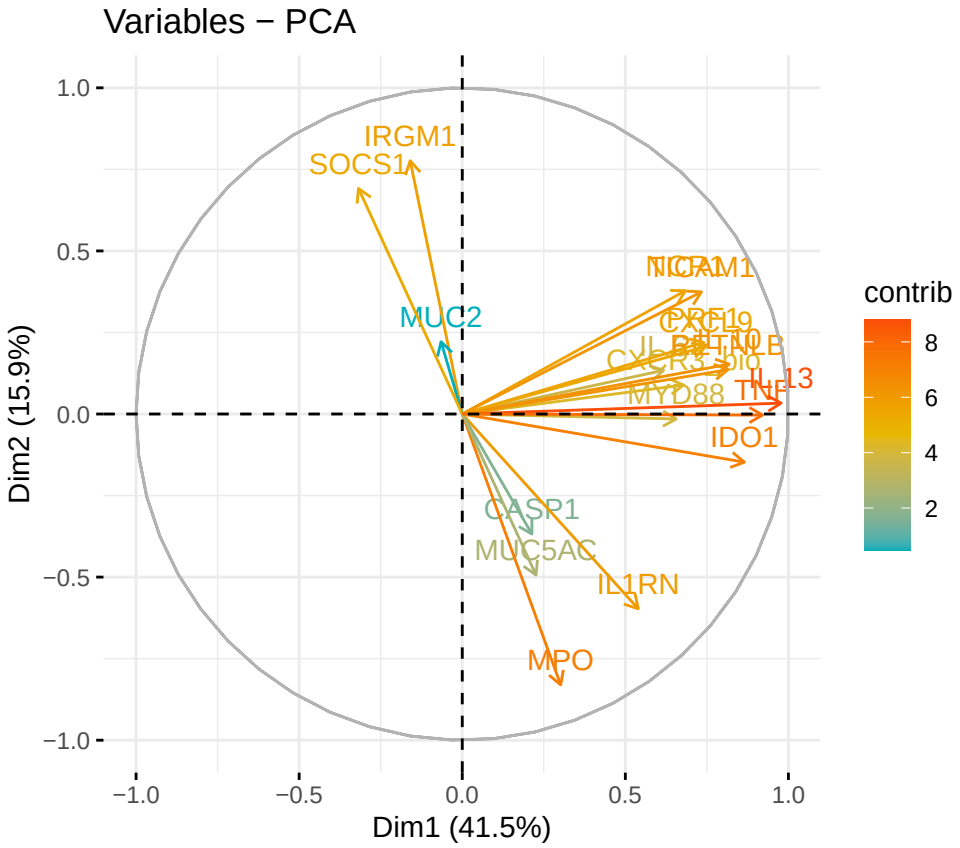

Contribution of variables to Dim−1
Contributions (%)
12.5
10.0
7.5
5.0
2.5
0.0
IL.13
TNF
IDO1
IL.10
RETNLB
CXCL9
PRF1
TICAM1
NCR1
CXCR3_bio
MYD88
IL.6
IL1RN
SOCS1
MPO
MUC5AC
CASP1
IRGM1
Contribution of variables to Dim−2
Contributions (%)
20
15
10
5
0
MPO
IRGM1
SOCS1
IL1RN
MUC5AC
NCR1
TICAM1
CASP1
MUC2
PRF1
CXCL9
IL.10
IDO1
RETNLB
IL.6
CXCR3_bio
IL.13
MYD88



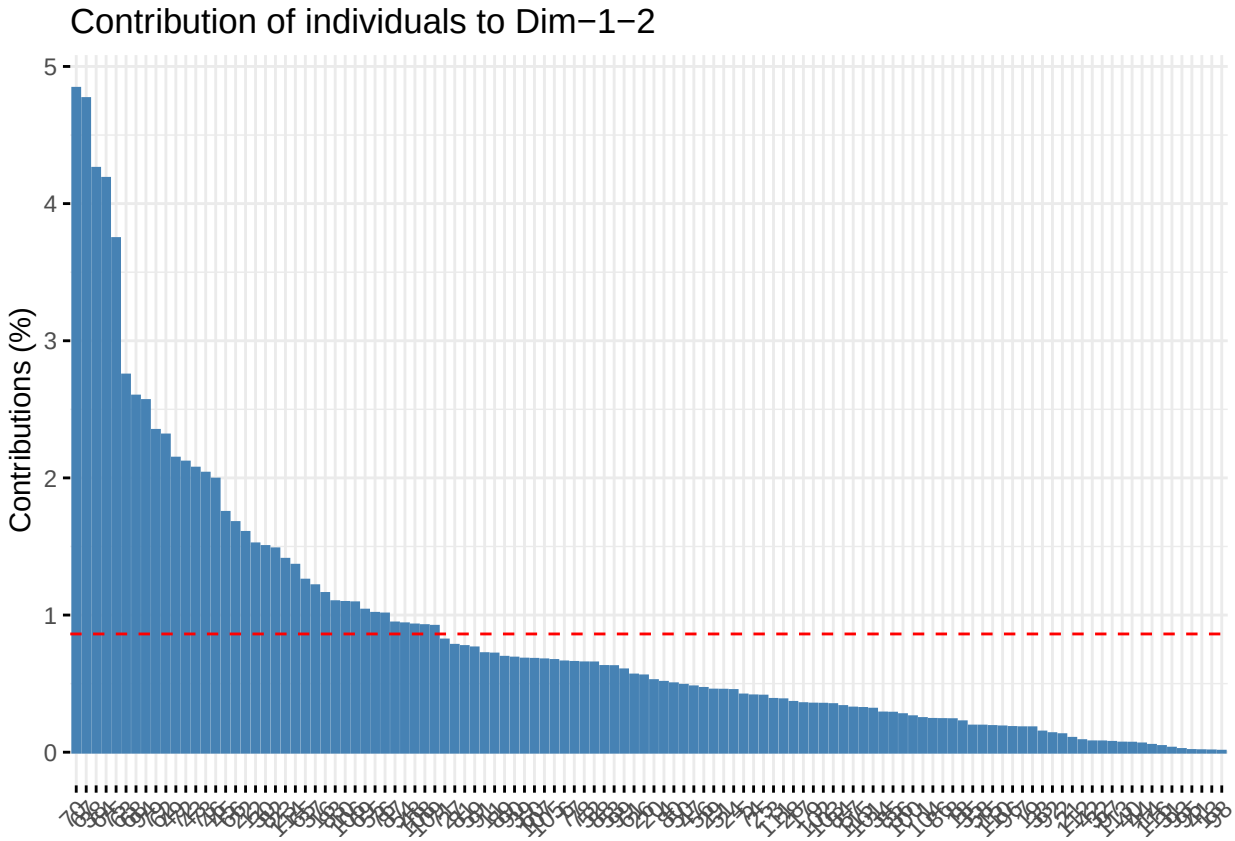
The total contribution to PC1 and PC2 is obtained with the following R code:
The red dashed line on the graph above indicates the expected average contribution. If the contribution of the variables were uniform, the expected value would be 1/length(variables) = 1/10 = 10%. For a given component, a variable with a contribution larger than this cutoff could be considered as important in contributing to the component.

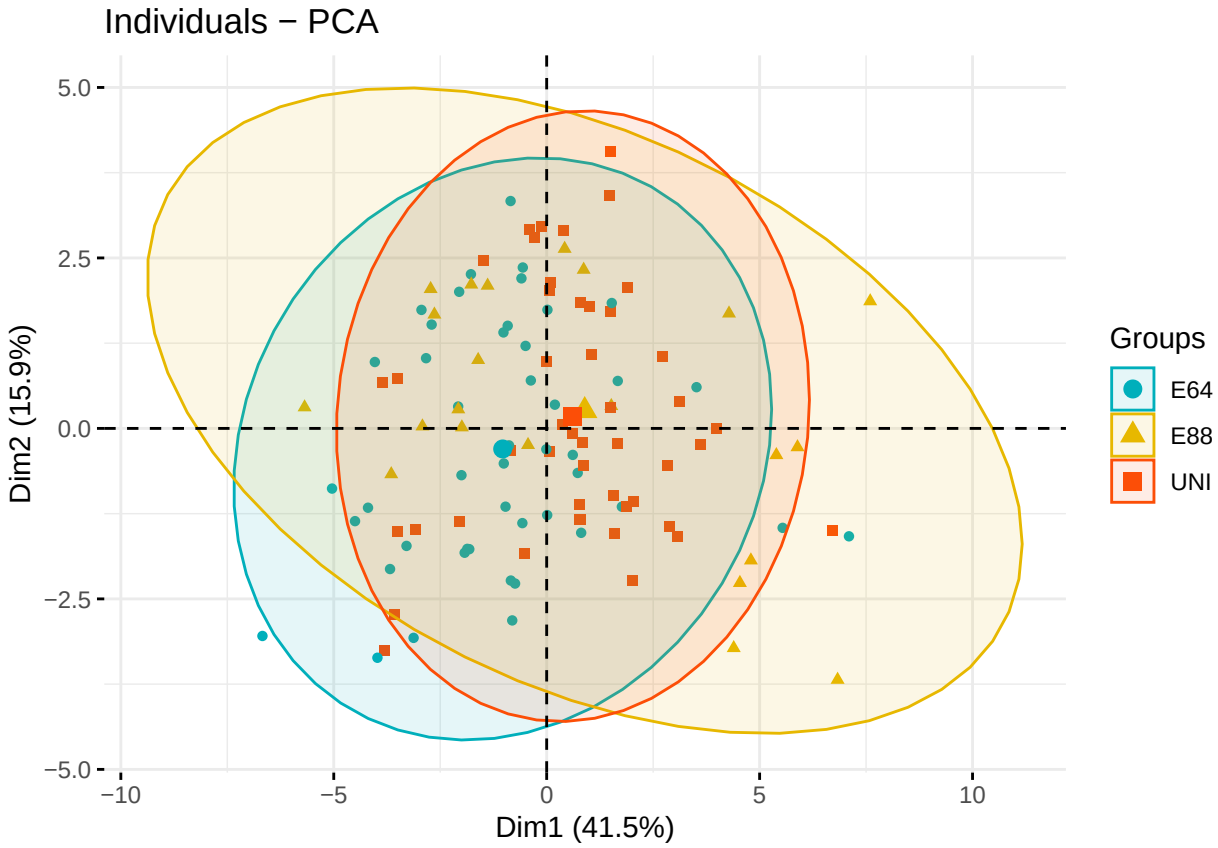
Note that, the total contribution of a given variable, on explaining the variations retained by two principal components, say PC1 and PC2, is calculated as contrib = [(C1 * Eig1) + (C2 * Eig2)]/(Eig1 + Eig2), where

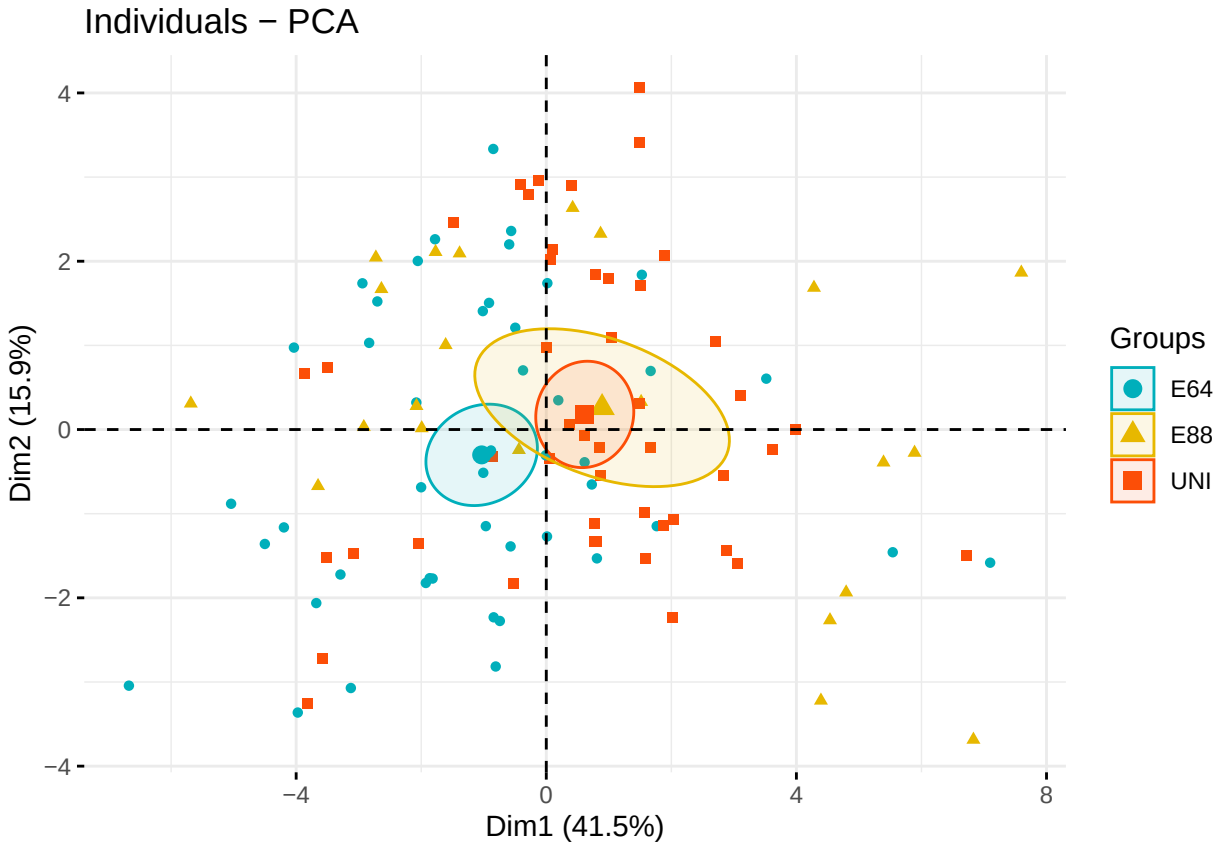
C1 and C2 are the contributions of the variable on PC1 and PC2, respectively Eig1 and Eig2 are the eigenvalues of PC1 and PC2, respectively. Recall that eigenvalues measure the amount of variation retained by each PC. In this case, the expected average contribution (cutoff) is calculated as follow: As mentioned above, if the contributions of the 10 variables were uniform, the expected average contribution on a given PC would be 1/10 = 10%. The expected average contribution of a variable for PC1 and PC2 is : [(10* Eig1) + (10 * Eig2)]/(Eig1 + Eig2)

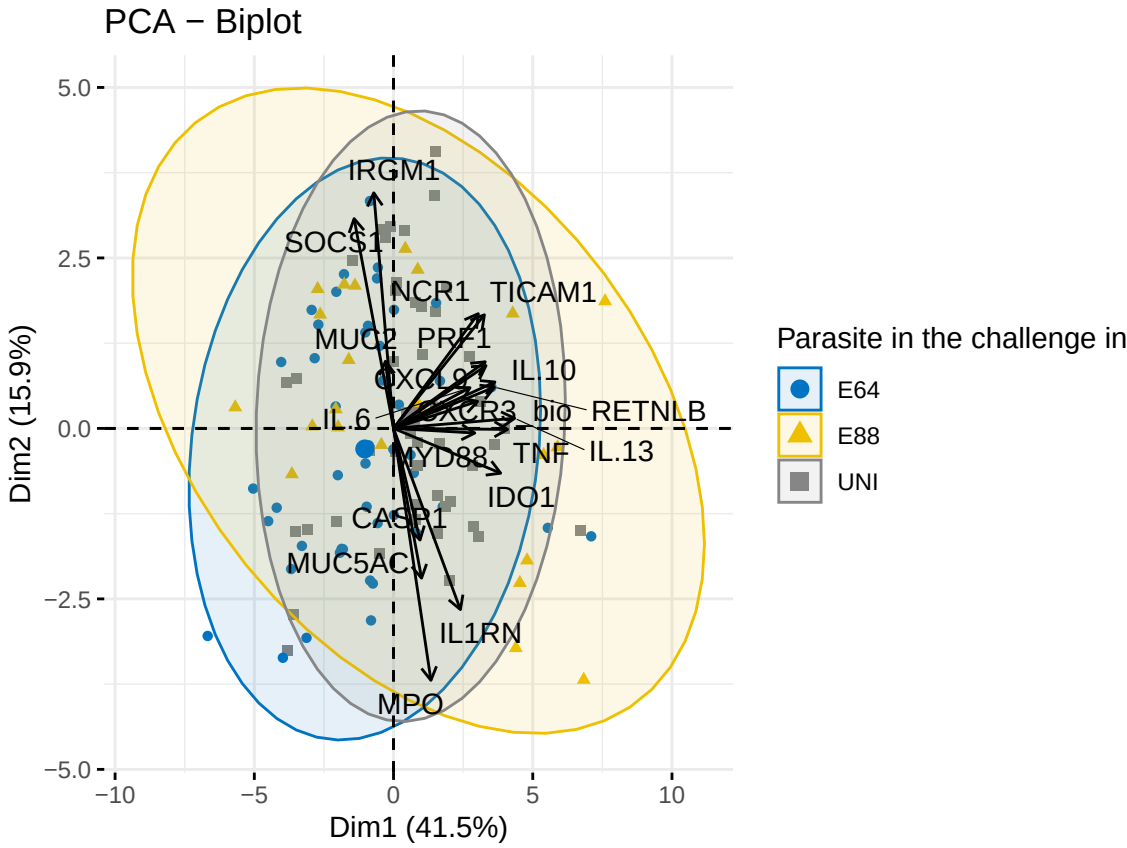


To visualize the contribution of individuals to the first two principal components, type this:




Individuals − PCA
5.0
2.5
0.0
−2.5
−5.0
−10
−5
0
5
10
Dim2 (15.9%)
Dim1 (41.5%)
Groups
E64
E88
UNI

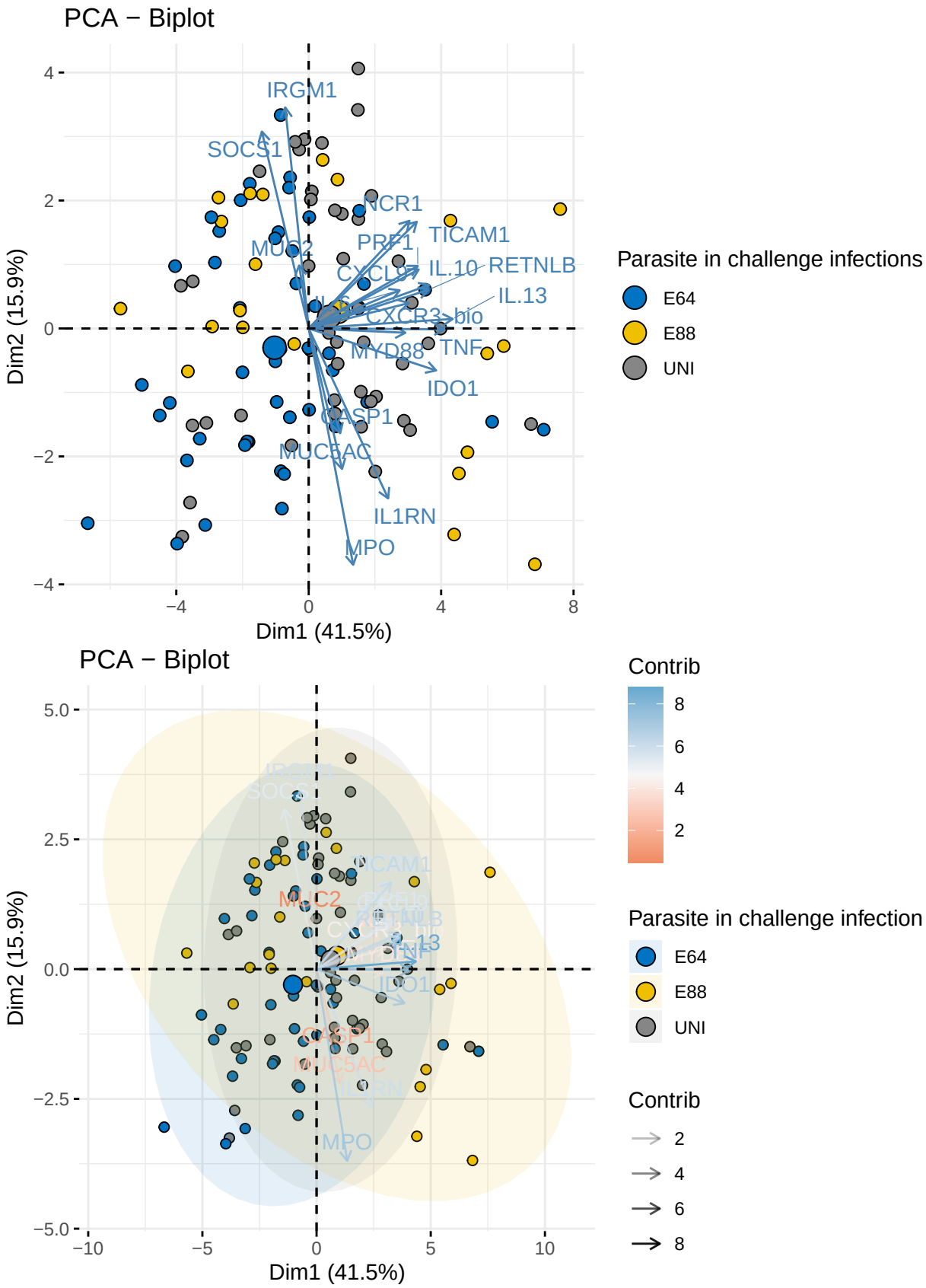

Individuals − PCA
4
2
0
−2
−4
−4
0
4
8
Dim2 (15.9%)
Dim1 (41.5%)
Groups
E64
E88
UNI



PCA + Biplot combination

In the following example, we want to color both individuals and variables by groups. The trick is to use pointshape = 21 for individual points. This particular point shape can be filled by a color using the argument fill.ind. The border line color of individual points is set to "black" using col.ind. To color variable by groups, the argument col.var will be used.

To customize individuals and variable colors, we use the helper functions fill_palette() and color_palette() [in ggpubr package].


PCA − Biplot
IRGM1
SOCS1
NCR1
PRF1
TICAM1
MUC2
CXCL9
IL.10
RETNLB
IL.13
CXCR3
bio
MYD88
TNF
IDO1
CASP1
MUC5AC
IL1RN
MPO
Dim2 (15.9%)
Dim1 (41.5%)
Parasite in challenge infections
E64
E88
UNI
PCA − Biplot
Contrib
8
6
4
2
Parasite in challenge infection
E64
E88
UNI
Contrib
2
4
6
8
Dim2 (15.9%)
Dim1 (41.5%)

```
##
## Call:
## lm(formula = max_WL ~ pc1 + pc2 + challenge_infection, data = g)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -14.4027  -3.0794   0.1195   3.5224  14.2423
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)              91.7467     0.7956 115.324  < 2e-16 ***
## pc1                       0.1173     0.1829   0.641 0.522840
## pc2                      -0.7231     0.2842  -2.544 0.012337 *
## challenge_infectionE88   -6.1131     1.4142  -4.323 3.38e-05 ***
## challenge_infectionUNI    4.4111     1.1359   3.883 0.000175 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.258 on 111 degrees of freedom
## Multiple R-squared:  0.3805, Adjusted R-squared:  0.3582
## F-statistic: 17.04 on 4 and 111 DF,  p-value: 6.364e-11
```

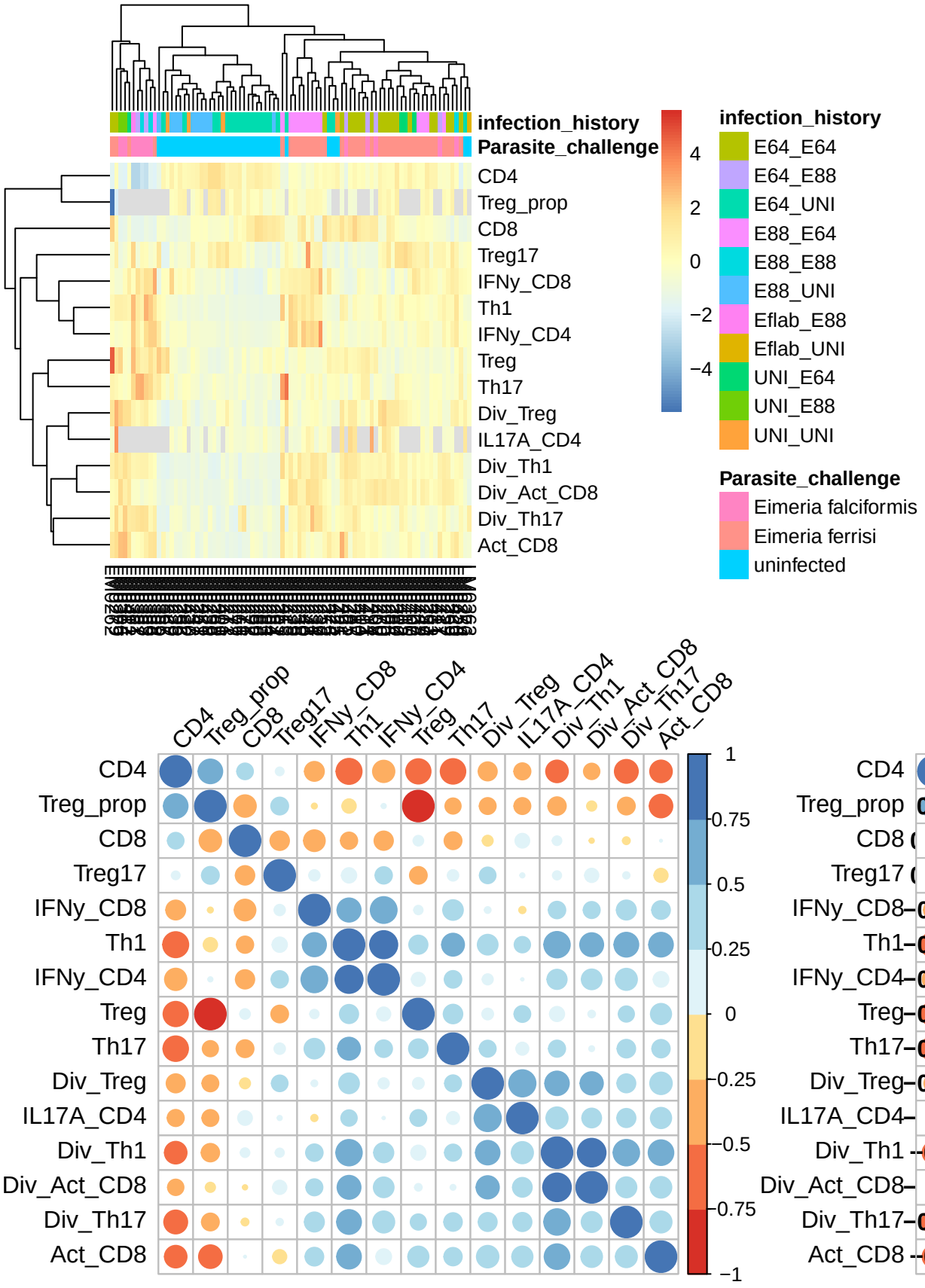
```
## [1] 721.1667
```

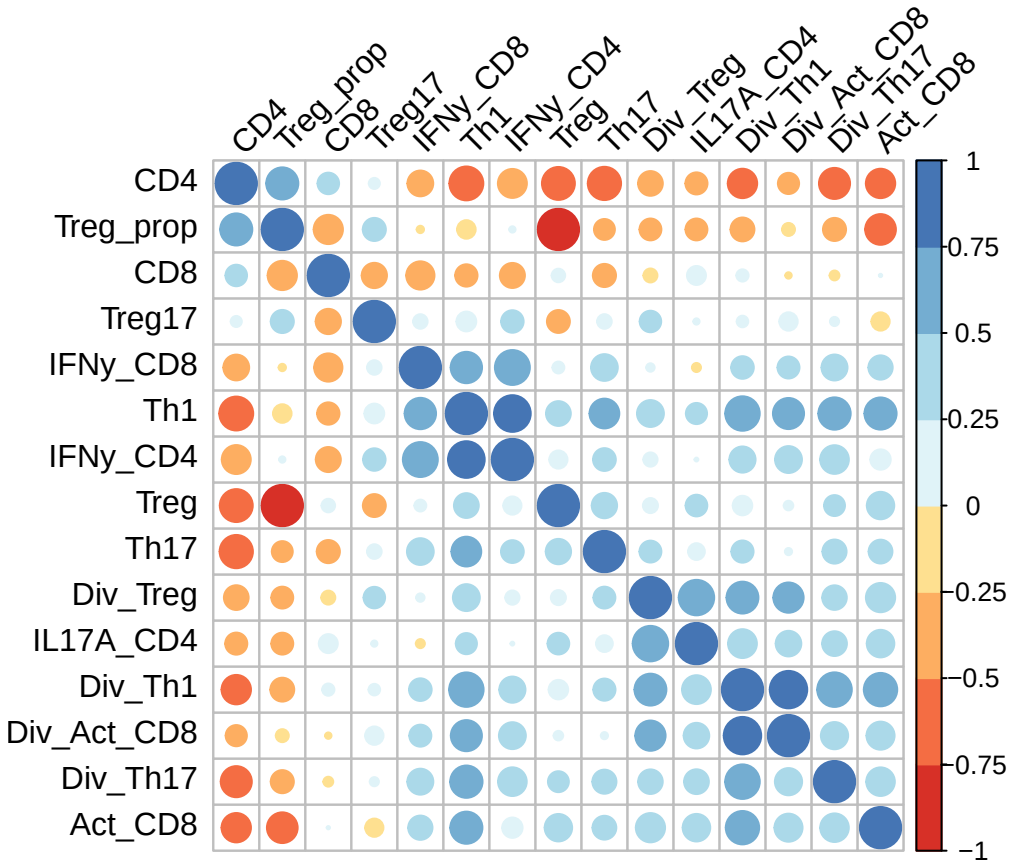
```
##
## Call:
## lm(formula = max_WL ~ pc1 + pc2, data = g)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -17.122  -3.155   1.295   4.938  10.348
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  92.3746     0.6026 153.288   <2e-16 ***
## pc1           0.1256     0.2147   0.585   0.5599
## pc2          -0.7165     0.3468  -2.066   0.0411 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.49 on 113 degrees of freedom
## Multiple R-squared:  0.0392, Adjusted R-squared:  0.0222
## F-statistic: 2.305 on 2 and 113 DF,  p-value: 0.1044
```

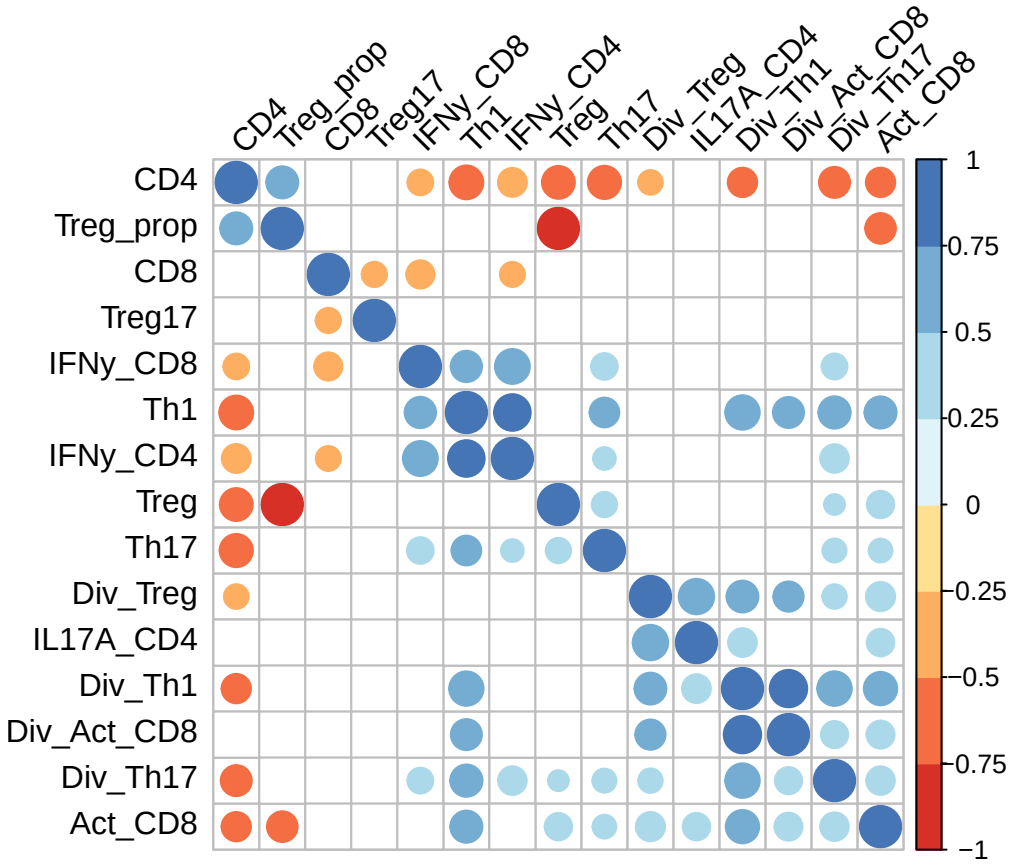
```
##                    df      AIC
## weight_lm           6 721.1667
## weight_lm_exp_only  4 768.0702
```

FACS

```
## Note: Using an external vector in selections is ambiguous.
## i Use `all_of(CellCount.cols)` instead of `CellCount.cols` to silence this message.
## i See <https://tidyselect.r-lib.org/reference/faq-external-vector.html>.
## This message is displayed once per session.
```

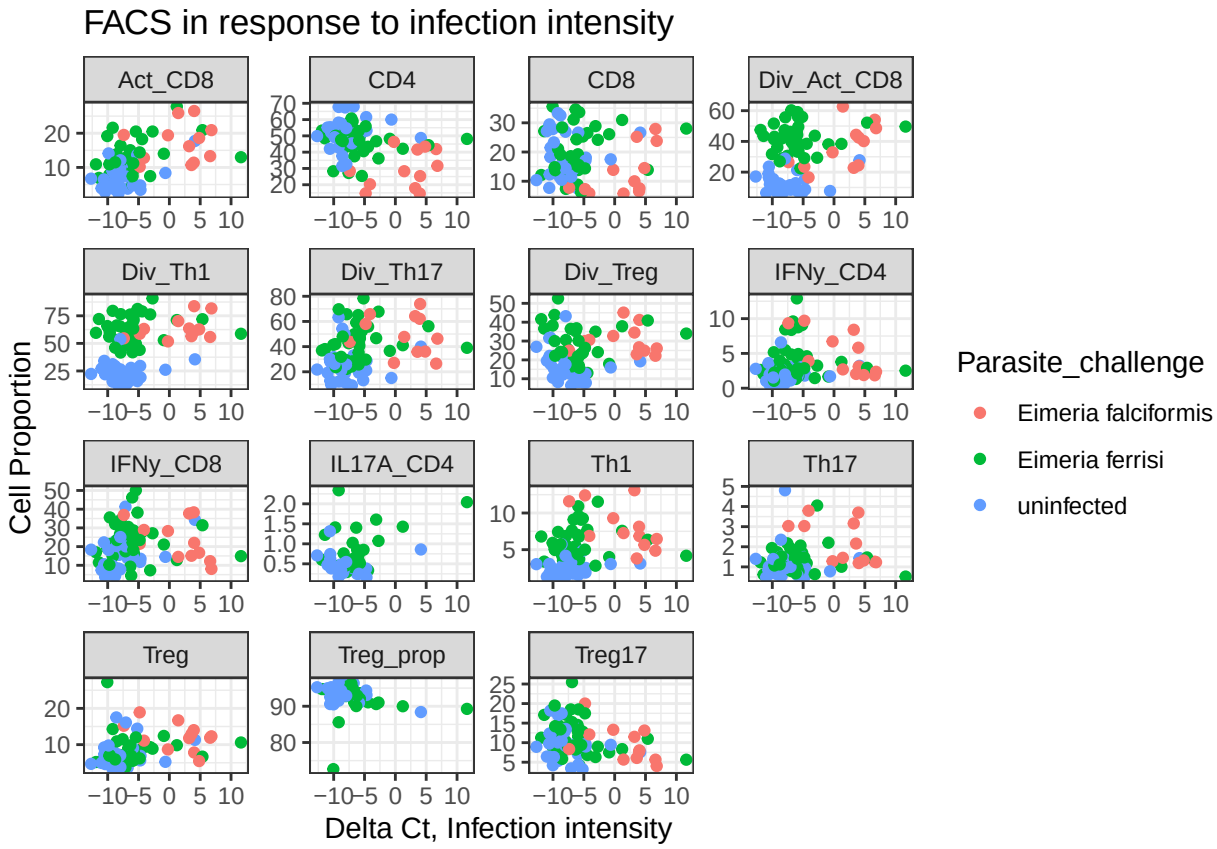

infection_history
Parasite_challenge
CD4
Treg_prop
CD8
Treg17
IFNy_CD8
Th1
IFNy_CD4
Treg
Th17
Div_Treg
IL17A_CD4
Div_Th1
Div_Act_CD8
Div_Th17
Act_CD8
4
2
0
−2
−4
infection_history
E64_E64
E64_E88
E64_UNI
E88_E64
E88_E88
E88_UNI
Eflab_E88
Eflab_UNI
UNI_E64
UNI_E88
UNI_UNI
Parasite_challenge
Eimeria falciformis
Eimeria ferrisi
uninfected
1
0.75
0.5
0.25
0
−0.25
−0.5
−0.75
−1

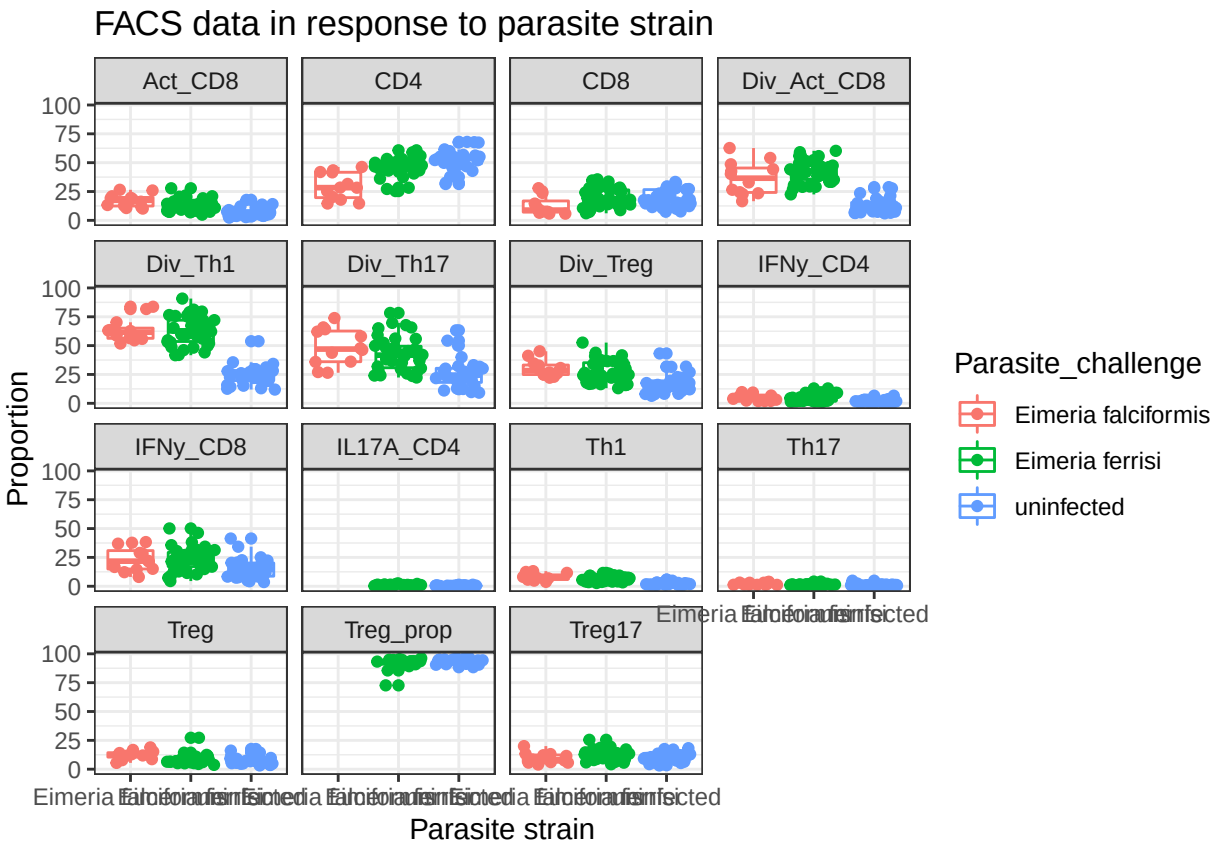

CD4
Treg_prop
CD8
Treg17
IFNy_CD8
Th1
IFNy_CD4
Treg
Th17
Div_Treg
IL17A_CD4
Div_Th1
Div_Act_CD8
Div_Th17
Act_CD8
1
0.75
0.5
0.25
0
−0.25
−0.5
−0.75
−1


CD4
Treg_prop
CD8
Treg17
IFNy_CD8
Th1
IFNy_CD4
Treg
Th17
Div_Treg
IL17A_CD4
Div_Th1
Div_Act_CD8
Div_Th17
Act_CD8
1
0.75
0.5
0.25
0
−0.25
−0.5
−0.75
−1

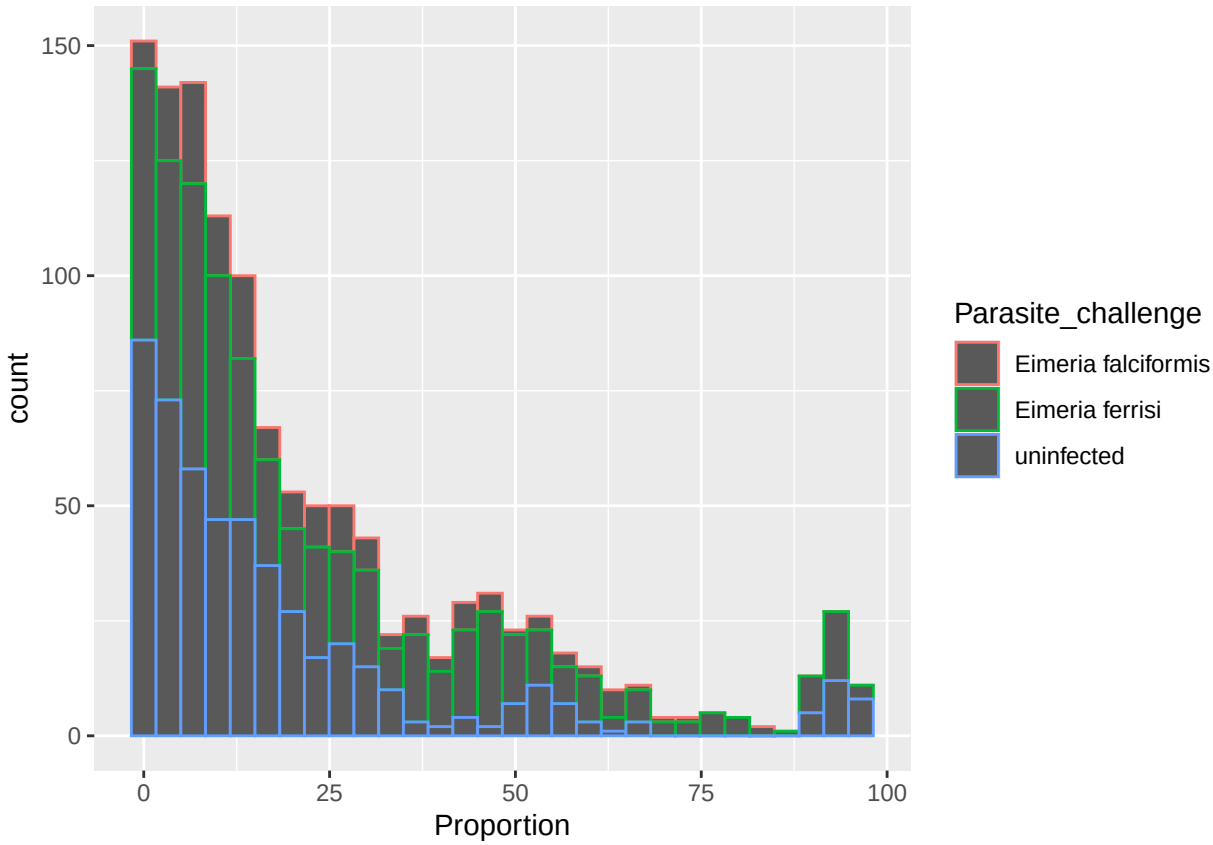
PCA FACS

```
## Adding missing grouping variables: `infection`
```

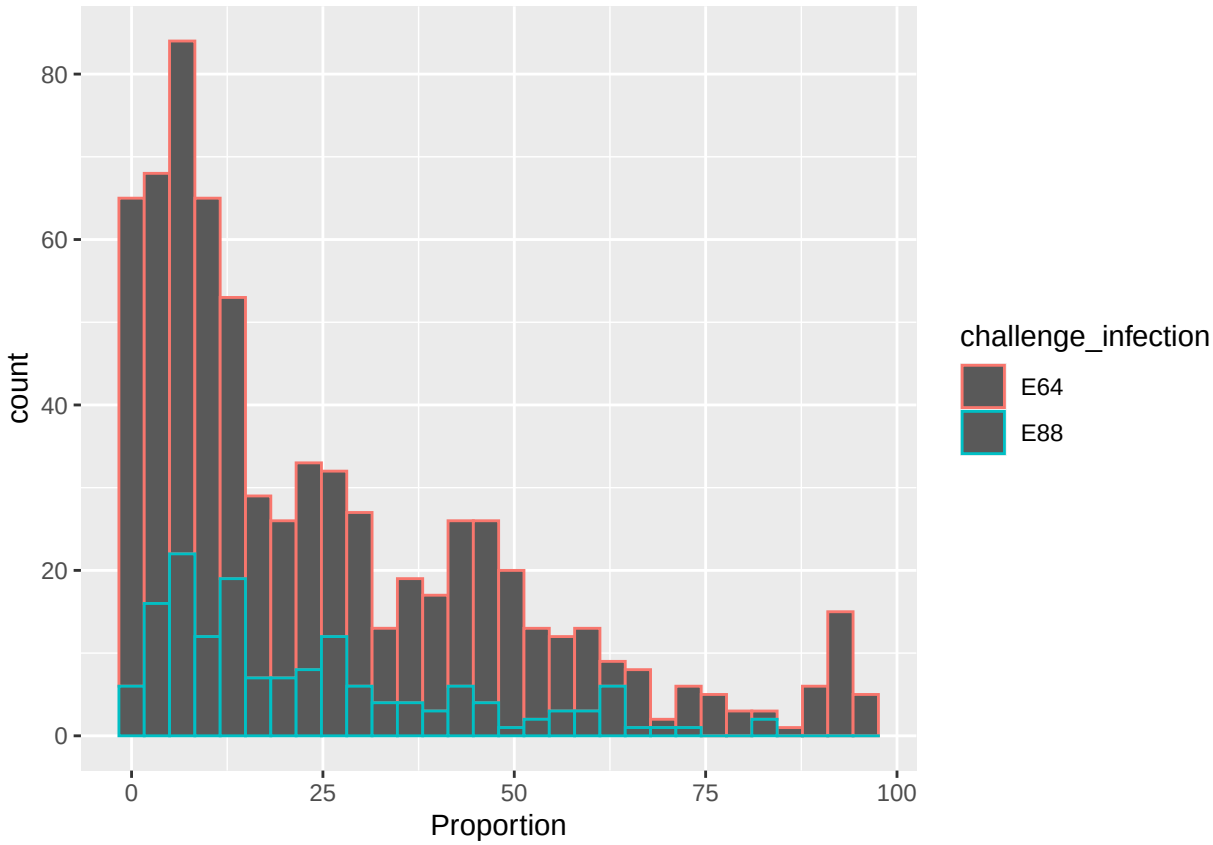





```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
## Warning: Removed 66 rows containing non-finite values (stat_bin).
```




```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
## Warning: Removed 46 rows containing non-finite values (stat_bin).
```




```
##     EH_ID           primary_infection  challenge_infection infection_history
##  Length:85          Length:85          Length:85           Length:85
##  Class :character   Class :character   Class :character    Class :character
##  Mode  :character   Mode  :character   Mode  :character    Mode  :character
##
##
##
##
##  mouse_strain       hybrid_status      Parasite_primary   Parasite_challenge
##  Length:85          Length:85          Length:85          Length:85
##  Class :character   Class :character   Class :character   Class :character
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character
##
##
##
##
##      max_WL          max_OOC          Position             CD4
##  Min.   : 73.45   Min.   :      0   Length:85          Min.   :14.60
##  1st Qu.: 89.78   1st Qu.:      0   Class :character   1st Qu.:42.86
##  Median : 94.58   Median :  72500   Mode  :character   Median :48.49
##  Mean   : 92.96   Mean   : 260500                      Mean   :46.52
##  3rd Qu.: 97.72   3rd Qu.: 317500                      3rd Qu.:53.40
##  Max.   :100.00   Max.   :1447500                      Max.   :68.01
##
##       Treg           Div_Treg         Treg17            Th1
##  Min.   : 3.245   Min.   : 6.48   Min.   : 3.230   Min.   : 1.235
##  1st Qu.: 5.650   1st Qu.:16.00   1st Qu.: 7.520   1st Qu.: 2.505
```

```
##  Median : 7.005   Median :22.15   Median : 9.505   Median : 4.380
##  Mean   : 8.382   Mean   :23.41   Mean   :10.646   Mean   : 4.822
##  3rd Qu.: 9.840   3rd Qu.:30.20   3rd Qu.:13.400   3rd Qu.: 6.795
##  Max.   :27.230   Max.   :52.62   Max.   :25.480   Max.   :13.100
##
##     Div_Th1           Th17          Div_Th17          CD8
##  Min.   :11.91   Min.   :0.485   Min.   : 9.20   Min.   : 5.79
##  1st Qu.:27.50   1st Qu.:0.925   1st Qu.:24.22   1st Qu.:12.14
##  Median :51.87   Median :1.185   Median :33.08   Median :16.40
##  Mean   :47.54   Mean   :1.390   Mean   :36.65   Mean   :18.24
##  3rd Qu.:63.50   3rd Qu.:1.520   3rd Qu.:46.88   3rd Qu.:25.30
##  Max.   :90.78   Max.   :4.810   Max.   :78.31   Max.   :35.58
##
##     Act_CD8        Div_Act_CD8       IFNy_CD4         IFNy_CD8
##  Min.   : 2.365   Min.   : 6.07   Min.   : 0.340   Min.   : 3.605
##  1st Qu.: 6.720   1st Qu.:12.07   1st Qu.: 1.670   1st Qu.:13.490
##  Median :10.700   Median :29.02   Median : 2.580   Median :19.390
##  Mean   :10.927   Mean   :29.06   Mean   : 3.358   Mean   :20.395
##  3rd Qu.:13.700   3rd Qu.:43.53   3rd Qu.: 3.910   3rd Qu.:26.830
##  Max.   :27.805   Max.   :62.70   Max.   :12.910   Max.   :50.100
##
##    Treg_prop       IL17A_CD4          delta
##  Min.   :72.66   Min.   :0.1650   Min.   :-12.690
##  1st Qu.:91.25   1st Qu.:0.3850   1st Qu.: -8.791
##  Median :93.28   Median :0.5075   Median : -6.840
##  Mean   :92.62   Mean   :0.6732   Mean   : -5.561
##  3rd Qu.:94.68   3rd Qu.:0.7825   3rd Qu.: -4.750
##  Max.   :96.64   Max.   :2.3400   Max.   : 11.610
##  NA's   :33      NA's   :33       NA's   :3
## Warning in par(usr): argument 1 does not name a graphical parameter

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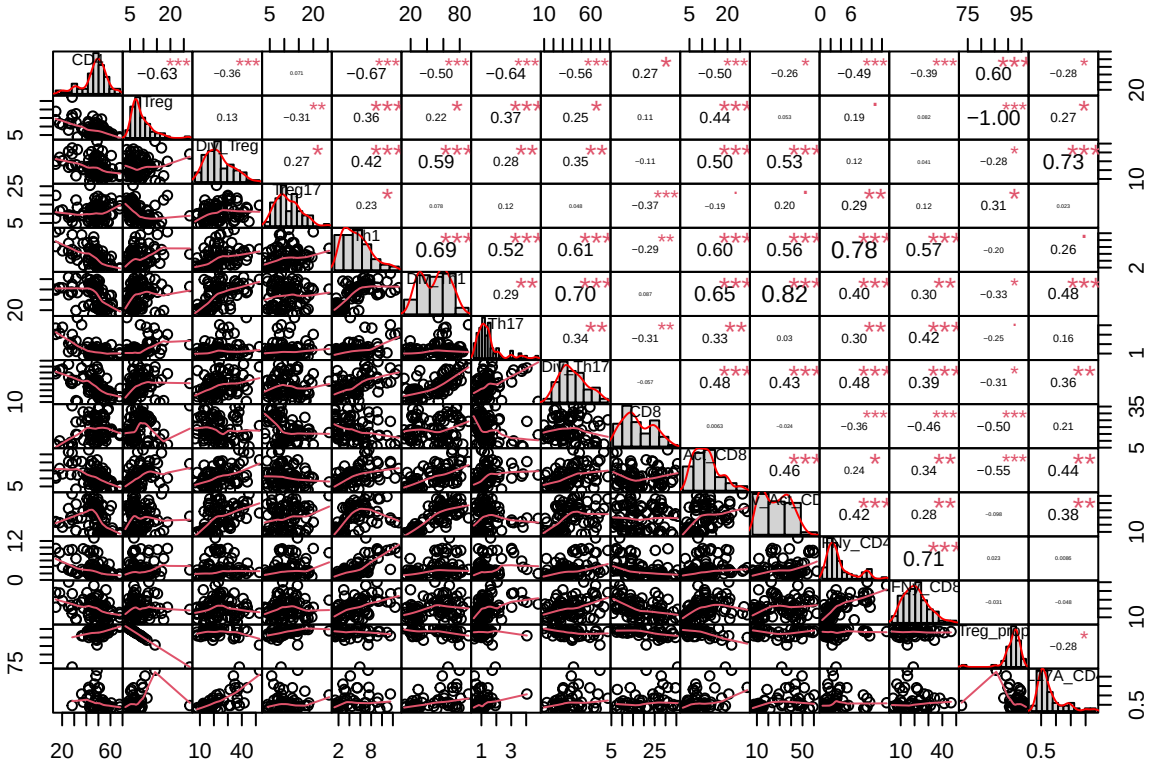
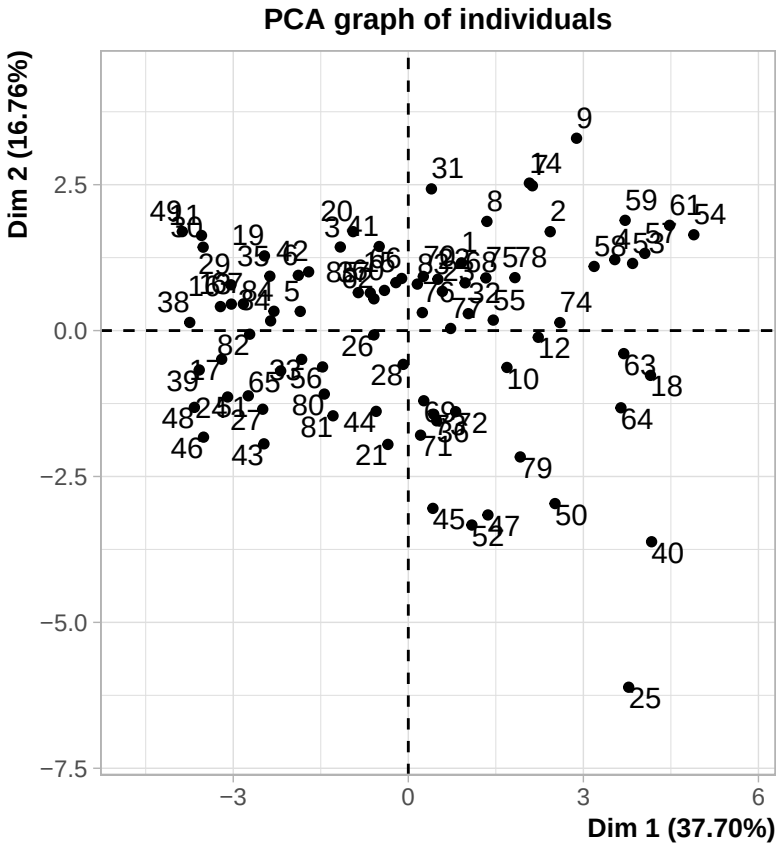
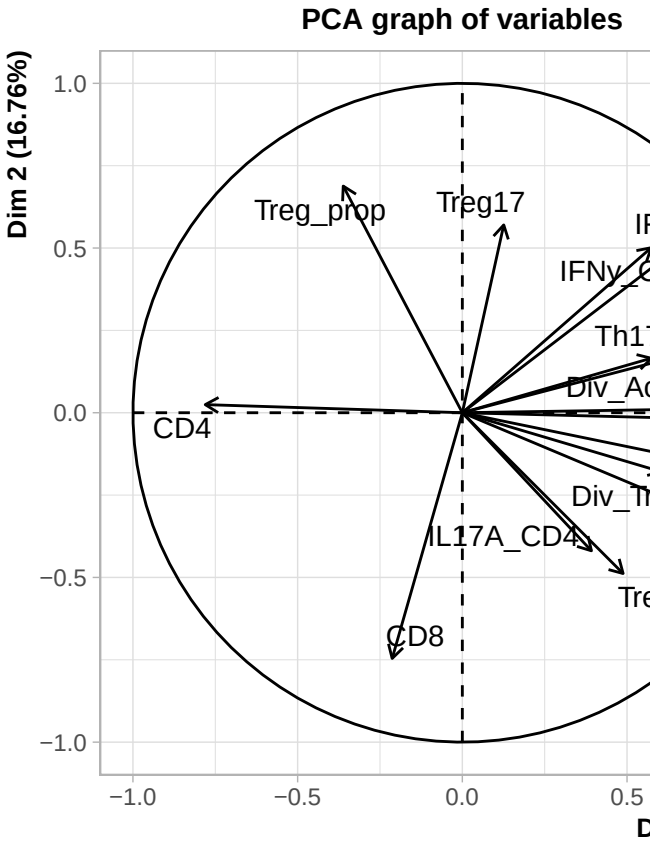
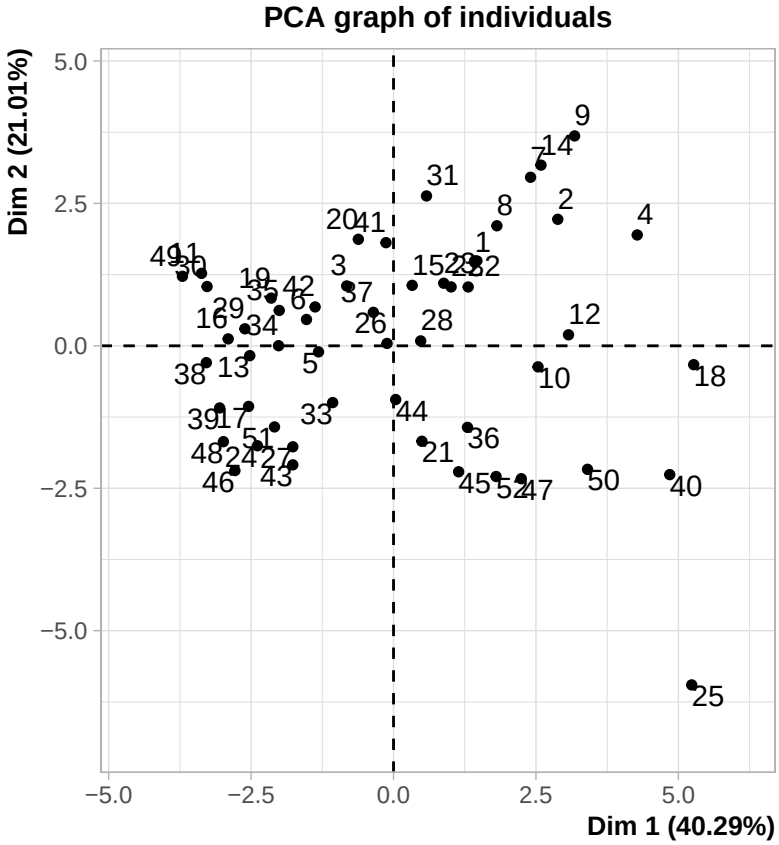
```

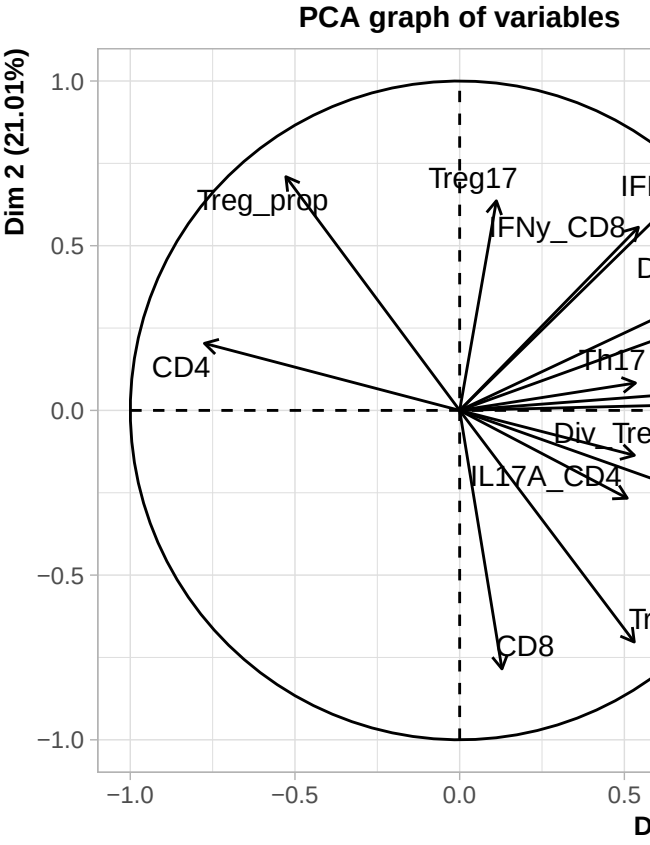



```
## Warning in PCA(f[12:26]): Missing values are imputed by the mean of the
## variable: you should use the imputePCA function of the missMDA package
```


PCA graph of individuals
Dim 2 (16.76%)
Dim 1 (37.70%)


PCA graph of variables
Dim 2 (16.76%)
Treg_prop
Treg17
CD4
CD8
IL17A_CD4

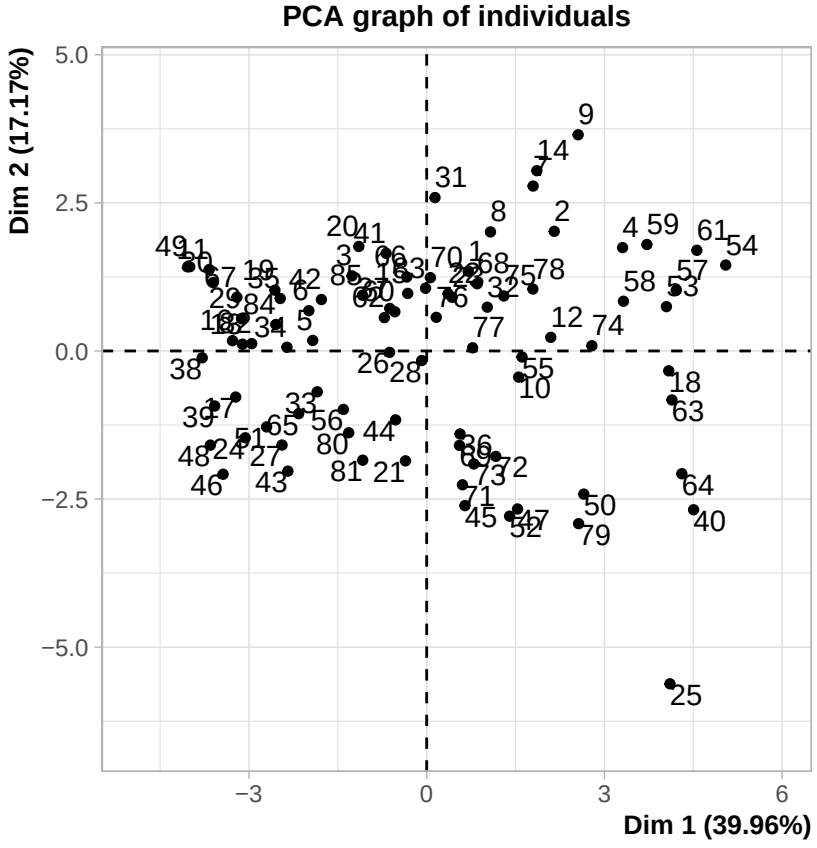

PCA graph of individuals
Dim 2 (21.01%)
Dim 1 (40.29%)

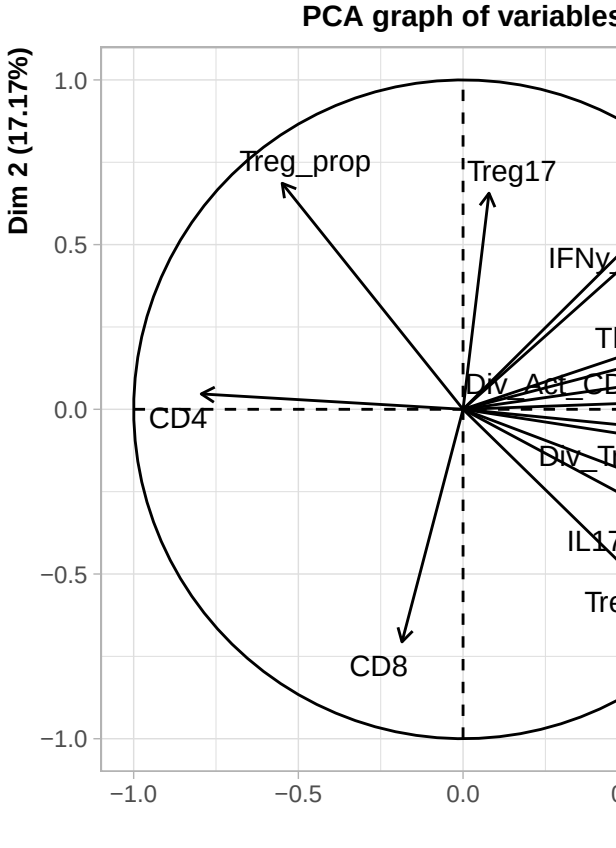

PCA graph of variables
Dim 2 (21.01%)
Treg_prop
Treg17
IFNy_CD8
CD4
CD8
IL17A_CD4

We will now continue by using an iterative pca to impute missing data A. Initialization: impute using the mean B. Step lampda: # a. do pca on imputed data table S dimensions retained # b. missing data imputed using pca # c. means (and standard deviations) updated C. Iterate the estimation and imputation steps (until convergence) (convergence: the act of converging and especially moving toward union or uniformity)

Overfitting is a common problem due to believing too much in links between variables. –> regularized iterative PCA (This version is what is being implented in missMDA) This is a way of taking less risk when imputing the missing data. The algorithm estimates the missing data values with values that have no influence on the PCA results, i.e., no influence on the coordinates of the individuals or variables.

```
##      CD4  Treg Div_Treg Treg17    Th1 Div_Th1  Th17 Div_Th17    CD8 Act_CD8
## 1 44.900 6.385   16.205 13.520  6.780  71.200 0.890   46.875 14.390  11.500
## 2 46.145 7.005   21.365 11.565 10.920  75.115 1.075   42.390 13.840  13.205
## 3 56.220 7.150   12.455  9.505  2.965  19.840 1.630   30.055 10.020  10.915
## 4 40.590 6.450   23.760 12.780  9.250  81.210 1.705   78.305 25.305  11.105
## 5 52.245 8.695   13.465 14.400  2.545  27.850 1.060   27.445 17.550   9.815
## 6 46.895 6.890   13.355  7.035  2.900  25.520 0.695   32.195  7.490   5.395
##   Div_Act_CD8 IFNy_CD4 IFNy_CD8 Treg_prop IL17A_CD4
## 1      49.520    4.915   21.740    93.605     0.415
## 2      59.090    9.085   27.535    92.970     0.385
## 3      11.535    3.045   41.360    92.845     0.575
## 4      55.935    9.085   38.165    93.505     0.850
## 5      12.830    2.005   19.390    91.305     0.250
## 6      21.310    2.795   19.230    93.110     0.270
```






```
##
## Call:
## PCA(X = comp$completeObs)
```

```
##
##
## Eigenvalues
##                        Dim.1   Dim.2   Dim.3   Dim.4   Dim.5   Dim.6   Dim.7
## Variance               5.994   2.576   1.814   1.160   0.702   0.605   0.501
## % of var.             39.958  17.172  12.094   7.734   4.677   4.033   3.343
## Cumulative % of var.  39.958  57.130  69.224  76.958  81.635  85.668  89.011
##                        Dim.8   Dim.9  Dim.10  Dim.11  Dim.12  Dim.13  Dim.14
## Variance               0.411   0.392   0.312   0.210   0.142   0.076   0.055
## % of var.              2.739   2.617   2.079   1.397   0.944   0.506   0.369
## Cumulative % of var.  91.750  94.366  96.446  97.843  98.787  99.293  99.662
##                       Dim.15
## Variance               0.051
## % of var.              0.338
## Cumulative % of var. 100.000
##
## Individuals
##                  Dist    Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3
## 1             |  2.569 |  0.703  0.097  0.075 |  1.347  0.828  0.275 |  0.776
## 2             |  4.021 |  2.154  0.910  0.287 |  2.020  1.863  0.252 |  0.598
## 3             |  3.353 | -1.260  0.312  0.141 |  1.268  0.734  0.143 | -1.746
## 4             |  4.841 |  3.307  2.147  0.467 |  1.745  1.390  0.130 |  0.850
## 5             |  2.599 | -1.923  0.726  0.547 |  0.177  0.014  0.005 | -0.872
## 6             |  2.925 | -1.988  0.776  0.462 |  0.681  0.212  0.054 | -1.101
## 7             |  4.194 |  1.797  0.634  0.184 |  2.784  3.539  0.441 |  0.822
## 8             |  3.597 |  1.077  0.228  0.090 |  2.009  1.844  0.312 | -0.161
## 9             |  5.264 |  2.557  1.284  0.236 |  3.649  6.083  0.481 | -0.320
## 10            |  3.373 |  1.552  0.473  0.212 | -0.442  0.089  0.017 | -0.292
## 11            |  4.153 | -3.671  2.646  0.782 |  1.374  0.863  0.110 |  0.226
## 12            |  3.819 |  2.096  0.862  0.301 |  0.229  0.024  0.004 | -0.176
## 13            |  3.468 | -3.110  1.898  0.804 |  0.115  0.006  0.001 | -1.211
## 14            |  4.715 |  1.860  0.679  0.156 |  3.043  4.229  0.417 |  1.612
## 15            |  1.937 | -0.319  0.020  0.027 |  0.971  0.431  0.251 |  0.681
## 16            |  3.364 | -3.278  2.109  0.949 |  0.173  0.014  0.003 |  0.041
## 17            |  3.622 | -3.225  2.041  0.793 | -0.778  0.276  0.046 | -0.768
## 18            |  5.427 |  4.087  3.278  0.567 | -0.336  0.051  0.004 | -0.648
## 19            |  3.055 | -2.562  1.288  0.703 |  1.026  0.481  0.113 | -0.789
## 20            |  2.668 | -1.145  0.258  0.184 |  1.764  1.421  0.437 |  0.849
## 21            |  3.219 | -0.358  0.025  0.012 | -1.855  1.572  0.332 |  0.653
## 22            |  2.150 |  0.362  0.026  0.028 |  0.965  0.426  0.202 |  0.096
## 23            |  2.817 |  0.430  0.036  0.023 |  0.905  0.374  0.103 |  1.921
## 24            |  3.925 | -3.062  1.841  0.609 | -1.466  0.982  0.139 | -1.499
## 25            |  8.816 |  4.107  3.311  0.217 | -5.619 14.421  0.406 | -2.451
## 26            |  1.424 | -0.626  0.077  0.193 | -0.024  0.000  0.000 |  0.277
## 27            |  3.504 | -2.441  1.170  0.485 | -1.588  1.152  0.205 | -1.421
## 28            |  3.573 | -0.084  0.001  0.001 | -0.162  0.012  0.002 |  3.146
## 29            |  3.849 | -3.125  1.917  0.659 |  0.543  0.135  0.020 | -0.104
## 30            |  4.024 | -3.604  2.549  0.802 |  1.154  0.609  0.082 | -0.199
## 31            |  3.499 |  0.140  0.004  0.002 |  2.589  3.062  0.548 |  1.091
## 32            |  3.424 |  1.024  0.206  0.089 |  0.739  0.250  0.047 |  2.335
## 33            |  3.565 | -1.846  0.669  0.268 | -0.690  0.217  0.037 | -1.077
## 34            |  2.886 | -2.359  1.092  0.668 |  0.063  0.002  0.000 |  0.297
## 35            |  3.571 | -2.472  1.199  0.479 |  0.886  0.358  0.062 |  1.008
## 36            |  2.842 |  0.564  0.062  0.039 | -1.401  0.897  0.243 | -0.966
```

```
## 37          |  2.930 | -0.622  0.076  0.045 |  0.718  0.236  0.060 |  0.294
## 38          |  4.022 | -3.789  2.817  0.887 | -0.116  0.006  0.001 |  0.524
## 39          |  3.913 | -3.579  2.514  0.836 | -0.929  0.394  0.056 |  0.230
## 40          |  6.692 |  4.507  3.986  0.453 | -2.681  3.283  0.161 |  2.323
## 41          |  3.489 | -0.685  0.092  0.039 |  1.648  1.241  0.223 |  2.202
## 42          |  2.620 | -1.777  0.620  0.460 |  0.868  0.344  0.110 | -0.168
## 43          |  3.272 | -2.343  1.077  0.513 | -2.029  1.880  0.385 | -0.130
## 44          |  2.977 | -0.524  0.054  0.031 | -1.163  0.618  0.153 |  2.218
## 45          |  4.040 |  0.647  0.082  0.026 | -2.611  3.114  0.418 |  2.299
## 46          |  4.210 | -3.437  2.318  0.666 | -2.081  1.978  0.244 | -0.219
## 47          |  3.963 |  1.534  0.462  0.150 | -2.668  3.250  0.453 |  1.908
## 48          |  4.232 | -3.652  2.618  0.745 | -1.590  1.154  0.141 |  0.176
## 49          |  4.676 | -4.032  3.191  0.743 |  1.425  0.927  0.093 |  0.620
## 50          |  4.549 |  2.652  1.381  0.340 | -2.417  2.668  0.282 |  1.692
## 51          |  3.102 | -2.702  1.433  0.759 | -1.283  0.751  0.171 |  0.009
## 52          |  4.471 |  1.400  0.385  0.098 | -2.790  3.554  0.389 |  2.023
## 53          |  5.476 |  4.048  3.216  0.546 |  0.748  0.256  0.019 | -2.923
## 54          |  5.869 |  5.049  5.003  0.740 |  1.450  0.960  0.061 | -1.937
## 55          |  2.600 |  1.610  0.509  0.383 | -0.102  0.005  0.002 | -1.172
## 56          |  3.776 | -1.406  0.388  0.139 | -0.987  0.445  0.068 | -2.673
## 57          |  5.306 |  4.215  3.487  0.631 |  1.028  0.483  0.038 | -2.630
## 58          |  4.875 |  3.322  2.167  0.465 |  0.839  0.322  0.030 | -1.975
## 59          |  5.209 |  3.719  2.714  0.510 |  1.797  1.475  0.119 | -2.467
## 60          |  4.694 | -0.537  0.057  0.013 |  0.662  0.200  0.020 | -2.496
## 61          |  6.400 |  4.561  4.084  0.508 |  1.699  1.319  0.071 | -2.170
## 62          |  2.547 | -0.713  0.100  0.078 |  0.562  0.144  0.049 | -1.182
## 63          |  5.259 |  4.140  3.365  0.620 | -0.827  0.312  0.025 |  0.924
## 64          |  5.749 |  4.308  3.643  0.562 | -2.073  1.963  0.130 |  0.453
## 65          |  4.316 | -2.161  0.917  0.251 | -1.059  0.512  0.060 | -2.845
## 66          |  2.171 | -0.336  0.022  0.024 |  1.249  0.712  0.331 |  0.756
## 67          |  3.622 | -3.204  2.015  0.782 |  0.907  0.375  0.063 |  0.629
## 68          |  2.481 |  0.853  0.143  0.118 |  1.135  0.589  0.209 |  1.465
## 69          |  2.346 |  0.554  0.060  0.056 | -1.594  1.161  0.462 | -0.491
## 70          |  2.379 |  0.063  0.001  0.001 |  1.238  0.700  0.271 |  0.611
## 71          |  2.952 |  0.605  0.072  0.042 | -2.260  2.332  0.586 |  0.449
## 72          |  2.560 |  1.167  0.267  0.208 | -1.781  1.448  0.484 |  0.293
## 73          |  2.599 |  0.796  0.124  0.094 | -1.907  1.661  0.538 | -0.290
## 74          |  3.656 |  2.789  1.527  0.582 |  0.089  0.004  0.001 |  1.502
## 75          |  5.314 |  1.302  0.333  0.060 |  0.928  0.393  0.030 | -0.407
## 76          |  2.777 |  0.163  0.005  0.003 |  0.568  0.147  0.042 |  1.782
## 77          |  2.100 |  0.776  0.118  0.136 |  0.053  0.001  0.001 |  1.033
## 78          |  2.954 |  1.793  0.631  0.368 |  1.045  0.499  0.125 |  0.243
## 79          |  4.264 |  2.565  1.291  0.362 | -2.916  3.883  0.468 |  0.519
## 80          |  2.362 | -1.315  0.339  0.310 | -1.381  0.871  0.342 | -0.990
## 81          |  2.617 | -1.079  0.229  0.170 | -1.844  1.553  0.496 | -0.816
## 82          |  3.130 | -2.954  1.712  0.891 |  0.124  0.007  0.002 | -0.209
## 83          |  1.640 | -0.019  0.000  0.000 |  1.059  0.512  0.417 |  0.201
## 84          |  3.203 | -2.546  1.272  0.632 |  0.447  0.091  0.019 | -1.094
## 85          |  1.701 | -1.084  0.231  0.406 |  0.941  0.404  0.306 |  0.426
##               ctr   cos2
## 1           0.391  0.091 |
## 2           0.232  0.022 |
## 3           1.978  0.271 |
## 4           0.469  0.031 |
```

```
## 5            0.494  0.113 |
## 6            0.786  0.142 |
## 7            0.438  0.038 |
## 8            0.017  0.002 |
## 9            0.066  0.004 |
## 10           0.055  0.007 |
## 11           0.033  0.003 |
## 12           0.020  0.002 |
## 13           0.950  0.122 |
## 14           1.686  0.117 |
## 15           0.301  0.124 |
## 16           0.001  0.000 |
## 17           0.383  0.045 |
## 18           0.273  0.014 |
## 19           0.403  0.067 |
## 20           0.467  0.101 |
## 21           0.277  0.041 |
## 22           0.006  0.002 |
## 23           2.393  0.465 |
## 24           1.457  0.146 |
## 25           3.895  0.077 |
## 26           0.050  0.038 |
## 27           1.309  0.164 |
## 28           6.419  0.775 |
## 29           0.007  0.001 |
## 30           0.026  0.002 |
## 31           0.772  0.097 |
## 32           3.537  0.465 |
## 33           0.752  0.091 |
## 34           0.057  0.011 |
## 35           0.659  0.080 |
## 36           0.605  0.115 |
## 37           0.056  0.010 |
## 38           0.178  0.017 |
## 39           0.034  0.003 |
## 40           3.499  0.120 |
## 41           3.145  0.398 |
## 42           0.018  0.004 |
## 43           0.011  0.002 |
## 44           3.189  0.555 |
## 45           3.428  0.324 |
## 46           0.031  0.003 |
## 47           2.362  0.232 |
## 48           0.020  0.002 |
## 49           0.249  0.018 |
## 50           1.856  0.138 |
## 51           0.000  0.000 |
## 52           2.654  0.205 |
## 53           5.542  0.285 |
## 54           2.434  0.109 |
## 55           0.890  0.203 |
## 56           4.632  0.501 |
## 57           4.486  0.246 |
## 58           2.530  0.164 |
```

```
## 59           3.945  0.224 |
## 60           4.040  0.283 |
## 61           3.053  0.115 |
## 62           0.906  0.215 |
## 63           0.554  0.031 |
## 64           0.133  0.006 |
## 65           5.248  0.434 |
## 66           0.371  0.121 |
## 67           0.256  0.030 |
## 68           1.392  0.349 |
## 69           0.156  0.044 |
## 70           0.242  0.066 |
## 71           0.131  0.023 |
## 72           0.056  0.013 |
## 73           0.054  0.012 |
## 74           1.463  0.169 |
## 75           0.108  0.006 |
## 76           2.060  0.412 |
## 77           0.692  0.242 |
## 78           0.038  0.007 |
## 79           0.174  0.015 |
## 80           0.636  0.176 |
## 81           0.432  0.097 |
## 82           0.028  0.004 |
## 83           0.026  0.015 |
## 84           0.776  0.117 |
## 85           0.118  0.063 |
##
## Variables
##                Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3    ctr
## CD4         | -0.795 10.539  0.632 |  0.047  0.085  0.002 |  0.397  8.675
## Treg        |  0.526  4.608  0.276 | -0.513 10.228  0.263 | -0.510 14.355
## Div_Treg    |  0.618  6.364  0.381 | -0.095  0.354  0.009 |  0.514 14.566
## Treg17      |  0.079  0.104  0.006 |  0.656 16.710  0.430 |  0.342  6.446
## Th1         |  0.870 12.638  0.757 |  0.291  3.291  0.085 | -0.053  0.155
## Div_Th1     |  0.828 11.428  0.685 | -0.082  0.259  0.007 |  0.405  9.055
## Th17        |  0.572  5.458  0.327 |  0.149  0.864  0.022 | -0.430 10.185
## Div_Th17    |  0.743  9.217  0.552 |  0.027  0.029  0.001 |  0.059  0.193
## CD8         | -0.185  0.574  0.034 | -0.706 19.354  0.499 |  0.236  3.066
## Act_CD8     |  0.758  9.587  0.575 | -0.286  3.179  0.082 |  0.041  0.091
## Div_Act_CD8 |  0.644  6.911  0.414 |  0.092  0.327  0.008 |  0.566 17.659
## IFNy_CD4    |  0.621  6.436  0.386 |  0.553 11.862  0.306 | -0.177  1.720
## IFNy_CD8    |  0.536  4.800  0.288 |  0.532 10.984  0.283 | -0.312  5.377
## Treg_prop   | -0.549  5.032  0.302 |  0.686 18.279  0.471 |  0.221  2.691
## IL17A_CD4   |  0.615  6.305  0.378 | -0.329  4.196  0.108 |  0.323  5.768
##                cos2
## CD4          0.157 |
## Treg         0.260 |
## Div_Treg     0.264 |
## Treg17       0.117 |
## Th1          0.003 |
## Div_Th1      0.164 |
## Th17         0.185 |
## Div_Th17     0.003 |
```

```
## CD8          0.056 |
## Act_CD8      0.002 |
## Div_Act_CD8  0.320 |
## IFNy_CD4     0.031 |
## IFNy_CD8     0.098 |
## Treg_prop    0.049 |
## IL17A_CD4    0.105 |
```

```
## NULL
```

```
## $Dim.1
## $quanti
##             correlation      p.value
## Th1           0.8703175 2.943471e-27
## Div_Th1       0.8276238 1.596060e-22
## Act_CD8       0.7580283 4.492673e-17
## Div_Th17      0.7432721 3.764290e-16
## Div_Act_CD8   0.6436080 3.063061e-11
## IFNy_CD4      0.6210972 2.270480e-10
## Div_Treg      0.6175982 3.056079e-10
## IL17A_CD4     0.6147436 3.883906e-10
## Th17          0.5719412 1.079666e-08
## IFNy_CD8      0.5363617 1.218142e-07
## Treg          0.5255354 2.412497e-07
## Treg_prop    -0.5491894 5.252093e-08
## CD4          -0.7947807 1.087537e-19
##
## attr(,"class")
## [1] "condes" "list"
##
## $Dim.2
## $quanti
##           correlation      p.value
## Treg_prop   0.6861704 4.249117e-13
## Treg17      0.6560699 9.395061e-12
## IFNy_CD4    0.5527736 4.125555e-08
## IFNy_CD8    0.5319037 1.618660e-07
## Th1         0.2911745 6.859347e-03
## Act_CD8    -0.2861658 7.930276e-03
## IL17A_CD4  -0.3287530 2.126702e-03
## Treg       -0.5132770 5.084715e-07
## CD8        -0.7060657 4.440787e-14
##
## attr(,"class")
## [1] "condes" "list"
##
## $Dim.3
## $quanti
##             correlation      p.value
## Div_Act_CD8   0.5660036 1.650437e-08
## Div_Treg      0.5140433 4.857300e-07
## Div_Th1       0.4053084 1.191116e-04
## CD4           0.3967074 1.707468e-04
## Treg17        0.3419675 1.358813e-03
## IL17A_CD4     0.3234929 2.528223e-03
```

```
## CD8           0.2358423 2.978669e-02
## Treg_prop     0.2209303 4.216380e-02
## IFNy_CD8     -0.3123195 3.614568e-03
## Th17         -0.4298530 4.032726e-05
## Treg         -0.5103074 6.064786e-07
##
## attr(,"class")
## [1] "condes" "list"
##
## $call
## $call$num.var
## [1] 1
##
## $call$proba
## [1] 0.05
##
## $call$weights
##  [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [39] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [77] 1 1 1 1 1 1 1 1 1
##
## $call$X
##          Dim.1    CD4   Treg Div_Treg Treg17    Th1 Div_Th1  Th17 Div_Th17
## 1   0.70274005 44.900  6.385   16.205 13.520  6.780  71.200 0.890   46.875
## 2   2.15371252 46.145  7.005   21.365 11.565 10.920  75.115 1.075   42.390
## 3  -1.26014366 56.220  7.150   12.455  9.505  2.965  19.840 1.630   30.055
## 4   3.30719107 40.590  6.450   23.760 12.780  9.250  81.210 1.705   78.305
## 5  -1.92290606 52.245  8.695   13.465 14.400  2.545  27.850 1.060   27.445
## 6  -1.98830926 46.895  6.890   13.355  7.035  2.900  25.520 0.695   32.195
## 7   1.79693547 49.470  6.065   24.795 13.950  6.870  76.515 1.110   65.735
## 8   1.07715289 45.740  6.520   17.115  8.645  9.585  51.870 1.090   40.600
## 9   2.55734813 46.330  6.465   21.000 14.540  7.020  67.360 1.615   65.055
## 10  1.55244898 43.325  8.915   13.090  6.825  7.710  79.020 1.185   55.835
## 11 -3.67145719 68.010  3.630   14.110 14.350  1.730  14.310 0.925   33.075
## 12  2.09560967 37.435  9.045   20.515  9.260  9.100  64.370 0.805   49.910
## 13 -3.10976423 53.250  6.895    7.850  9.015  2.505  19.190 0.945   28.815
## 14  1.86015854 43.090  6.120   21.885 25.480  7.620  60.780 1.415   45.325
## 15 -0.31936731 47.340  6.465   16.775 13.315  4.840  54.635 0.970   35.275
## 16 -3.27796278 61.525  5.650   12.710  9.660  1.875  29.575 0.535   21.155
## 17 -3.22466411 51.475  6.690   12.110  7.535  1.455  21.435 0.550   22.920
## 18  4.08663732 36.155  8.875   24.110  8.970 11.540  90.780 4.050   67.780
## 19 -2.56184560 54.575  5.110   13.005  9.130  1.835  22.300 1.075   30.890
## 20 -1.14545502 58.920  5.075   16.575 15.280  4.445  48.205 0.795   28.355
## 21 -0.35784719 49.925  7.915   15.795  4.280  3.710  75.720 0.765   46.720
## 22  0.36155681 43.270  7.155   16.365 10.450  5.485  65.425 1.170   29.270
## 23  0.42967182 53.240  5.215   41.605 11.280  6.795  59.590 1.225   36.960
## 24 -3.06239988 49.350  9.015    8.260  4.370  1.535  22.665 0.580   19.230
## 25  4.10716064 28.295 27.230   38.210  8.875  5.925  65.700 1.935   41.455
## 26 -0.62642215 53.270  6.670   23.525  7.885  3.540  53.200 1.360   24.045
## 27 -2.44132737 54.265  9.475   10.550  4.220  1.425  22.075 1.070   31.665
## 28 -0.08383332 48.490  5.220   36.585 17.105  3.370  72.075 0.620   38.040
## 29 -3.12519296 56.780  4.835   16.835 13.005  1.735  11.910 1.120   50.070
## 30 -3.60357020 67.430  3.900   13.000 12.720  1.855  13.035 1.440   19.120
## 31  0.14034538 53.510  4.525   30.580 17.135  5.615  41.680 0.975   22.355
```

```
## 32  1.02365226 49.935  6.265   43.855 12.800  5.395  56.130 0.875   30.460
## 33 -1.84647089 42.860  8.465    8.225 10.045  1.780  31.145 1.110   63.235
## 34 -2.35893055 55.305  7.315   22.150 12.340  1.835  34.180 1.010   12.905
## 35 -2.47171941 52.100  5.205   31.795 18.210  2.740  21.990 0.730   27.275
## 36  0.56421071 48.705 11.315   19.245  7.590  3.110  35.555 1.435   39.995
## 37 -0.62240660 42.070  5.530   31.595  9.750  3.055  29.220 0.840   30.170
## 38 -3.78862046 55.005  4.635   17.730 12.165  1.510  28.170 0.660    9.700
## 39 -3.57899552 55.135  4.955   19.550  6.445  1.305  27.140 0.485   19.200
## 40  4.50656799 48.920 14.300   52.620 14.605  7.425  79.505 1.730   69.700
## 41 -0.68478037 60.705  3.740   36.475 18.505  5.280  48.670 1.940   24.220
## 42 -1.77666382 49.850  4.700   26.940  8.940  3.020  22.305 1.400   21.805
## 43 -2.34270897 53.755  9.235   19.495  6.415  1.375  27.520 0.830   28.285
## 44 -0.52448739 48.380  6.965   36.775  9.390  4.130  60.855 0.680   27.710
## 45  0.64652384 46.695  9.310   34.995  6.330  2.810  76.265 0.635   46.690
## 46 -3.43662451 58.170  7.095   12.905  5.325  1.330  22.600 0.630   23.055
## 47  1.53423739 50.800  9.805   35.235  8.230  5.480  76.185 1.430   59.040
## 48 -3.65203408 57.615  5.520   13.720  5.700  1.235  29.350 0.590   20.910
## 49 -4.03169950 67.755  3.245   22.775 17.040  1.835  15.255 1.080   12.220
## 50  2.65247679 42.085  9.840   37.850  8.350  7.570  71.140 1.005   41.105
## 51 -2.70201349 54.710  7.000   17.570  9.180  1.315  26.475 0.925   25.815
## 52  1.40001974 48.125 10.595   33.980  5.645  4.170  58.705 0.520   39.065
## 53  4.04786211 14.600 14.000   26.700  7.630  8.130  60.600 3.700   62.100
## 54  5.04859649 17.900 11.800   34.500 11.500 13.100  63.500 3.160   64.200
## 55  1.60968376 27.200 11.500   25.600  9.050  4.780  54.900 2.170   42.700
## 56 -1.40568836 52.600 14.400    8.070  3.230  4.830  15.800 1.530   13.300
## 57  4.21504132 28.400 15.200   24.900  8.360 11.600  54.600 3.030   43.800
## 58  3.32240959 20.300 11.100   30.600 12.100  6.870  63.100 3.790   65.800
## 59  3.71858867 25.400 12.000   23.200  9.410  9.080  49.700 2.060   52.400
## 60 -0.53707478 31.500 17.500   13.600 17.500  5.730  19.400 2.350   12.400
## 61  4.56145967 14.700 18.900   30.000 20.000 12.400  58.700 3.030   58.000
## 62 -0.71339732 37.700  7.470   21.600 10.500  2.700  27.500 1.510   54.300
## 63  4.14040269 25.300  7.830   41.200  8.040  6.850  83.700 1.190   73.900
## 64  4.30805769 28.300 16.700   45.100  5.680  7.260  70.200 1.450   47.700
## 65 -2.16095906 45.400 16.100    6.480  3.430  3.260  12.600 1.000    9.200
## 66 -0.33617281 55.900  6.210   26.400 17.500  5.010  44.100 1.470   29.700
## 67 -3.20391349 61.400  4.100   21.400 15.500  1.460  33.800 0.990   17.000
## 68  0.85343990 47.200  5.660   30.200 18.500  6.800  63.400 1.520   47.900
## 69  0.55393957 48.200 12.400   17.900  7.520  3.990  52.900 2.200   36.600
## 70  0.06335840 50.100  7.080   22.200 14.200  4.950  59.500 1.070   23.700
## 71  0.60463330 41.900 11.900   22.200  5.660  4.860  55.800 1.260   26.500
## 72  1.16714606 46.800 10.900   24.100  5.860  4.200  66.300 1.520   48.000
## 73  0.79606100 41.600 12.900   23.000  6.090  3.800  56.500 2.160   35.900
## 74  2.78891097 44.300  6.690   40.900 11.000  6.350  71.900 1.470   56.200
## 75  1.30204649 32.600  3.810   43.200 13.500  4.170  53.800 4.810   11.100
## 76  0.16263889 49.700  6.950   30.000 19.500  5.040  62.200 1.410   42.000
## 77  0.77583644 43.400  5.480   24.900 13.100  5.660  62.700 1.320   36.100
## 78  1.79316087 46.300  8.690   32.700 13.300  9.290  51.800 1.280   27.100
## 79  2.56499828 31.600 12.300   26.100  4.030  6.460  81.700 1.230   46.300
## 80 -1.31512161 49.200  9.760   15.300  6.320  2.260  29.600 1.390   26.300
## 81 -1.07938992 53.400 10.400   14.300  4.680  1.580  43.200 1.520   37.100
## 82 -2.95360568 60.000  5.260   16.000  9.450  3.040  26.100 0.780   15.100
## 83 -0.01898106 47.600  5.920   24.300 13.400  5.750  46.100 1.120   31.900
## 84 -2.54568952 50.600  5.740   18.500  7.520  2.020  20.700 1.310   15.300
## 85 -1.08401268 53.000  5.560   21.900 12.800  4.380  41.900 1.410   25.800
```

```
##       CD8 Act_CD8 Div_Act_CD8 IFNy_CD4 IFNy_CD8 Treg_prop IL17A_CD4
## 1  14.390  11.500      49.520    4.915   21.740  93.60500 0.4150000
## 2  13.840  13.205      59.090    9.085   27.535  92.97000 0.3850000
## 3  10.020  10.915      11.535    3.045   41.360  92.84500 0.5750000
## 4  25.305  11.105      55.935    9.085   38.165  93.50500 0.8500000
## 5  17.550   9.815      12.830    2.005   19.390  91.30500 0.2500000
## 6   7.490   5.395      21.310    2.795   19.230  93.11000 0.2700000
## 7   9.065   8.900      55.690    8.455   34.310  93.93500 0.2950000
## 8  13.995   9.200      55.970    8.755   28.690  93.46000 0.2800000
## 9   8.840   8.375      45.895   12.910   46.265  93.53500 0.6100000
## 10 26.505  18.260      38.450    4.590   27.800  91.07500 0.3350000
## 11 13.900   3.785       8.985    1.690   13.755  96.36000 0.3850000
## 12 31.115  13.460      38.515    9.600   30.505  90.93500 0.6400000
## 13 18.080   3.455       8.710    1.950   13.490  93.10000 0.1650000
## 14 16.055   7.815      60.255    8.380   29.545  93.86500 1.0250000
## 15 19.235   4.930      44.240    4.355   23.725  93.51000 0.7300000
## 16 17.080   4.755      15.410    1.810   11.825  94.33000 0.3800000
## 17 28.360   5.640       6.335    1.650   16.100  93.29000 0.2700000
## 18 24.175  20.500      29.365    3.240   27.110  91.01500 1.0750000
## 19 11.410   4.455      12.675    2.580   22.560  94.87000 0.4800000
## 20 17.805   7.630      39.930    4.845   26.830  94.90500 0.4200000
## 21 33.620  13.385      33.365    1.740   16.375  92.06000 0.5150000
## 22 10.565  11.430      47.355    3.415   26.765  92.79500 0.5000000
## 23 12.140  10.910      47.475    2.620   16.955  94.73000 0.6000000
## 24 26.665   4.740       7.560    1.760   14.625  90.95000 0.2500000
## 25 35.575  19.175      31.745    3.055   19.105  72.66000 0.4600000
## 26 17.865  11.125      29.020    2.900   23.535  93.26000 0.7600000
## 27 27.880   6.615      10.910    1.110   20.565  90.52500 0.3950000
## 28 27.135   6.945      43.535    2.015   11.530  94.70000 1.2250000
## 29 18.020   2.365       6.815    1.130    8.335  95.16500 0.3850000
## 30 14.640   4.765       7.740    1.825   15.605  96.08000 0.5250000
## 31  7.365  16.415      45.830    5.475   31.365  95.40500 0.4650000
## 32 13.720   7.845      51.610    5.170   21.410  93.70500 1.4100000
## 33 20.855   3.855      10.130    1.360    8.335  91.53500 0.3500000
## 34 12.335   3.985      23.610    1.225   10.585  92.52500 0.6200000
## 35 18.260   2.810      15.015    2.010    8.880  94.67500 0.4600000
## 36 26.645  17.735      27.745    3.215   34.270  88.40000 0.8600000
## 37  7.725   6.500      18.930    3.605   22.265  94.40000 1.3150000
## 38 21.500   3.325      12.075    0.410    3.605  95.24500 0.3850000
## 39 27.155   3.900       6.500    1.020    7.420  94.96000 0.4750000
## 40 21.090  21.605      36.210    2.315   14.775  85.59000 2.3400000
## 41 18.575   8.135      46.220    2.310   17.460  96.20000 0.6000000
## 42 10.375   6.720      17.135    2.780   18.350  95.23500 0.7100000
## 43 29.465   4.220      16.695    0.830    9.825  90.60000 0.7450000
## 44 24.340   7.410      46.670    1.325    4.500  92.95500 0.8500000
## 45 28.860   7.460      43.700    1.455    7.310  90.59000 1.6050000
## 46 33.330   8.910       6.915    0.400    5.010  92.62000 0.4300000
## 47 34.585  15.035      35.205    1.540    9.265  90.04500 1.4050000
## 48 32.530   7.580       9.960    0.430    4.315  94.32000 0.3350000
## 49 14.995   5.160       6.565    1.070    9.730  96.64500 0.1800000
## 50 30.975  27.805      38.400    3.785   12.825  89.99500 1.4300000
## 51 26.945   9.665      10.630    0.665    7.805  92.89500 0.5450000
## 52 28.025  12.985      49.650    2.520   14.905  89.26500 2.0400000
## 53  6.580  11.400      24.400    5.820   38.300  90.50758 1.0426441
```

```
## 54  9.980  16.200      22.800    8.400   37.700  90.61363 1.0875071
## 55  8.930  12.400      30.600    2.850   23.700  91.14051 0.8781702
## 56 15.400  13.700       6.070    3.050   21.500  92.09561 0.6640916
## 57  7.770  19.500      26.500    9.340   36.900  90.69359 1.0397215
## 58  5.870  12.800      16.600    3.910   28.900  91.05230 0.9716460
## 59  6.140  20.500      22.500    9.130   50.100  91.79981 0.9457349
## 60 14.700   3.370      11.800    6.590    7.210  93.26599 0.6362830
## 61  7.300  10.200      23.500    9.700   21.500  91.17478 1.0277385
## 62 10.500   7.520       7.410    2.720   20.300  93.27272 0.6268053
## 63  7.560  26.500      42.500    3.110   22.000  88.81618 1.1520976
## 64  5.790  25.900      62.700    2.700   14.500  87.41996 1.2471387
## 65 11.500   7.370       8.520    1.110   20.100  92.49025 0.6008500
## 66 14.400  14.400      29.100    2.870   23.500  93.75014 0.6166391
## 67 16.400   4.370      11.600    0.340   16.200  95.17693 0.3809497
## 68 15.600  11.200      38.900    2.840   18.200  92.89333 0.7308085
## 69 26.100  14.000      38.100    1.670   21.100  90.24852 0.8791302
## 70 13.800  11.200      43.000    2.240   35.600  93.49048 0.6532436
## 71 27.900  13.300      54.100    1.850   12.200  89.52706 0.9263936
## 72 28.400  13.900      41.800    2.600   23.500  89.67448 0.9461751
## 73 25.200  10.700      44.300    2.050   15.100  89.77365 0.9209664
## 74 13.900  20.900      52.200    2.920   31.400  90.60534 0.9718971
## 75 14.400  12.100      28.800    1.960   25.100  92.39949 0.7844306
## 76 14.800  10.900      41.400    1.060   10.300  92.73381 0.7051832
## 77 14.500  18.600      40.200    1.890   16.700  91.81908 0.7933162
## 78 13.900  19.400      32.900    6.730   28.300  92.21576 0.8210417
## 79 23.800  20.900      48.600    2.360    8.070  87.62885 1.1446338
## 80 23.300  14.100      15.500    1.540   18.200  91.63115 0.6974956
## 81 24.500  13.400      16.200    1.320   16.900  91.00440 0.7484055
## 82 17.500   8.380       7.740    1.700   14.500  94.20965 0.4536871
## 83 19.100  11.500      27.000    3.970   32.000  93.35634 0.6573152
## 84 11.700   7.110       7.550    0.750   24.400  94.29099 0.4696145
## 85 15.000   7.470      33.400    2.130   22.100  93.89512 0.5692334
```

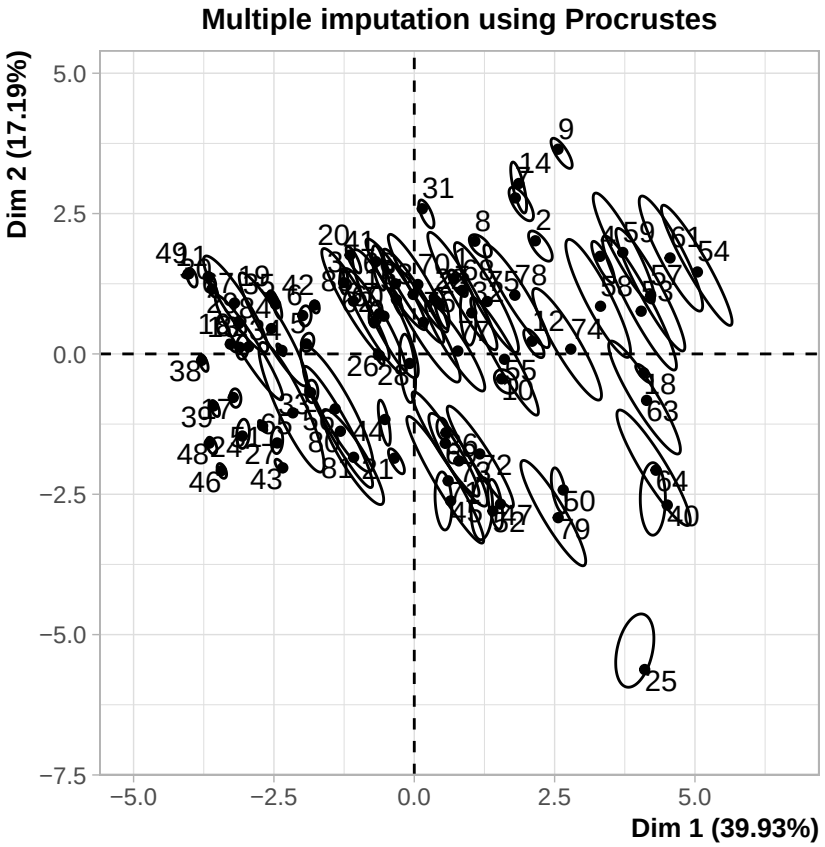
Caution: When imputing data, the percentages of inertia associated with the first dimensions will be overestimated.

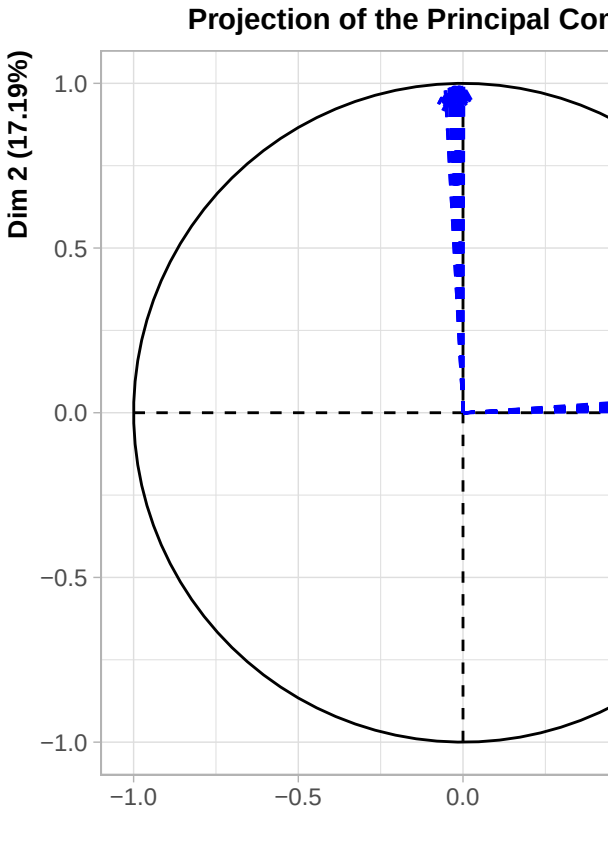
Another problem: the imputed data are, when the pca is performed considered like real observations. But they are estimations!!

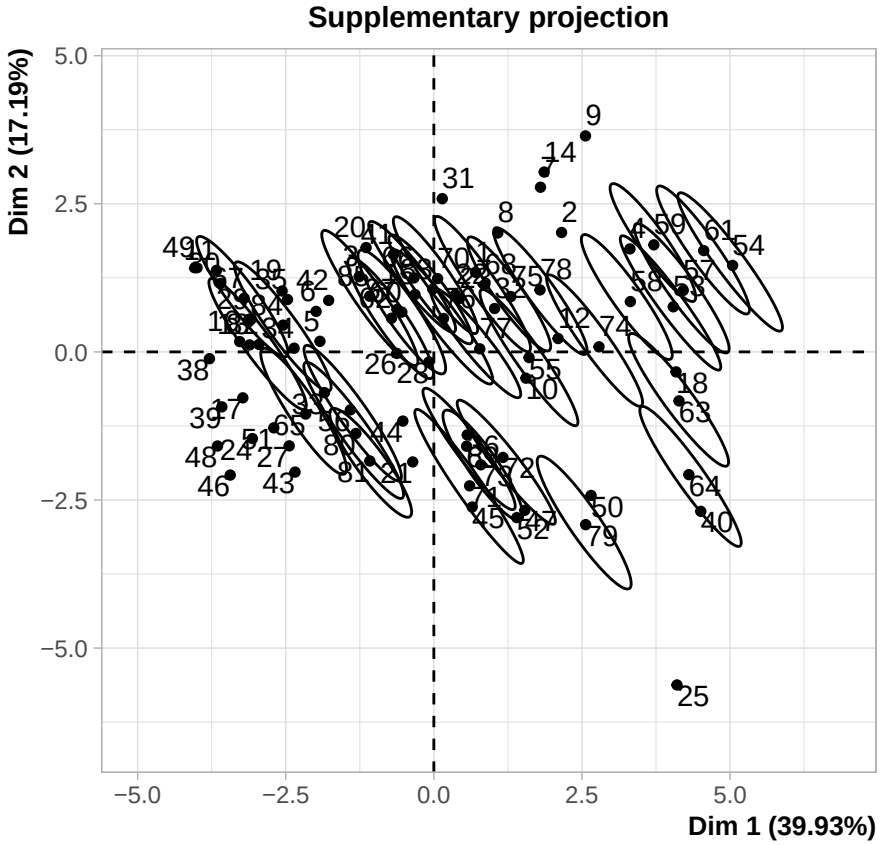
Visualizing uncertainty due to issing data:

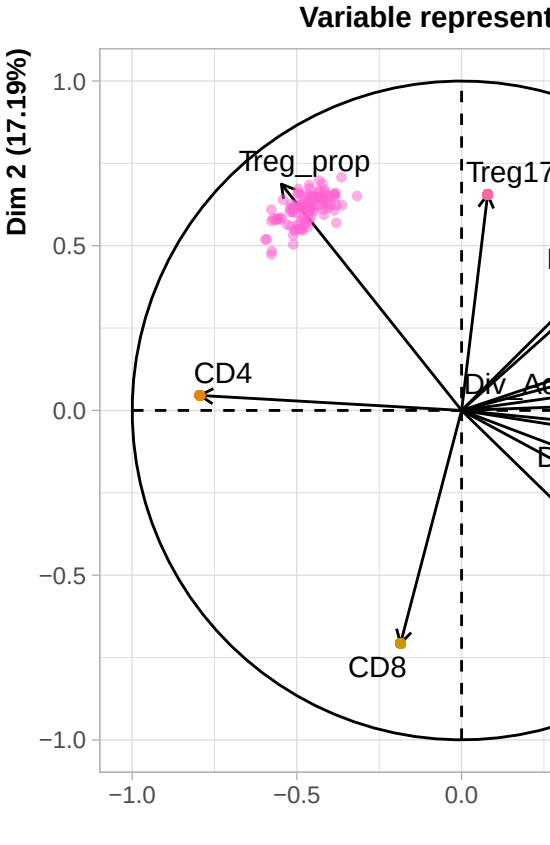
–> mulrimple imputation: generate several plausible values for each missing data point

We here visualize the variability, that is uncertainty on the plane defined by two pca axes.

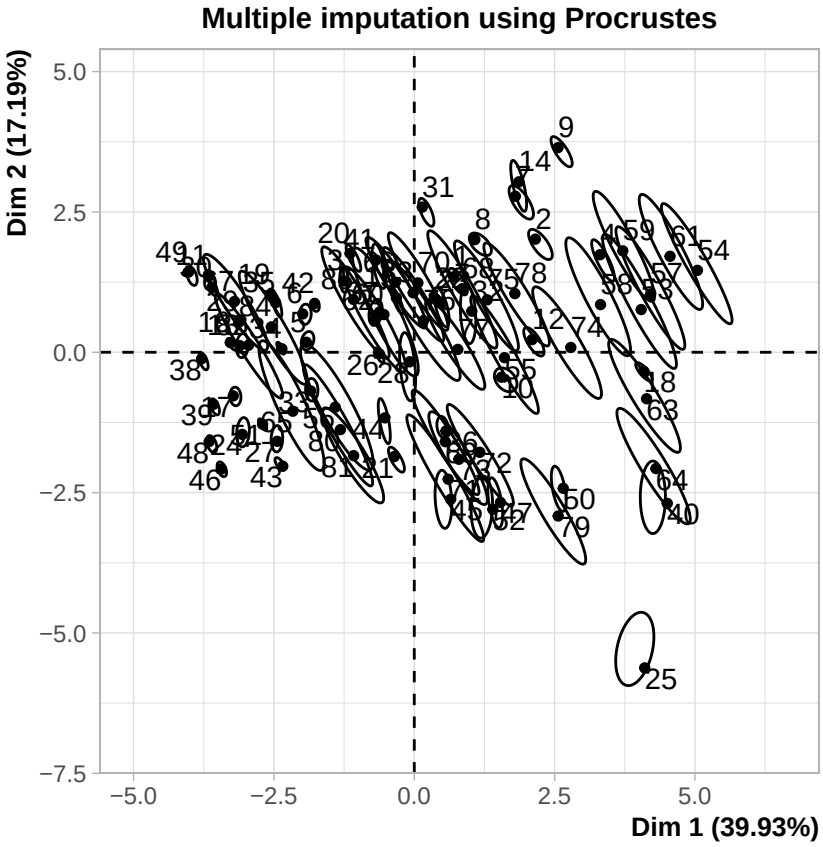

Multiple imputation using Procrustes
Dim 2 (17.19%)
Dim 1 (39.93%)


Projection of the Principal Cor
Dim 2 (17.19%)

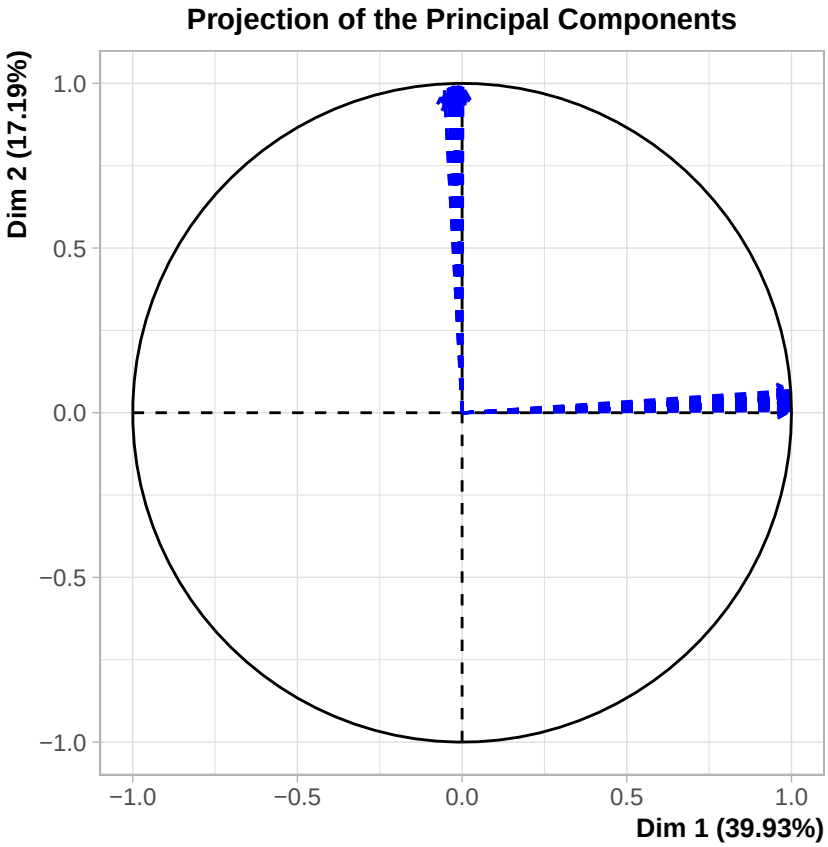

Supplementary projection
Dim 2 (17.19%)
Dim 1 (39.93%)


Variable represent
Dim 2 (17.19%)
Treg_prop
Treg17
CD4
CD8

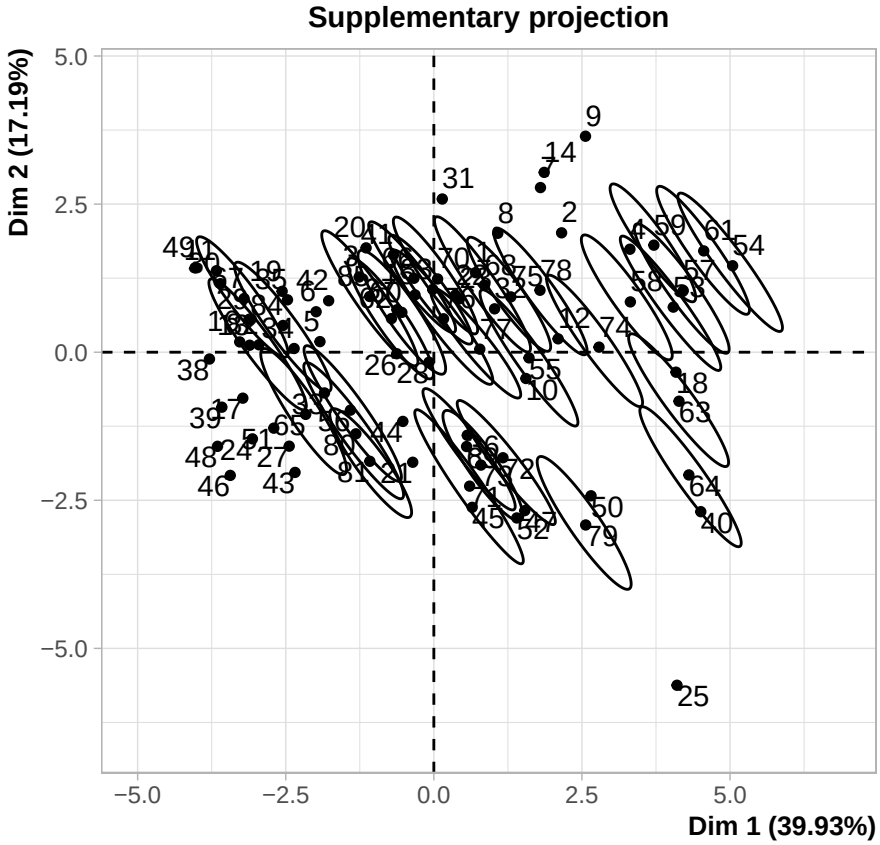
```
## $PlotIndProc
```



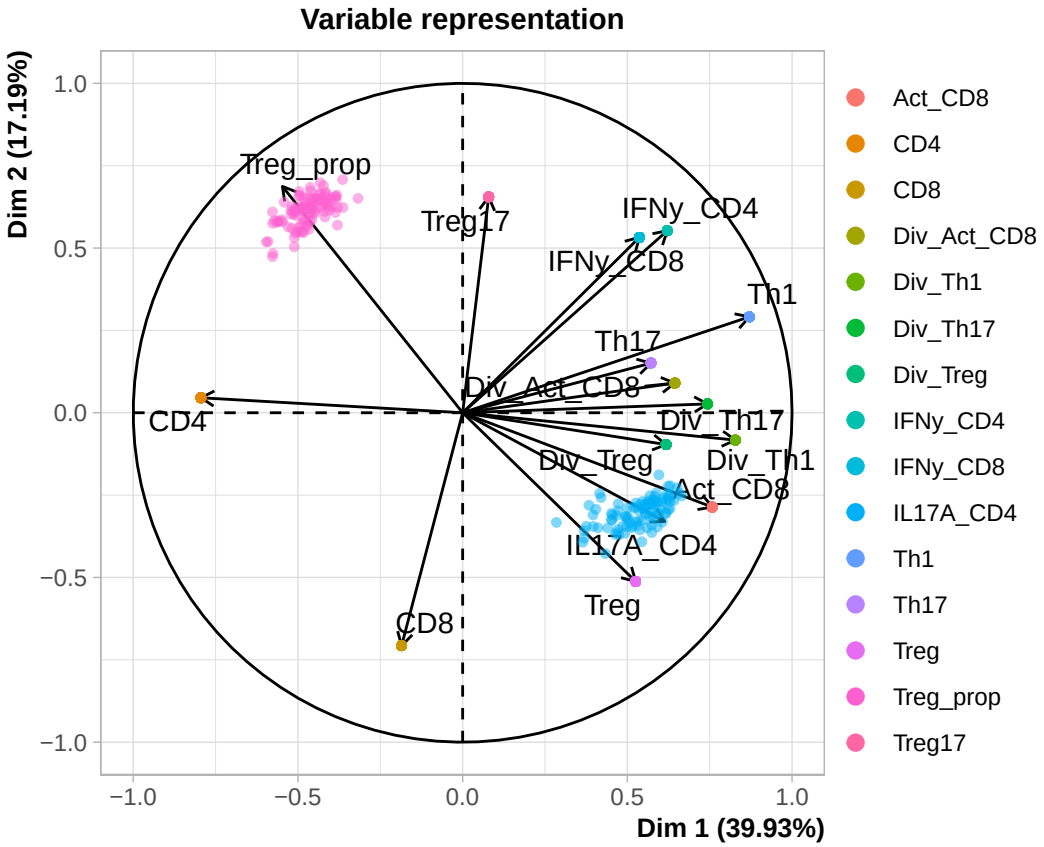

```
##
## $PlotDim
```




```
##
## $PlotIndSupp
```




```
##
## $PlotVar
```



Individuals lying on the axis have no missing data, but individuals that far away have many missing data. big ellipse = big uncertainty tight elipse (line) = low uncertainty

Variable representation: Poins tight together)look like one) - have no missing variables –> low uncertainty Points spread – > higher variability – > higher uncertainty

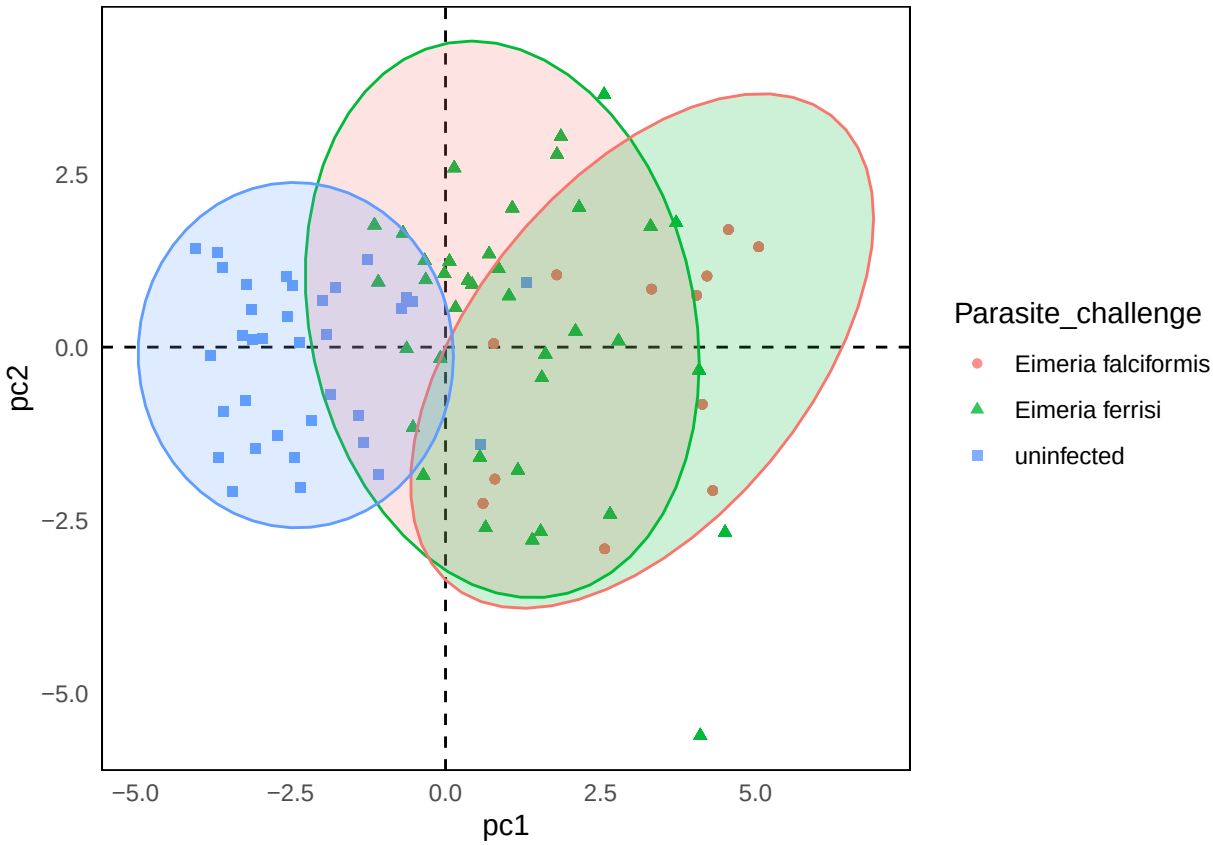
High uncertainty–> we should interpret the result with care

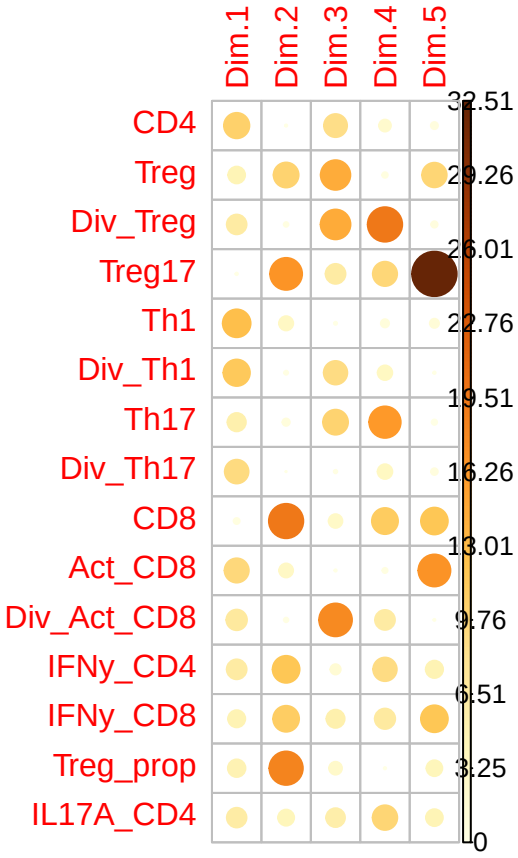
The individuals with many missing data values make the axes move, and thus the positions of all individuals

Therefore in the last plots every individual is getting an eclipse as they are as well influenced by the missing data of the others.

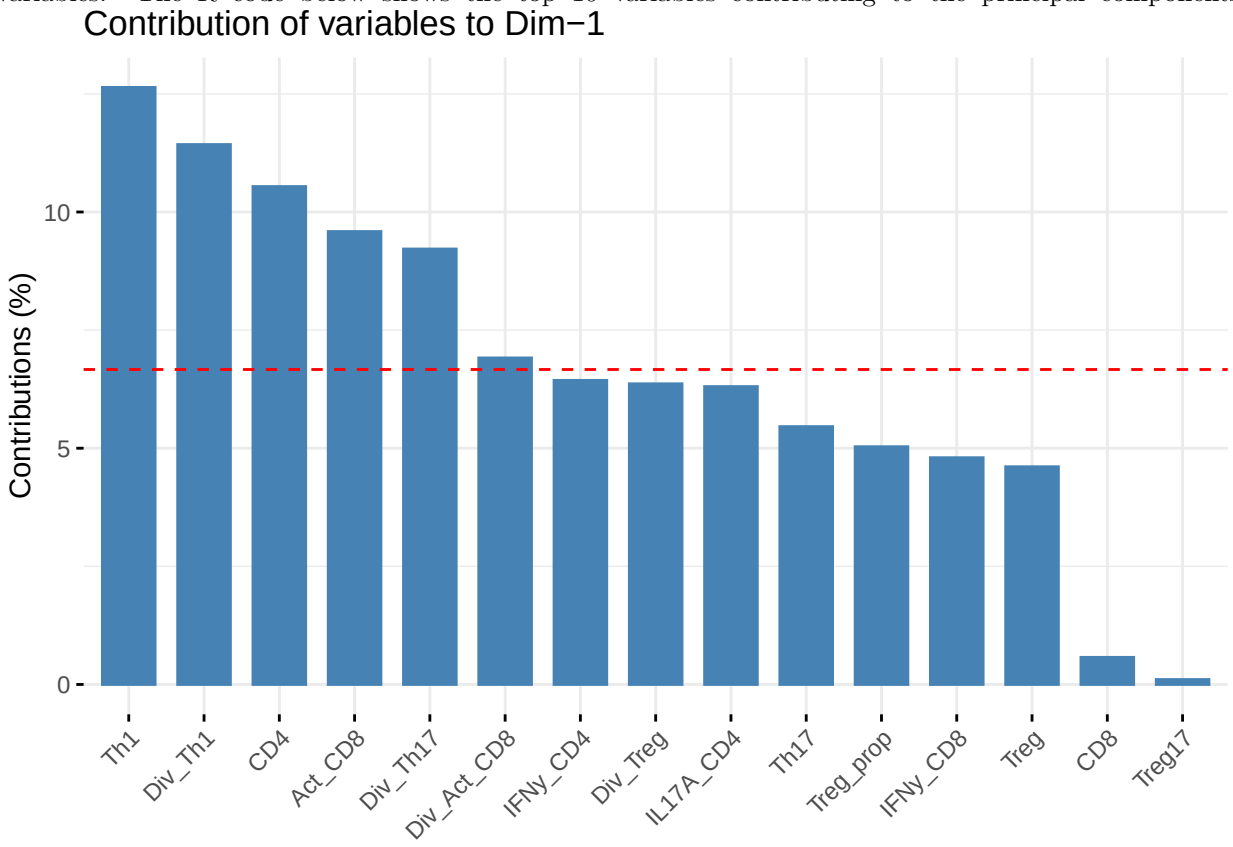
THe plot with the dimensions shows the projections of the pca dimensions of each imputed table on the pca plane obtained using the original imputed data table

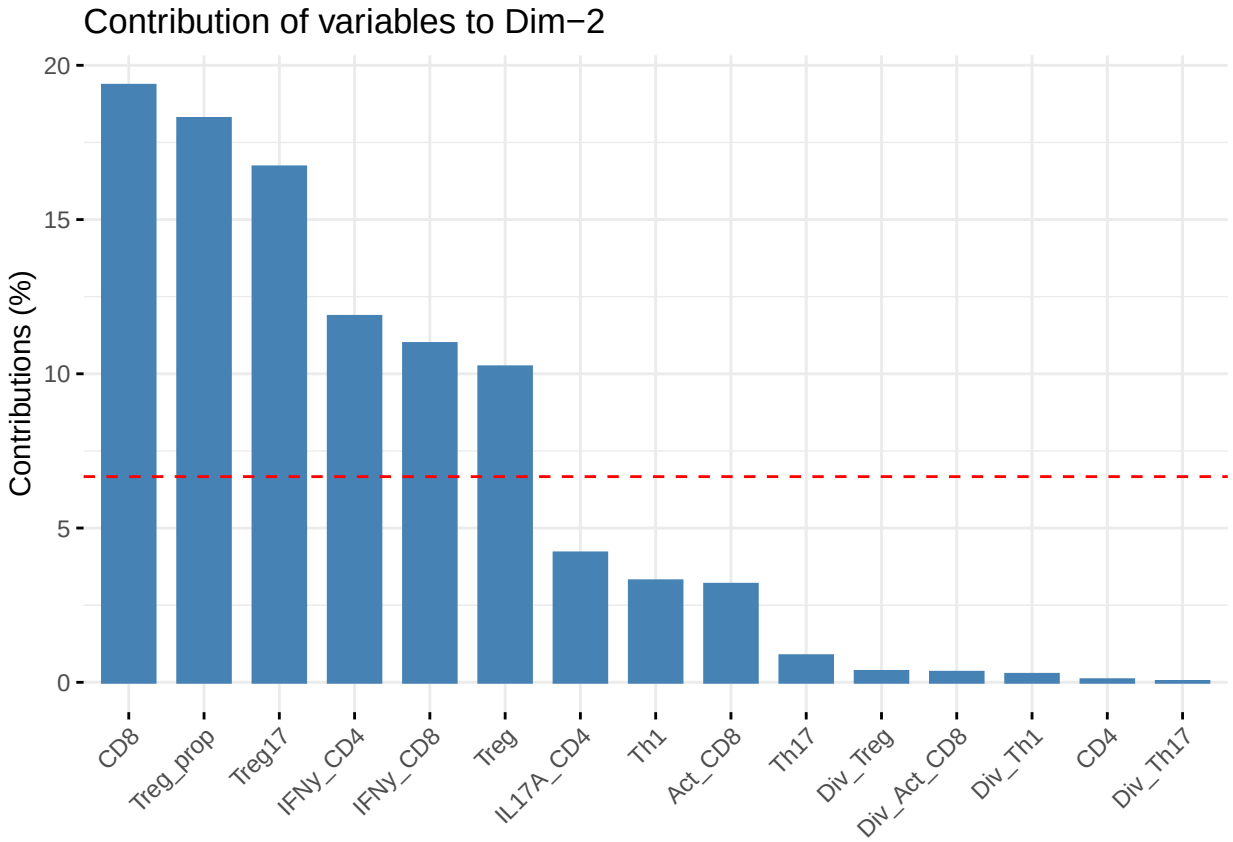
As all of the arrows are close to either the first or second axes, this means that the axes are stable with respect to the set of imputed tables –> we don't have evidence of instability here.

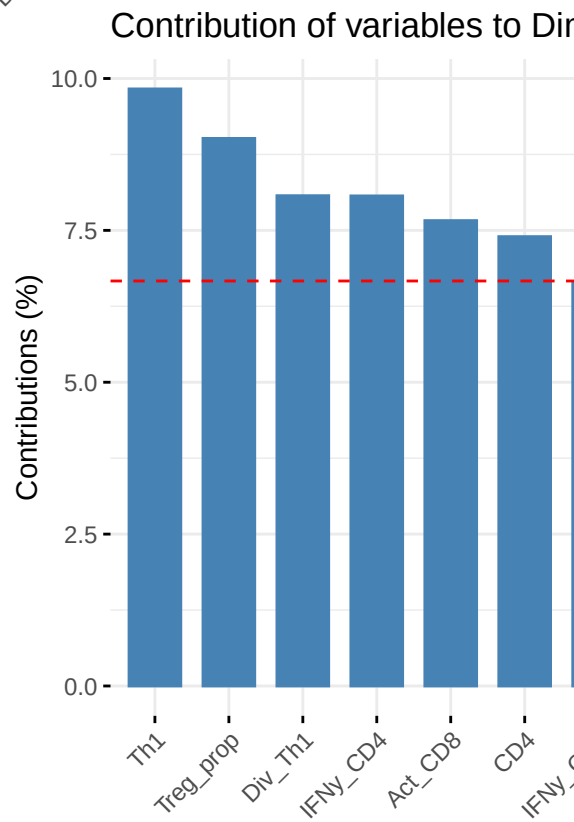

2.5
0.0
−2.5
−5.0
pc2
−5.0
−2.5
0.0
2.5
5.0
pc1
Parasite_challenge
Eimeria falciformis
Eimeria ferrisi
uninfected


Dim.1
Dim.2
Dim.3
Dim.4
Dim.5
CD4
Treg
Div_Treg
Treg17
Th1
Div_Th1
Th17
Div_Th17
CD8
Act_CD8
Div_Act_CD8
IFNy_CD4
IFNy_CD8
Treg_prop
IL17A_CD4
32.51
29.26
26.01
22.76
19.51
16.26
13.01
9.76
6.51
3.25
0

The function fviz_contrib() [factoextra package] can be used to draw a bar plot of variable contributions. If your data contains many variables, you can decide to show only the top contributing variables. The R code below shows the top 10 variables contributing to the principal components:





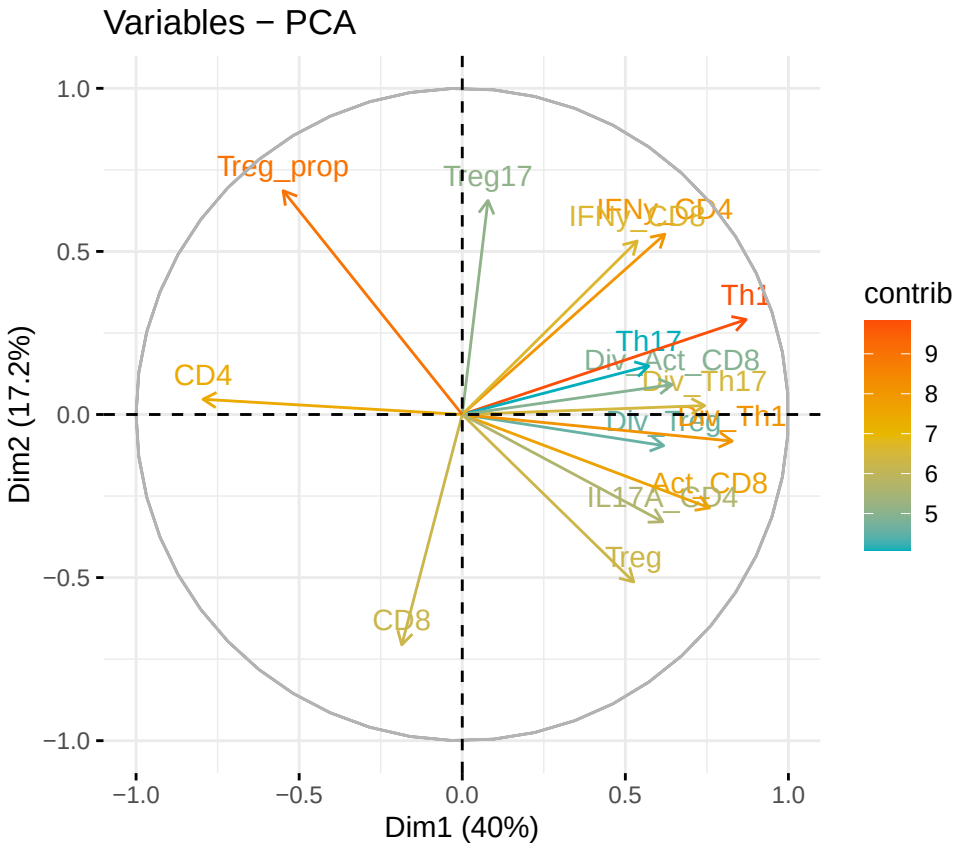


The total contribution to PC1 and PC2 is obtained with the following R code:
The red dashed line on the graph above indicates the expected average contribution. If the contribution of

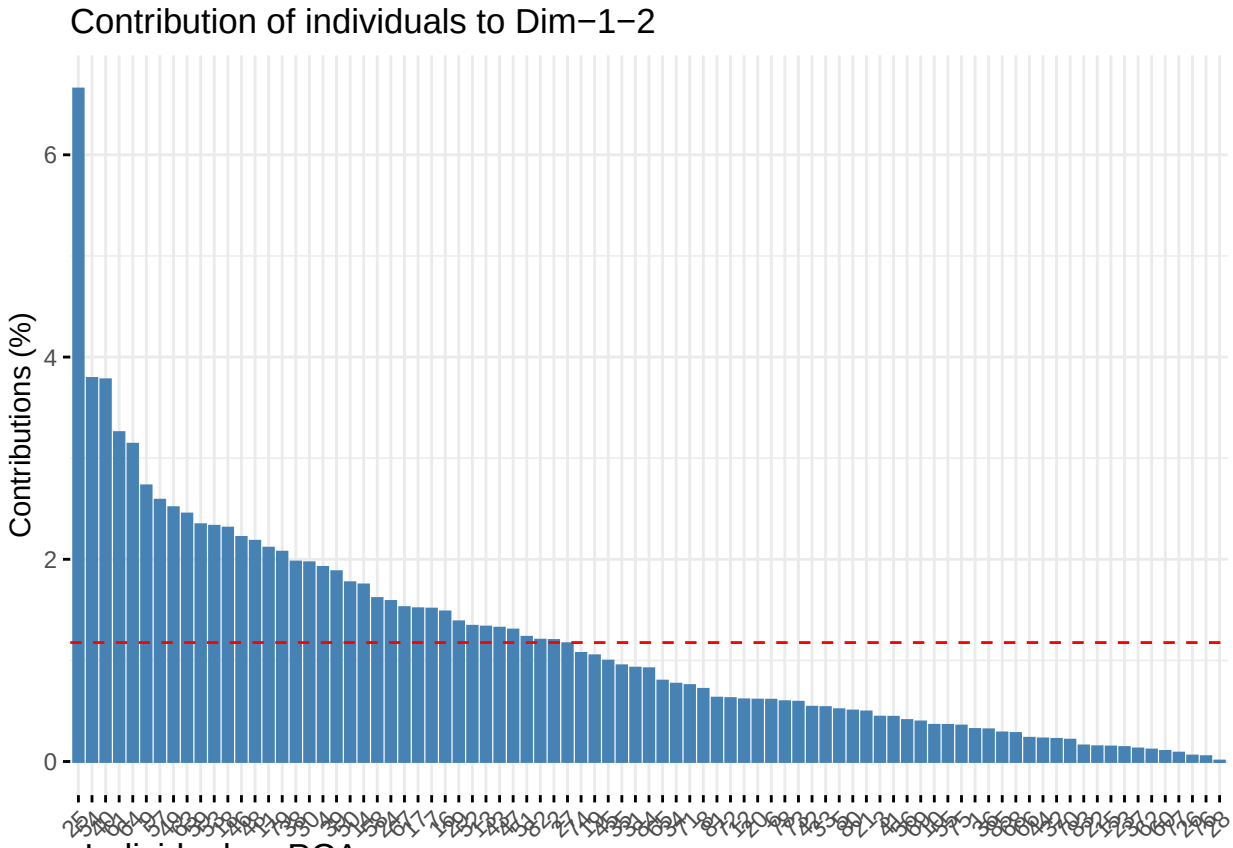
the variables were uniform, the expected value would be 1/length(variables) = 1/10 = 10%. For a given component, a variable with a contribution larger than this cutoff could be considered as important in contributing to the component.

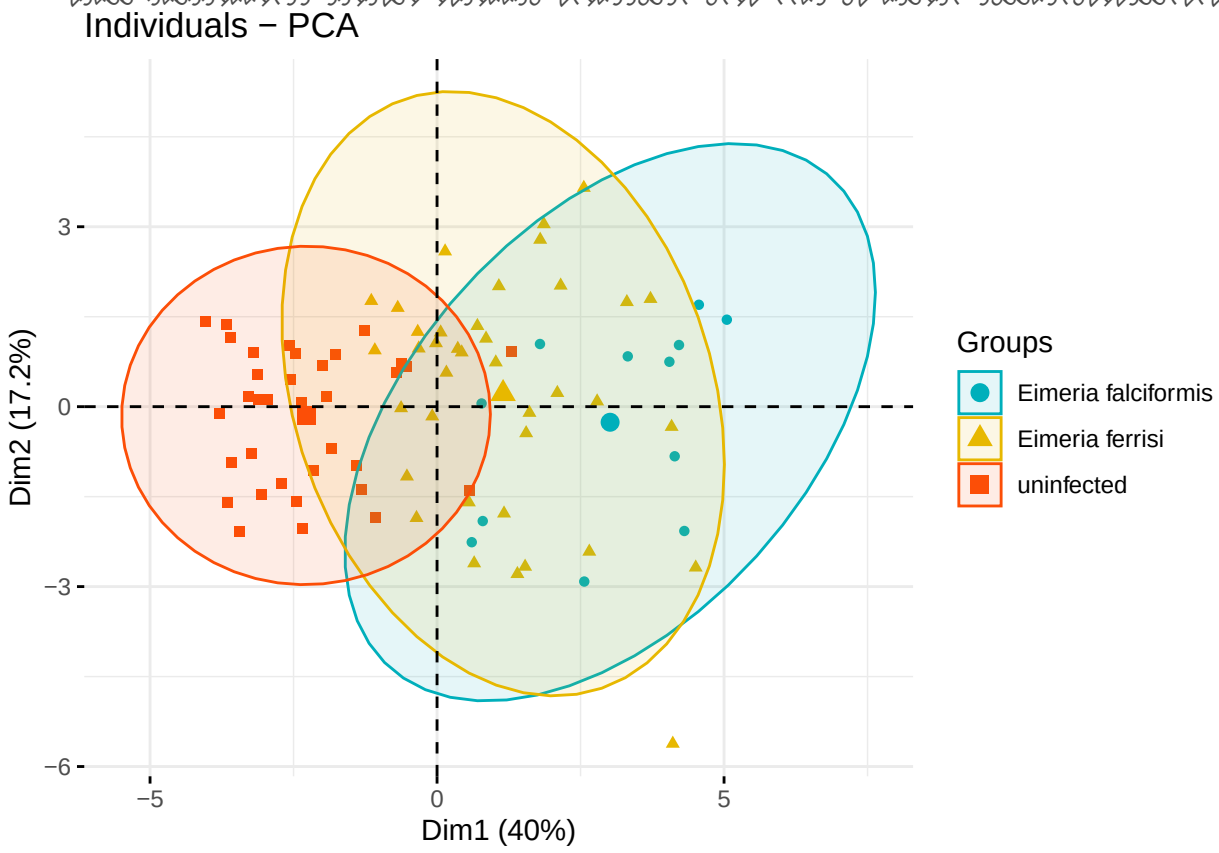
Note that, the total contribution of a given variable, on explaining the variations retained by two principal components, say PC1 and PC2, is calculated as contrib = [(C1 * Eig1) + (C2 * Eig2)]/(Eig1 + Eig2), where

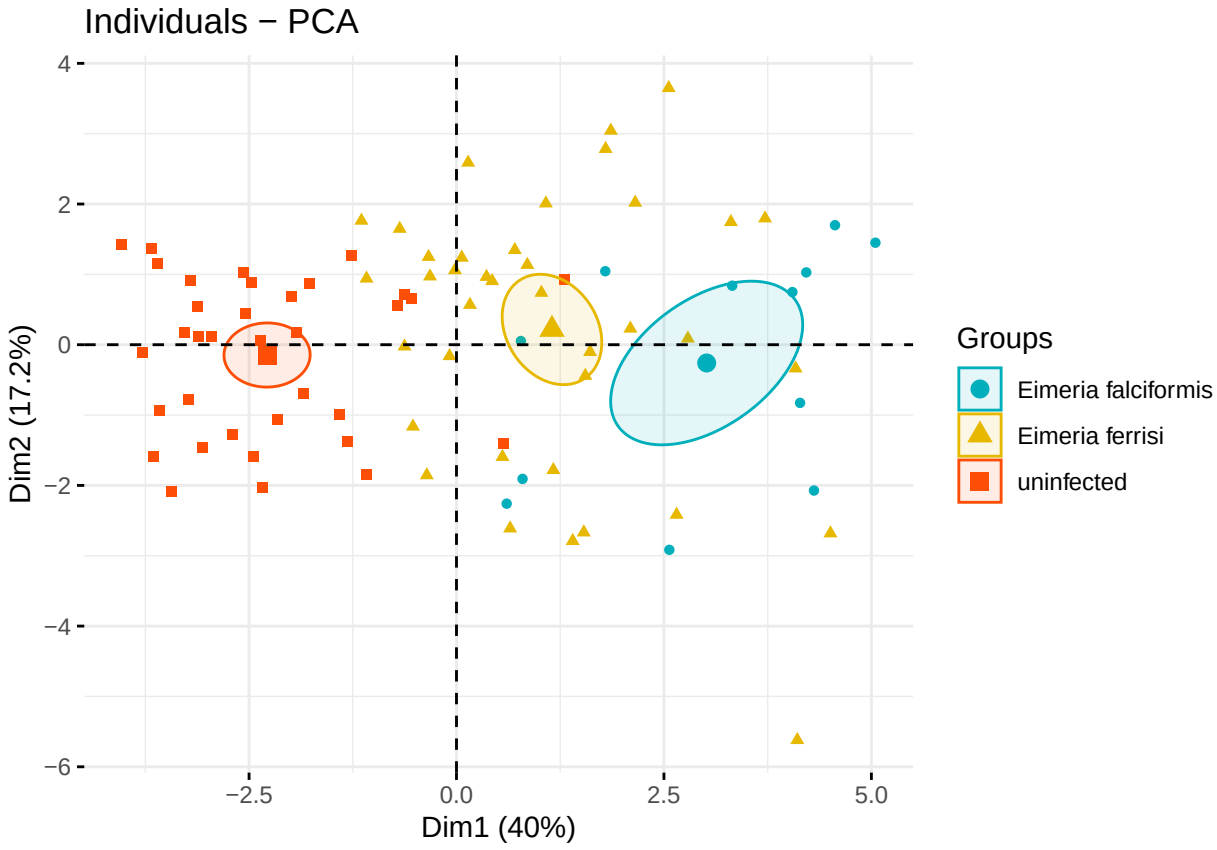
C1 and C2 are the contributions of the variable on PC1 and PC2, respectively Eig1 and Eig2 are the eigenvalues of PC1 and PC2, respectively. Recall that eigenvalues measure the amount of variation retained by each PC. In this case, the expected average contribution (cutoff) is calculated as follow: As mentioned above, if the contributions of the 10 variables were uniform, the expected average contribution on a given PC would be 1/10 = 10%. The expected average contribution of a variable for PC1 and PC2 is : [(10* Eig1) + (10 * Eig2)]/(Eig1 + Eig2)

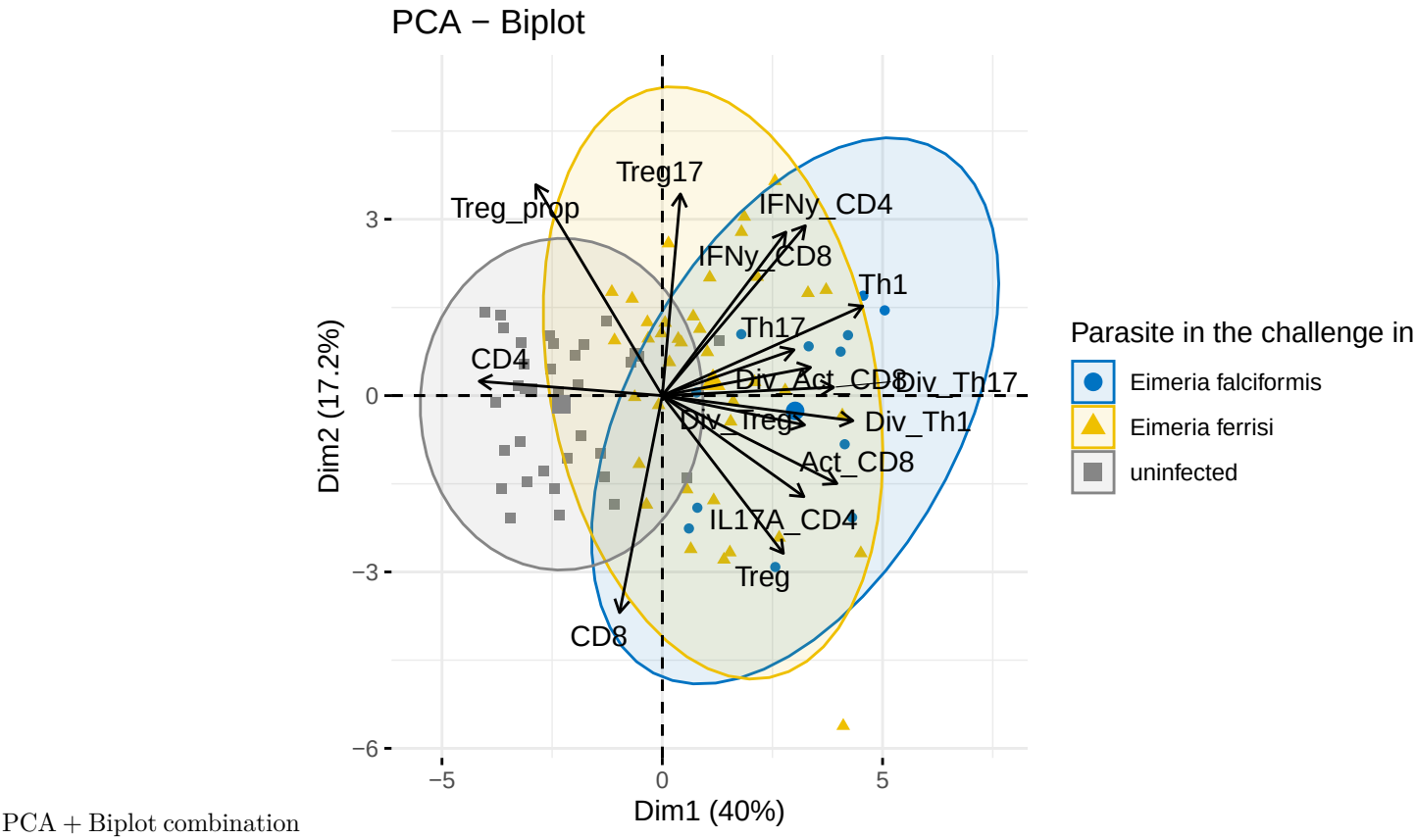


To visualize the contribution of individuals to the first two principal components, type this:


Contribution of individuals to Dim−1−2
Contributions (%)
0
2
4
6


Individuals − PCA
Dim2 (17.2%)
3
0
−3
−6
−5
0
5
Dim1 (40%)
Groups
Eimeria falciformis
Eimeria ferrisi
uninfected

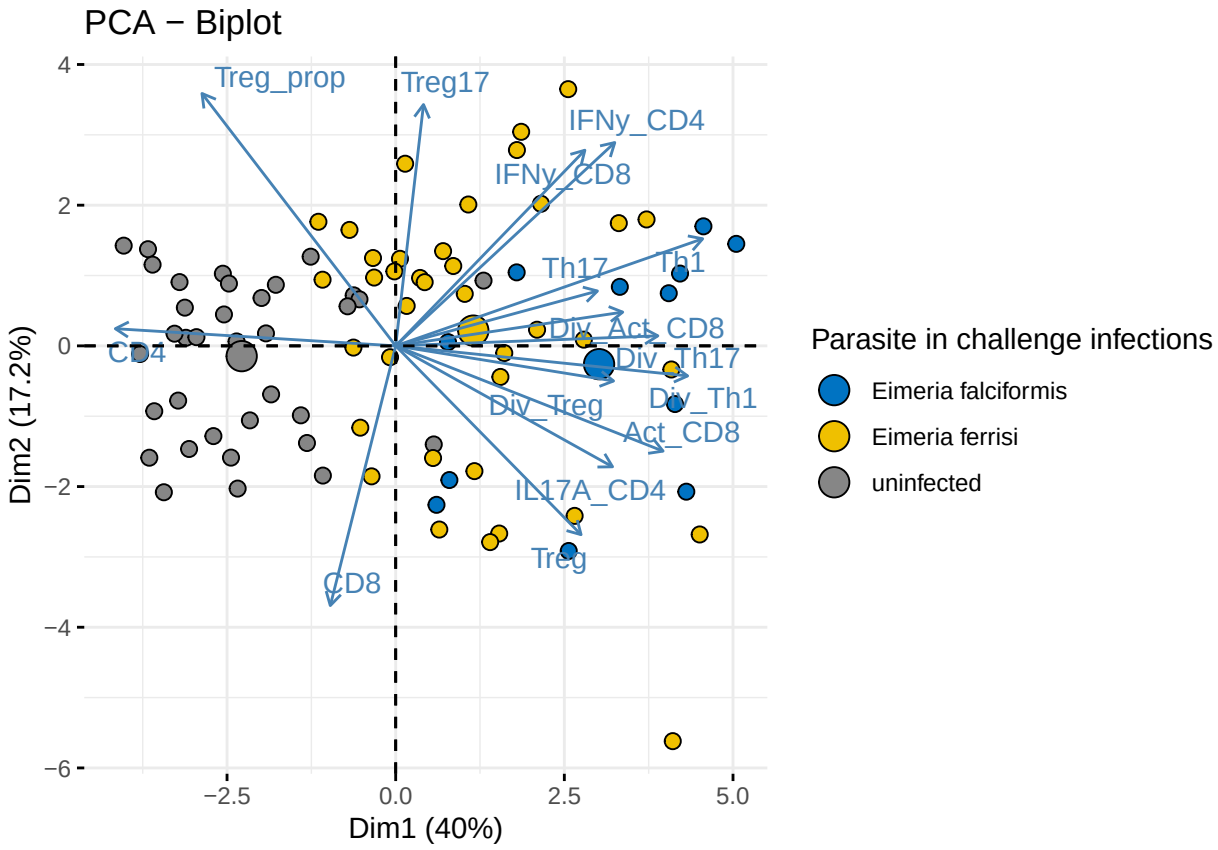


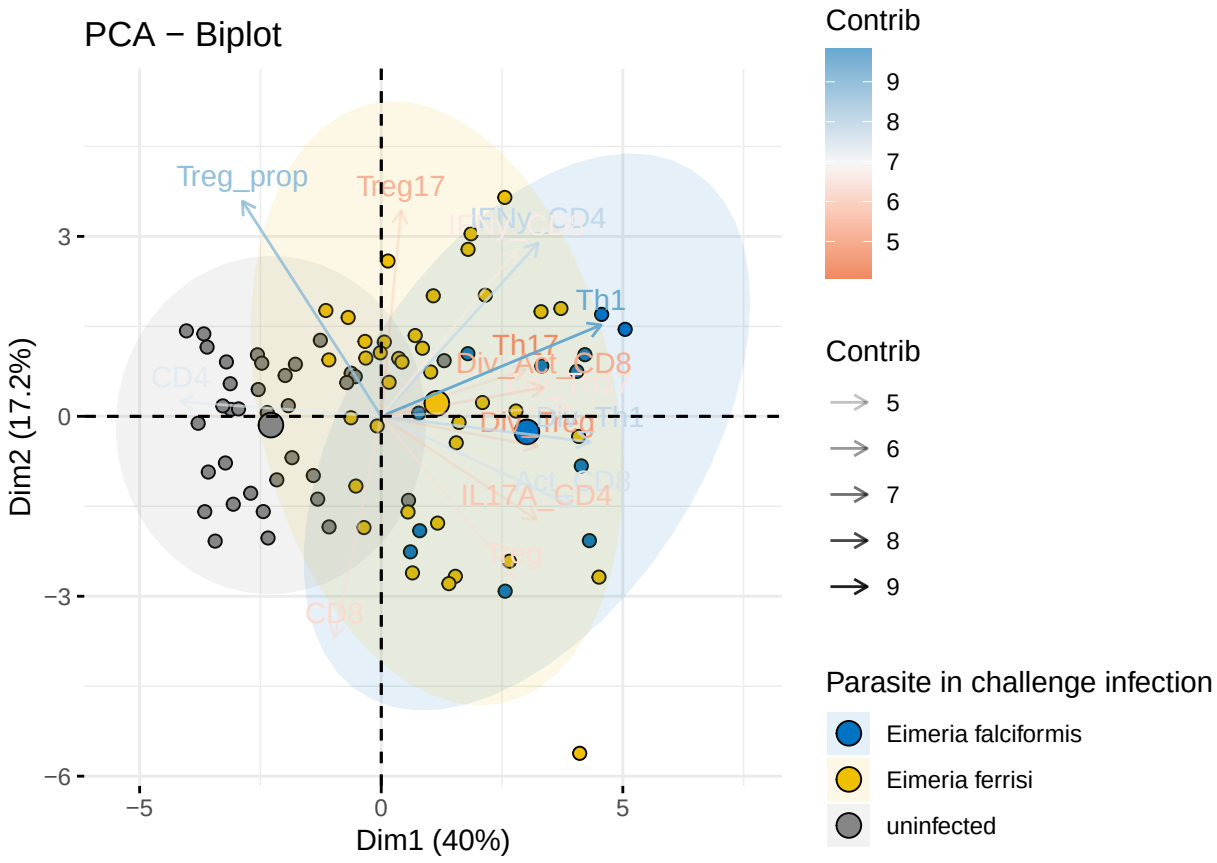


PCA + Biplot combination

In the following example, we want to color both individuals and variables by groups. The trick is to use pointshape = 21 for individual points. This particular point shape can be filled by a color using the argument fill.ind. The border line color of individual points is set to "black" using col.ind. To color variable by groups, the argument col.var will be used.

To customize individuals and variable colors, we use the helper functions fill_palette() and color_palette() [in ggpubr package].






```
##
## Call:
## lm(formula = max_WL ~ pc1 + pc2 + Parasite_challenge, data = f)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -16.5153  -2.8123   0.0956   3.6260  10.0898
##
## Coefficients:
##                                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      81.03793    1.85414  43.706  < 2e-16 ***
## pc1                               0.92903    0.38685   2.402   0.0186 *
## pc2                              -0.04972    0.34111  -0.146   0.8845
## Parasite_challengeEimeria ferrisi 11.00136    1.80891   6.082 3.86e-08 ***
## Parasite_challengeuninfected      17.01763    2.64360   6.437 8.36e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.999 on 80 degrees of freedom
## Multiple R-squared:  0.421,  Adjusted R-squared:  0.3921
## F-statistic: 14.54 on 4 and 80 DF,  p-value: 5.732e-09

## [1] 521.6388

##
## Call:
## lm(formula = max_WL ~ pc1 + pc2, data = f)
```

```
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -17.574  -3.088   1.439   4.302   9.075
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 92.96344    0.67013 138.724  < 2e-16 ***
## pc1         -0.79584    0.27372  -2.907  0.00469 **
## pc2         -0.03366    0.41754  -0.081  0.93594
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.178 on 82 degrees of freedom
## Multiple R-squared:  0.09352,    Adjusted R-squared:  0.07141
## F-statistic:  4.23 on 2 and 82 DF,  p-value: 0.01785
```

```
##                    df      AIC
## weight_lm           6 521.6388
## weight_lm_exp_only  4 555.7427
```