Management of genome-scale data with Bioconductor

Bioconductor Infrastructure: ExpressionSet and SummarizedExperimentSet

- Similar classes of objects expressionset usually array-based experiments and summarized experiment usually sequencing based experiments (rows = genomic ranges)
- Expression set lives in **Biobase** library
- **GeoQuery** allows you to pull down expressionsets by name using GSE identifier. Downloads the expressionset of microarray data
- List with single element in it access element
- Lots of metadata assayData, pheontypic data, experiment, anotations
- First sample column indexing
- first row or first feature row indexing
- Index by name
- pData phenotypic data information about columns of expression set
- as.numeric on factor to see how many replicates of each strain
- pData should have same # of rows as columns in the expression set
- Feature data accessible with **FData** genes / probe sets. Gene ID, gene symbol
- Experiment data and annotation data

library(Biobase)

```
## Loading required package: BiocGenerics
## Loading required package: parallel
## Attaching package: 'BiocGenerics'
## The following objects are masked from 'package:parallel':
##
##
       clusterApply, clusterApplyLB, clusterCall, clusterEvalQ,
##
       clusterExport, clusterMap, parApply, parCapply, parLapply,
       parLapplyLB, parRapply, parSapply, parSapplyLB
##
## The following objects are masked from 'package:stats':
##
##
       IQR, mad, sd, var, xtabs
## The following objects are masked from 'package:base':
##
##
       anyDuplicated, append, as.data.frame, basename, cbind, colnames,
##
       dirname, do.call, duplicated, eval, evalq, Filter, Find, get, grep,
##
       grepl, intersect, is.unsorted, lapply, Map, mapply, match, mget,
       order, paste, pmax, pmax.int, pmin, pmin.int, Position, rank,
##
##
       rbind, Reduce, rownames, sapply, setdiff, sort, table, tapply,
##
       union, unique, unsplit, which.max, which.min
## Welcome to Bioconductor
##
       Vignettes contain introductory material; view with
##
       'browseVignettes()'. To cite Bioconductor, see
##
##
       'citation("Biobase")', and for packages 'citation("pkgname")'.
library(GEOquery)
## Setting options('download.file.method.GEOquery'='auto')
```

```
## Setting options('GEOquery.inmemory.gpl'=FALSE)
geoq <- getGEO("GSE9514")</pre>
                          # download a microarray dataset from GEO
## Found 1 file(s)
## GSE9514_series_matrix.txt.gz
##
## -- Column specification ------
## cols(
##
    ID REF = col character(),
##
    GSM241146 = col_double(),
##
    GSM241147 = col double(),
    GSM241148 = col_double(),
##
##
    GSM241149 = col_double(),
##
    GSM241150 = col_double(),
##
    GSM241151 = col_double(),
##
    GSM241152 = col_double(),
    GSM241153 = col_double()
## )
## File stored at:
## /var/folders/cn/qxqp12fd2gx3m17yb_flfkxc0000gn/T//RtmpIFf3Qf/GPL90.soft
names (geoq)
## [1] "GSE9514_series_matrix.txt.gz"
e <- geoq[[1]]
                 # extract ExpressionSet
## ExpressionSet (storageMode: lockedEnvironment)
## assayData: 9335 features, 8 samples
##
    element names: exprs
## protocolData: none
## phenoData
    sampleNames: GSM241146 GSM241147 ... GSM241153 (8 total)
##
    varLabels: title geo_accession ... data_row_count (31 total)
##
    varMetadata: labelDescription
## featureData
##
    featureNames: 10000_at 10001_at ... AFFX-YFL039CM_at (9335 total)
##
    fvarLabels: ID ORF ... Gene Ontology Molecular Function (17 total)
    fvarMetadata: Column Description labelDescription
## experimentData: use 'experimentData(object)'
    pubMedIds: 18326586
## Annotation: GPL90
# exprs gives matrix of microarray values
         # number of features and samples in ExpressionSet
## Features Samples
##
      9335
ncol(e)
## Samples
##
```

```
nrow(e)
## Features
      9335
exprs(e)[1:3,1:3]
##
               GSM241146
                           GSM241147
                                       GSM241148
## 10000_at
                15.33081
                            9.459372
                                        7.984865
## 10001 at
               283.47190 300.729460 270.016080
## 10002_i_at 2569.45360 2382.814700 2711.814500
head(exprs(e))[,1]
                      # first column
##
      10000_at
                  10001_at 10002_i_at 10003_f_at
                                                      10004_at
                                                                  10005_at
##
               283.471900 2569.453600 7917.580600
                                                      4.744475
                                                                253.808090
exprs(e)[1,]
                # first row
## GSM241146 GSM241147 GSM241148 GSM241149 GSM241150 GSM241151 GSM241152 GSM241153
## 15.330812 9.459372 7.984865 7.899956 8.710567 7.749938 11.783052 8.327735
exprs(e)["10000_at",]
                         # can also index by name
## GSM241146 GSM241147 GSM241148 GSM241149 GSM241150 GSM241151 GSM241152 GSM241153
## 15.330812 9.459372 7.984865 7.899956 8.710567 7.749938 11.783052 8.327735
rownames(e)[1]
                  # row names are probe sets
## [1] "10000_at"
                 # rows are features, columns are samples
dim(exprs(e))
## [1] 9335
# pData gives phenotype data (sample information)
pData(e)[1:3,1:6]
##
                                                                             title
## GSM241146 hem1 strain grown in YPD with 250 uM ALA (08-15-06 Philpott YG S98 1)
               WT strain grown in YPD under Hypoxia (08-15-06_Philpott_YG_S98_10)
## GSM241147
## GSM241148
                WT strain grown in YPD under Hypoxia (08-15-06_Philpott_YG_S98_11)
##
            geo_accession
                                          status submission_date last_update_date
## GSM241146
                 GSM241146 Public on Nov 06 2007
                                                     Nov 02 2007
                                                                      Aug 14 2011
## GSM241147
                 GSM241147 Public on Nov 06 2007
                                                     Nov 02 2007
                                                                      Aug 14 2011
## GSM241148
                 GSM241148 Public on Nov 06 2007
                                                     Nov 02 2007
                                                                      Aug 14 2011
##
             type
## GSM241146 RNA
## GSM241147 RNA
## GSM241148 RNA
names(pData(e))
   [1] "title"
                                  "geo_accession"
##
   [3] "status"
                                  "submission_date"
  [5] "last_update_date"
                                  "type"
   [7] "channel_count"
                                  "source_name_ch1"
##
   [9] "organism_ch1"
                                  "characteristics_ch1"
##
## [11] "molecule_ch1"
                                  "extract_protocol_ch1"
## [13] "label_ch1"
                                  "label_protocol_ch1"
```

```
## [15] "taxid_ch1"
                                  "hyb_protocol"
## [17] "scan_protocol"
                                  "description"
## [19] "data_processing"
                                  "platform id"
## [21] "contact_name"
                                  "contact_email"
## [23] "contact_department"
                                  "contact_institute"
## [25] "contact address"
                                  "contact city"
## [27] "contact state"
                                  "contact_zip/postal_code"
## [29] "contact_country"
                                  "supplementary_file"
## [31] "data_row_count"
pData(e)$characteristics_ch1 # column in GEO to describe experimental state/condition
## [1] "BY4742 hem1 delta strain" "BY4742"
## [3] "BY4742"
                                  "BY4742 hem1 delta strain"
## [5] "BY4742 hem1 delta strain" "BY4742 hem1 delta strain"
## [7] "BY4742 strain"
                                  "BY4742 strain"
as.numeric(pData(e)$characteristics_ch1) # help see replicates of each state
## Warning: NAs introduced by coercion
## [1] NA NA NA NA NA NA NA
dim(pData(e)) # rows of pData correspond to columns of exprs
## [1] 8 31
dim(e)
## Features Samples
      9335
# fData gives feature data (probe information)
fData(e)[1:3,1:3]
##
                      ID
                             ORF SPOT_ID
## 10000_at
               10000_at YLR331C
## 10001_at 10001_at YLR332W
## 10002_i_at 10002_i_at YLR333C
dim(fData(e))
              # rows of fData correspond to rows of exprs
## [1] 9335
names(fData(e))
## [1] "ID"
                                           "ORF"
## [3] "SPOT_ID"
                                           "Species Scientific Name"
## [5] "Annotation Date"
                                           "Sequence Type"
## [7] "Sequence Source"
                                           "Target Description"
## [9] "Representative Public ID"
                                           "Gene Title"
## [11] "Gene Symbol"
                                           "ENTREZ GENE ID"
## [13] "RefSeq Transcript ID"
                                           "SGD accession number"
## [15] "Gene Ontology Biological Process" "Gene Ontology Cellular Component"
## [17] "Gene Ontology Molecular Function"
head(fData(e)$"Gene Symbol")
## [1] ""
               "MID2" "RPS25B" "RPS25B" ""
                                                    "NUP2"
```

```
head(rownames(e))
## [1] "10000_at"
                    "10001_at"
                                  "10002_i_at" "10003_f_at" "10004_at"
## [6] "10005_at"
# additional annotation tied to ExpressionSet
experimentData(e)
## Experiment data
     Experimenter name: Olga,,Protchenko
##
     Laboratory:
##
     Contact information: olgap@intra.niddk.nih.gov
##
     Title: Changes in gene expression in response to heme deficiency and hypoxia
     URL: https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE9514
##
     PMIDs: 18326586
##
##
     Abstract: A 33 word abstract is available. Use 'abstract' method.
##
##
     notes:
##
      contact_address:
##
         10 Center Dr, Bldg.10-Rm.9B-05
##
      contact_city:
##
         Bethesda
##
      contact_country:
##
         USA
##
      contact_department:
         NIDDK
##
      contact_email:
##
         olgap@intra.niddk.nih.gov
##
##
      contact_institute:
##
         National Institutes of health
##
      contact_name:
##
         Olga,,Protchenko
##
      contact_state:
##
         MD
##
      contact_zip/postal_code:
##
         20892
##
      contributor:
##
         Olga,,Protchenko
## Caroline,,Philpott
##
      geo_accession:
         GSE9514
##
##
      last_update_date:
##
         Jul 01 2016
##
      overall design:
         I.Heme depletion.The hem1 delta strain was grown for 6 hrs in YPD media su
## pplemented with 250 uM ALA. Cells were washed three times with water to re
## move excess ALA. Cells were then inoculated in duplicates into 15 ml cultu
## res of
## YPD media that was supplemented either with or without ALA. Cultur
## es were induced for 16 h before 5 ml of cells were harvested and washed
## hree times in DEPC water. The culture density at the time of harvest
## was
## approximately OD600=0.5.
## II.Hypoxia. BY45742 strain was grown for 6 hrs i
```

```
## n
## YPD medium and then inoculated in 15 ml the same medium and grown
## r normoxic or hypoxic conditions for 12 hrs. To create hypoxic
## conditions
## , cultures were incubated in an anaerobic chamber using a
## BBL-GasPak (BD
## Biosciences).
##
      platform_id:
##
         GPL90
##
     platform_taxid:
##
         4932
##
     pubmed_id:
##
        18326586
##
     relation:
##
         BioProject: https://www.ncbi.nlm.nih.gov/bioproject/PRJNA103313
##
      sample_id:
         GSM241146 GSM241147 GSM241148 GSM241149 GSM241150 GSM241151 GSM241152 GSM2
##
## 41153
##
      sample_taxid:
##
         4932
##
      status:
         Public on Nov 06 2007
##
##
      submission date:
        Nov 05 2007
##
##
      summary:
##
         We addressed changes in gene expression profile in response to
## reduced ox
## ygen tension in wild type or heme depletion caused by
## deletion of heme bi
## osynthesis gene hem1
## Keywords: Response to heme depletion and hypoxia
##
      supplementary_file:
##
         ftp://ftp.ncbi.nlm.nih.gov/geo/series/GSE9nnn/GSE9514/suppl/GSE9514_RAW.ta
## r
##
      title:
##
         Changes in gene expression in response to heme deficiency and hypoxia
##
      type:
         Expression profiling by array
annotation(e)
## [1] "GPL90"
```

Assessment: ExpressionSet

```
library(GSE5859Subset)
data(GSE5859Subset)
dim(geneExpression)

## [1] 8793 24
dim(sampleInfo)
```

```
## [1] 24 4
dim(geneAnnotation)
## [1] 8793
identical(colnames(geneExpression), sampleInfo$filename)
## [1] TRUE
identical(rownames(geneExpression), geneAnnotation$PROBEID)
## [1] TRUE
pd = AnnotatedDataFrame(sampleInfo)
rownames(pd) = colnames(geneExpression)
experiment_date <- pData(pd) ["GSM136530.CEL.gz","date"]</pre>
paste("experiment date: ", experiment_date)
## [1] "experiment date: 2005-06-27"
varLabels(pd)
## [1] "ethnicity" "date"
                                 "filename"
                                             "group"
fd = AnnotatedDataFrame(geneAnnotation)
rownames(fd) = geneAnnotation$PROBEID
pData(fd)["204810_s_at", "CHR"]
## [1] "chr19"
eset = ExpressionSet(geneExpression,phenoData = pd,featureData = fd)
ind1 <- which(featureData(eset)$CHR == "chrY")</pre>
ind2 <- pData(eset)$group == 1</pre>
femaleY <- colMeans(exprs(eset)[ind1, ind2])</pre>
maleY <- colMeans(exprs(eset)[ind1, !ind2])</pre>
boxplot(maleY, femaleY)
9
                                                            0
\infty
                                                            0
                         1
                                                            2
median_diff=median(maleY) - median(femaleY)
```

[1] "Difference in median expression of genes on the Y chromosome between maleY and femaleY: 0.8049

Reading Microarray Raw Data: Single-Color Arrays

- loading microArray data into R: Affymetrix one-color arrays and Agilent two-color
- Affy package: parsers for reading in raw data files
- cel files are raw data
- sample info files have table describing each sample
- **pm** = perfect match probe-level intensities
- columns of probe-level data will match the rows of pData each row represents a sample and column matches sample. Rownames pData match colnames pm
- Keep character which represents platform that the technology used
- Bioconductor has a package which matches gene IDs to meaningful terms
- Experiment data, sample information, third piece of information which connects us to other information which describes genes
- Last step: turn into gene-level information -> probe level. Algorithm **rma** implemented in Bioconductor to do this using quantile normalization and background correction.
- If only want gene expression data and not probe-level, you can use **justRMA** function to read and process in one shot

```
wd <- getwd()
datadir <- paste0(wd, "/rawdata-master")  # downloaded files
basedir <- paste0(datadir, "/celfiles")
setwd(basedir)
library(affy)
tab <- read.delim("sampleinfo.txt",check.names=FALSE,as.is=TRUE)
rownames(tab) <- tab$filenames</pre>
tab
```

```
##
                                           filenames 37777 at 684 at 1597 at
## 1521a99hpp_av06.CEL.gz
                              1521a99hpp_av06.CEL.gz
                                                          0.00
                                                                  0.25
                                                                           0.5
## 1532a99hpp_av04.CEL.gz
                              1532a99hpp_av04.CEL.gz
                                                          0.00
                                                                  0.25
                                                                           0.5
## 2353a99hpp_av08.CEL.gz
                              2353a99hpp_av08.CEL.gz
                                                          0.00
                                                                  0.25
                                                                           0.5
## 1521b99hpp_av06.CEL.gz
                              1521b99hpp_av06.CEL.gz
                                                          0.25
                                                                  0.50
                                                                           1.0
                              1532b99hpp_av04.CEL.gz
## 1532b99hpp_av04.CEL.gz
                                                          0.25
                                                                  0.50
                                                                           1.0
## 2353b99hpp_av08r.CEL.gz 2353b99hpp_av08r.CEL.gz
                                                          0.25
                                                                  0.50
                                                                           1.0
##
                            38734_at 39058_at 36311_at 36889_at 1024_at 36202_at
## 1521a99hpp_av06.CEL.gz
                                             2
                                                       4
                                                                 8
                                    1
                                                                        16
                                             2
                                                                8
## 1532a99hpp_av04.CEL.gz
                                    1
                                                       4
                                                                        16
                                                                                  32
## 2353a99hpp_av08.CEL.gz
                                    1
                                             2
                                                       4
                                                                8
                                                                        16
                                                                                  32
## 1521b99hpp_av06.CEL.gz
                                    2
                                             4
                                                       8
                                                                16
                                                                        32
                                                                                  64
## 1532b99hpp_av04.CEL.gz
                                    2
                                             4
                                                                16
                                                                        32
                                                       8
                                                                                  64
## 2353b99hpp_av08r.CEL.gz
                                    2
                                             4
                                                                16
                                                                        32
                                                       8
                                                                                  64
                            36085_at 40322_at 407_at 1091_at 1708_at 33818_at
## 1521a99hpp_av06.CEL.gz
                                   64
                                           128
                                                  0.00
                                                           512
                                                                   1024
                                                                             256
## 1532a99hpp_av04.CEL.gz
                                   64
                                           128
                                                  0.00
                                                           512
                                                                   1024
                                                                             256
## 2353a99hpp av08.CEL.gz
                                   64
                                           128
                                                  0.00
                                                           512
                                                                   1024
                                                                             256
## 1521b99hpp_av06.CEL.gz
                                  128
                                           256
                                                  0.25
                                                          1024
                                                                      0
                                                                             512
## 1532b99hpp_av04.CEL.gz
                                  128
                                           256
                                                  0.25
                                                          1024
                                                                      0
                                                                             512
## 2353b99hpp_av08r.CEL.gz
                                  128
                                           256
                                                  0.25
                                                          1024
                                                                             512
                                                                      0
##
                            546_at
```

```
## 1521a99hpp_av06.CEL.gz
                                32
## 1532a99hpp_av04.CEL.gz
                                32
## 2353a99hpp_av08.CEL.gz
                                32
## 1521b99hpp_av06.CEL.gz
                                64
## 1532b99hpp_av04.CEL.gz
                                64
## 2353b99hpp_av08r.CEL.gz
                                64
fns <- list.celfiles(basedir)</pre>
## [1] "1521a99hpp_av06.CEL.gz"
                                  "1521b99hpp_av06.CEL.gz"
## [3] "1532a99hpp_av04.CEL.gz"
                                  "1532b99hpp_av04.CEL.gz"
## [5] "2353a99hpp_av08.CEL.gz"
                                  "2353b99hpp_av08r.CEL.gz"
fns %in% tab[,1] ##check
## [1] TRUE TRUE TRUE TRUE TRUE TRUE
ab <- ReadAffy(phenoData=tab)
dim(pm(ab))
## Warning: replacing previous import 'AnnotationDbi::tail' by 'utils::tail' when
## loading 'hgu95acdf'
## Warning: replacing previous import 'AnnotationDbi::head' by 'utils::head' when
## loading 'hgu95acdf'
##
## [1] 201807
dim(pData(ab))
## [1] 6 17
rownames(ab)
##
       [1] "100_g_at"
                                           "1000_at"
       [3] "1001_at"
##
                                           "1002_f_at"
##
       [5] "1003_s_at"
                                           "1004_at"
##
       [7] "1005_at"
                                           "1006_at"
##
       [9] "1007_s_at"
                                           "1008_f_at"
##
      [11] "1009_at"
                                           "101_at"
##
      [13] "1010_at"
                                           "1011_s_at"
##
      [15] "1012_at"
                                           "1013_at"
      [17] "1014 at"
##
                                           "1015 s at"
      [19] "1016_s_at"
                                           "1017_at"
##
##
      [21] "1018_at"
                                           "1019_g_at"
##
      [23] "102_at"
                                           "1020_s_at"
##
      [25] "1021_at"
                                           "1022_f_at"
      [27] "1023_at"
                                           "1024_at"
##
##
      [29] "1025_g_at"
                                           "1026_s_at"
##
      [31] "1027_at"
                                           "1028_at"
##
      [33] "1029_s_at"
                                           "103_at"
##
      [35] "1030_s_at"
                                           "1031_at"
##
      [37] "1032_at"
                                           "1033_g_at"
##
      [39] "1034_at"
                                           "1035_g_at"
      [41] "1036_at"
                                           "1037_at"
##
```

```
##
      [43] "1038_s_at"
                                            "1039_s_at"
##
      [45] "104_at"
                                            "1040_s_at"
##
      [47] "1041 at"
                                            "1042 at"
##
      [49] "1043_s_at"
                                            "1044_s_at"
##
      [51] "1045 s at"
                                            "1046 at"
##
      [53] "1047 s at"
                                            "1048 at"
##
      [55] "1049 g at"
                                            "105 at"
      [57] "1050 at"
                                            "1051_g_at"
##
##
      [59] "1052_s_at"
                                            "1053 at"
##
      [61] "1054_at"
                                            "1055_g_at"
##
      [63] "1056_s_at"
                                            "1057_at"
      [65] "1058_at"
                                            "1059_at"
##
##
      [67] "106_at"
                                            "1060_g_at"
##
      [69] "1061_at"
                                            "1062_g_at"
##
      [71] "1063_s_at"
                                            "1064_at"
##
      [73] "1065_at"
                                            "1066_at"
##
      [75] "1067_at"
                                            "1068_g_at"
##
      [77] "1069 at"
                                            "107 at"
##
      [79] "1070_at"
                                            "1071_at"
##
      [81] "1072_g_at"
                                            "1073 at"
##
      [83] "1074_at"
                                            "1075_f_at"
##
      [85] "1076 at"
                                            "1077 at"
      [87] "1078_at"
##
                                            "1079_g_at"
      [89] "108_g_at"
                                            "1080_s_at"
##
##
      [91] "1081 at"
                                            "1082 at"
      [93] "1083_s_at"
##
                                            "1084 at"
      [95] "1085_s_at"
##
                                            "1086_at"
      [97] "1087_at"
                                            "1088_at"
##
##
      [99] "1089_i_at"
                                            "109_at"
##
     [101] "1090_f_at"
                                            "1091_at"
##
     [103] "1092_at"
                                            "1093_at"
##
     [105] "1094_g_at"
                                            "1095_s_at"
##
     [107] "1096_g_at"
                                            "1097_s_at"
     [109] "1098_at"
                                            "1099_s_at"
##
##
     [111] "110 at"
                                            "1100 at"
##
     [113] "1101_at"
                                            "1102_s_at"
##
     [115] "1103 at"
                                            "1104 s at"
##
     [117] "1105_s_at"
                                            "1106_s_at"
                                            "1108_s_at"
##
     [119] "1107_s_at"
##
     [121] "1109_s_at"
                                            "111_at"
     [123] "1110 at"
                                            "1111 at"
##
     [125] "1112_g_at"
##
                                            "1113_at"
##
     [127] "1114_at"
                                            "1115 at"
##
     [129] "1116_at"
                                            "1117_at"
     [131] "1118_at"
##
                                            "1119_at"
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79] "32266_a+

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                                        "712_s_at"
## [12273] "713_at"
                                        "714_at"
                                        "716_at"
## [12275] "715_s_at"
## [12277] "717_at"
                                        "718_at"
## [12279] "719_g_at"
                                        "720_at"
## [12281] "721_g_at"
                                        "722_at"
## [12283] "723_s_at"
                                       "724_at"
                                       "726_f_at"
## [12285] "725_i_at"
## [12287] "727_at"
                                       "728 at"
## [12289] "729 i at"
                                        "730_r_at"
## [12291] "731_f_at"
                                       "732_f_at"
## [12293] "733_at"
                                        "734 at"
## [12295] "735_s_at"
                                        "736 f at"
                                       "738_at"
## [12297] "737_at"
                                        "740_at"
## [12299] "739_at"
## [12301] "741_g_at"
                                        "742 at"
                                        "744_at"
## [12303] "743_at"
## [12305] "745_at"
                                        "746_at"
                                        "748_s_at"
## [12307] "747_at"
## [12309] "749_at"
                                        "750 at"
## [12311] "751_at"
                                        "752_s_at"
## [12313] "753_at"
                                        "754_s_at"
                                       "756_at"
## [12315] "755_at"
## [12317] "757_at"
                                        "758_at"
                                        "760_at"
## [12319] "759 at"
## [12321] "761_g_at"
                                        "762_f_at"
## [12323] "763_at"
                                        "764 s at"
## [12325] "765_s_at"
                                        "766_at"
## [12327] "767 at"
                                        "768 at"
## [12329] "769_s_at"
                                        "770_at"
## [12331] "771_s_at"
                                        "772_at"
## [12333] "773_at"
                                        "774_g_at"
## [12335] "775_at"
                                        "776_at"
## [12337] "777_at"
                                        "778_s_at"
## [12339] "779_at"
                                        "780_at"
## [12341] "781_at"
                                        "782_at"
## [12343] "783_at"
                                        "784_g_at"
                                        "786_at"
## [12345] "785_at"
                                        "788_s_at"
## [12347] "787_at"
                                        "790_at"
## [12349] "789 at"
## [12351] "791_g_at"
                                        "792_s_at"
## [12353] "793_at"
                                        "794 at"
```

```
## [12355] "795_s_at"
                                        "796 i at"
## [12357] "797_at"
                                         "798 at"
## [12359] "799 at"
                                        "800 g at"
## [12361] "801_at"
                                        "802 at"
## [12363] "803_at"
                                        "804 s at"
## [12365] "805 at"
                                        "806 at"
## [12367] "807 at"
                                        "808 at"
                                        "810_at"
## [12369] "809 at"
## [12371] "811_at"
                                        "812 at"
                                        "814_s_at"
## [12373] "813_at"
## [12375] "815_at"
                                        "816_g_at"
## [12377] "817_at"
                                       "818_s_at"
## [12379] "819_at"
                                        "820 at"
                                        "822_s_at"
## [12381] "821_s_at"
                                        "824_at"
## [12383] "823_at"
## [12385] "825_at"
                                        "826_at"
## [12387] "827_s_at"
                                        "828_at"
## [12389] "829 s at"
                                       "830_at"
                                       "832_at"
## [12391] "831_at"
                                        "834_at"
## [12393] "833 at"
## [12395] "835_at"
                                        "836 at"
## [12397] "837 s at"
                                        "838_s_at"
## [12399] "839_at"
                                        "840_at"
## [12401] "841 at"
                                        "842 at"
## [12403] "843 at"
                                        "844 at"
                                       "846_s_at"
## [12405] "845 at"
                                        "848_at"
## [12407] "847_at"
## [12409] "849_g_at"
                                        "850_r_at"
                                        "852_at"
## [12411] "851_s_at"
## [12413] "853 at"
                                        "854 at"
## [12415] "855_at"
                                        "856_at"
                                        "858_at"
## [12417] "857_at"
## [12419] "859_at"
                                        "860_at"
## [12421] "861_g_at"
                                        "862_at"
## [12423] "863 g at"
                                        "864_at"
## [12425] "865_at"
                                        "866_at"
## [12427] "867 s at"
                                        "868 at"
                                        "870_f_at"
## [12429] "869_at"
## [12431] "871_s_at"
                                        "872_i_at"
## [12433] "873_at"
                                        "874_at"
## [12435] "875 g at"
                                        "876 at"
## [12437] "877 at"
                                        "878_s_at"
## [12439] "879_at"
                                        "880 at"
## [12441] "881_at"
                                        "882_at"
## [12443] "883_s_at"
                                        "884_at"
## [12445] "885_g_at"
                                        "886_at"
## [12447] "887_at"
                                        "888_s_at"
## [12449] "889_at"
                                        "890 at"
## [12451] "891_at"
                                        "892_at"
                                        "894_g_at"
## [12453] "893_at"
## [12455] "895_at"
                                        "896_at"
                                        "898_s_at"
## [12457] "897 at"
## [12459] "899 at"
                                        "900 at"
## [12461] "901 g at"
                                         "902 at"
```

```
## [12463] "903 at"
                                        "904 s at"
## [12465] "905_at"
                                        "906 at"
## [12467] "907 at"
                                        "908 at"
## [12469] "909_g_at"
                                        "910_at"
## [12471] "911_s_at"
                                        "912_s_at"
## [12473] "913 at"
                                        "914 g at"
## [12475] "915 at"
                                        "916 at"
## [12477] "917_g_at"
                                       "918_at"
## [12479] "919_at"
                                        "920 at"
## [12481] "921_s_at"
                                        "922_at"
## [12483] "923_at"
                                        "924_s_at"
## [12485] "925_at"
                                        "926_at"
## [12487] "927_s_at"
                                        "928_at"
                                        "930_at"
## [12489] "929_at"
                                        "932_i_at"
## [12491] "931_at"
## [12493] "933_f_at"
                                        "934_at"
## [12495] "935_at"
                                        "936_s_at"
## [12497] "937 at"
                                        "938_at"
                                       "940_g_at"
## [12499] "939_at"
                                       "942_at"
## [12501] "941 at"
                                        "944_s_at"
## [12503] "943_at"
## [12505] "945 at"
                                        "946_at"
## [12507] "947_at"
                                        "948_s_at"
## [12509] "949 s at"
                                        "950 at"
## [12511] "951 at"
                                        "952 at"
## [12513] "953_g_at"
                                       "954_s_at"
## [12515] "955_at"
                                        "956_at"
## [12517] "957_at"
                                        "958_s_at"
## [12519] "959_at"
                                        "960_g_at"
## [12521] "961_at"
                                        "962_at"
                                        "964_at"
## [12523] "963_at"
## [12525] "965_at"
                                        "966_at"
## [12527] "967_g_at"
                                        "968_i_at"
## [12529] "969_s_at"
                                       "970_r_at"
                                       "972_s_at"
## [12531] "971 s at"
## [12533] "973_at"
                                        "974 at"
                                        "976_s_at"
## [12535] "975 at"
## [12537] "977_s_at"
                                        "978_at"
## [12539] "979_g_at"
                                        "980_at"
## [12541] "981_at"
                                        "982_at"
                                       "984_g_at"
## [12543] "983 at"
## [12545] "985_s_at"
                                        "986_at"
## [12547] "987_g_at"
                                        "988 at"
## [12549] "989_at"
                                        "990_at"
## [12551] "991_g_at"
                                        "992_at"
## [12553] "993_at"
                                        "994_at"
## [12555] "995_g_at"
                                        "996_at"
## [12557] "997_at"
                                        "998_s_at"
## [12559] "999_at"
                                       "AFFX-BioB-3_at"
                                       "AFFX-BioB-5_at"
## [12561] "AFFX-BioB-3_st"
                                      "AFFX-BioB-M_at"
## [12563] "AFFX-BioB-5_st"
                                    "AFFX-BioC-3_at"
"AFFX-BioC-5_at"
## [12565] "AFFX-BioB-M_st"
## [12567] "AFFX-BioC-3_st"
## [12569] "AFFX-BioC-5_st"
                                       "AFFX-BioDn-3_at"
```

```
## [12571] "AFFX-BioDn-3 st"
                                          "AFFX-BioDn-5 at"
## [12573] "AFFX-BioDn-5_st"
                                          "AFFX-CreX-3_at"
## [12575] "AFFX-CreX-3 st"
                                          "AFFX-CreX-5 at"
## [12577] "AFFX-CreX-5_st"
                                          "AFFX-DapX-3_at"
## [12579] "AFFX-DapX-5_at"
                                          "AFFX-DapX-M at"
## [12581] "AFFX-HSAC07/X00351 3 at"
                                          "AFFX-HSAC07/X00351 3 st"
## [12583] "AFFX-HSAC07/X00351 5 at"
                                          "AFFX-HSAC07/X00351 5 st"
## [12585] "AFFX-HSAC07/X00351_M_at"
                                          "AFFX-HSACO7/X00351 M st"
## [12587] "AFFX-hum alu at"
                                          "AFFX-HUMGAPDH/M33197 3 at"
                                          "AFFX-HUMGAPDH/M33197_5_at"
## [12589] "AFFX-HUMGAPDH/M33197_3_st"
## [12591] "AFFX-HUMGAPDH/M33197_5_st"
                                          "AFFX-HUMGAPDH/M33197_M_at"
## [12593] "AFFX-HUMGAPDH/M33197_M_st"
                                          "AFFX-HUMISGF3A/M97935_3_at"
## [12595] "AFFX-HUMISGF3A/M97935_5_at"
                                          "AFFX-HUMISGF3A/M97935_MA_at"
## [12597] "AFFX-HUMISGF3A/M97935_MB_at"
                                         "AFFX-HUMRGE/M10098_3_at"
## [12599] "AFFX-HUMRGE/M10098_5_at"
                                          "AFFX-HUMRGE/M10098_M_at"
## [12601] "AFFX-HUMTFRR/M11507_3_at"
                                          "AFFX-HUMTFRR/M11507_5_at"
## [12603] "AFFX-HUMTFRR/M11507_M_at"
                                          "AFFX-LysX-3_at"
## [12605] "AFFX-LysX-5 at"
                                          "AFFX-LvsX-M at"
## [12607] "AFFX-M27830_3_at"
                                          "AFFX-M27830_5_at"
## [12609] "AFFX-M27830 M at"
                                          "AFFX-MurFAS at"
## [12611] "AFFX-MurIL10_at"
                                          "AFFX-MurIL2_at"
## [12613] "AFFX-MurIL4_at"
                                          "AFFX-PheX-3 at"
## [12615] "AFFX-PheX-5 at"
                                          "AFFX-PheX-M at"
## [12617] "AFFX-ThrX-3 at"
                                          "AFFX-ThrX-5 at"
## [12619] "AFFX-ThrX-M at"
                                          "AFFX-TrpnX-3 at"
## [12621] "AFFX-TrpnX-5_at"
                                          "AFFX-TrpnX-M_at"
## [12623] "AFFX-YEL002c/WBP1_at"
                                          "AFFX-YEL018w/_at"
## [12625] "AFFX-YEL021w/URA3_at"
                                          "AFFX-YEL024w/RIP1_at"
colnames(pm(ab))
## [1] "1521a99hpp_av06.CEL.gz"
                                  "1532a99hpp_av04.CEL.gz"
## [3] "2353a99hpp_av08.CEL.gz"
                                  "1521b99hpp_av06.CEL.gz"
## [5] "1532b99hpp_av04.CEL.gz"
                                 "2353b99hpp_av08r.CEL.gz"
annotation(ab)
## [1] "hgu95a"
```

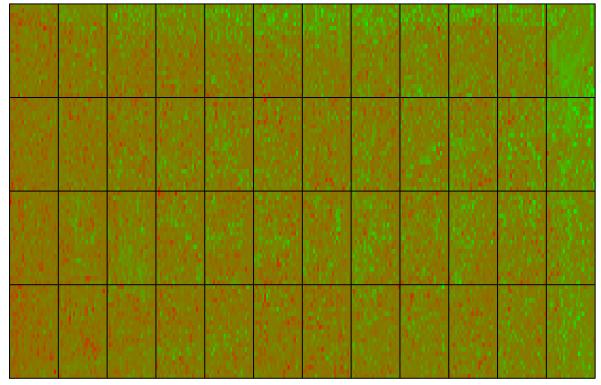
Agilent two-color Arrays

- Package limma for two-color arrays
- Read in sample information pairing of files to tell you what is red channel, what is green channel. Different scanners have different way of storing.
- **lima** format is described in documentation **readTargets**
- read.maimages source which tells the package what imaging software was used to produce these files
- MA.RG stores the log ratio of red and green
- Function to look at images

```
# datadir defined in previous video
library(limma)
##
## Attaching package: 'limma'
## The following object is masked from 'package:BiocGenerics':
```

```
##
##
       plotMA
library(rafalib)
datadir <- paste0(wd, "/rawdata-master")</pre>
                                              # downloaded files
basedir <- pasteO(datadir, "/agilent")</pre>
setwd(basedir)
targets <- readTargets("TargetBeta7.txt")</pre>
RG <- read.maimages(targets$FileName, source="genepix") # red and green 23k genes
## Read 6Hs.195.1.gpr
## Read 6Hs.168.gpr
## Read 6Hs.166.gpr
## Read 6Hs.187.1.gpr
## Read 6Hs.194.gpr
## Read 6Hs.243.1.gpr
MA <- MA.RG(RG,bc.method="none") # M and A, same information but transformed
dim(RG$R)
## [1] 23184
dim(RG$G)
## [1] 23184
                 6
dim(MA$M)
## [1] 23184
dim(MA$A)
## [1] 23184
plot(MA$A[,1], MA$M[,1]) # MA plot for first sample
                                     0
      က
                                     0
      \sim
                                               0
MA$M[, 1]
      0
                                  000
                                                                       0
                       8
                                     10
                                                     12
                                                                    14
                                                                                    16
                                            MA$A[, 1]
```

```
# microarray image
mypar(1,1)
imageplot(MA$M[,2], RG$printer, zlim=c(-3,3))
```



z-range -3 to 3.4 (saturation -3, 3)

0./ar * ar\

#dev.off()

Assessment: Reading microarray data

```
library(hgu95acdf)

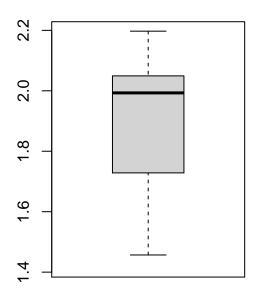
wd <- getwd()
datadir <- paste0(wd, "/rawdata-master")  # downloaded files
basedir <- paste0(datadir, "/celfiles")
setwd(basedir)
library(affy)
tab <- read.delim("sampleinfo.txt",check.names=FALSE,as.is=TRUE)
rownames(tab) <- tab$filenames</pre>
```

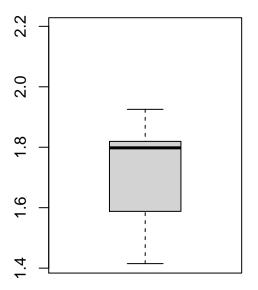
```
##
                                       filenames 37777_at 684_at 1597_at
## 1521a99hpp_av06.CEL.gz
                           1521a99hpp_av06.CEL.gz
                                                     0.00
                                                            0.25
                                                                    0.5
## 1532a99hpp_av04.CEL.gz
                           1532a99hpp_av04.CEL.gz
                                                     0.00
                                                            0.25
                                                                    0.5
## 2353a99hpp_av08.CEL.gz
                           2353a99hpp_av08.CEL.gz
                                                     0.00
                                                           0.25
                                                                    0.5
## 1521b99hpp av06.CEL.gz
                          1521b99hpp av06.CEL.gz
                                                     0.25
                                                            0.50
                                                                    1.0
## 1532b99hpp_av04.CEL.gz
                           1532b99hpp_av04.CEL.gz
                                                     0.25
                                                            0.50
                                                                    1.0
```

```
## 2353b99hpp_av08r.CEL.gz 2353b99hpp_av08r.CEL.gz
                                                        0.25
##
                           38734_at 39058_at 36311_at 36889_at 1024_at 36202_at
## 1521a99hpp av06.CEL.gz
                                   1
                                            2
                                                     4
## 1532a99hpp_av04.CEL.gz
                                            2
                                                               8
                                                                      16
                                                                               32
                                   1
                                                     4
## 2353a99hpp_av08.CEL.gz
                                   1
                                            2
                                                     4
                                                               8
                                                                      16
                                                                               32
                                   2
                                                                      32
## 1521b99hpp av06.CEL.gz
                                            4
                                                     8
                                                              16
                                                                               64
## 1532b99hpp_av04.CEL.gz
                                            4
                                                     8
                                                              16
                                                                      32
                                   2
## 2353b99hpp_av08r.CEL.gz
                                            4
                                                     8
                                                              16
                                                                      32
                                                                               64
##
                           36085_at 40322_at 407_at 1091_at 1708_at 33818_at
## 1521a99hpp_av06.CEL.gz
                                  64
                                          128
                                                0.00
                                                          512
                                                                 1024
                                                                           256
## 1532a99hpp_av04.CEL.gz
                                  64
                                          128
                                                0.00
                                                          512
                                                                 1024
                                                                           256
## 2353a99hpp_av08.CEL.gz
                                          128
                                                0.00
                                                          512
                                                                 1024
                                                                           256
                                  64
## 1521b99hpp_av06.CEL.gz
                                 128
                                          256
                                                0.25
                                                         1024
                                                                    0
                                                                           512
## 1532b99hpp_av04.CEL.gz
                                                0.25
                                 128
                                          256
                                                         1024
                                                                    0
                                                                           512
## 2353b99hpp_av08r.CEL.gz
                                 128
                                          256
                                                0.25
                                                         1024
                                                                    0
                                                                           512
##
                           546_at
## 1521a99hpp_av06.CEL.gz
                                32
## 1532a99hpp_av04.CEL.gz
                                32
                                32
## 2353a99hpp_av08.CEL.gz
## 1521b99hpp_av06.CEL.gz
                                64
## 1532b99hpp_av04.CEL.gz
                                64
## 2353b99hpp_av08r.CEL.gz
                                64
level_gene_spike = tab[tab$filenames == "1521a99hpp_av06.CEL.gz", "36311_at"]
paste("level gene 36311_at spiked: ", level_gene_spike)
## [1] "level gene 36311_at spiked: 4"
fns <- list.celfiles(basedir)</pre>
ab <- ReadAffy(phenoData=tab)</pre>
pn = probeNames(ab)
num_features_associated_w_gene=length(pn[pn == "36311_at"])
paste("number of features associated with gene 36311_at: ", num_features_associated_w_gene)
## [1] "number of features associated with gene 36311_at: 16"
ab sub <- ab[,ab$filenames %in% c("1532a99hpp av04.CEL.gz", "1532b99hpp av04.CEL.gz")]
probe_level_intensities = pm(ab_sub)
probeset_ids = which(pn == "36085_at")
probe_level_intensities_at_probeset = probe_level_intensities[probeset_ids,]
sample_metadata = pData(ab_sub)
par(mfrow=c(1, 2))
r_1 = log2(probe_level_intensities_at_probeset[,"1532a99hpp_av04.CEL.gz"]) / log2(sample_metadata[ "153
r_2 = log2(probe_level_intensities_at_probeset[,"1532b99hpp_av04.CEL.gz"]) / log2(sample_metadata[ "153
lmts \leftarrow range(r_1, r_2)
boxplot(r_1, main="1532a99hpp_av04.CEL.gz", ylim=lmts)
boxplot(r_2, main="1532b99hpp_av04.CEL.gz", ylim=lmts)
```

1532a99hpp_av04.CEL.gz

1532b99hpp_av04.CEL.gz





SummarizedExperiment class

- Similar to ExpressionSets but preferred for sequencing-based data
- Accomodates experiments where genomic location is important
- Most commonly used for NGS
- assay function to access counts
- colData equivalent to pData on ExpressionSet
- rows correspond to genes collections of exons (GRanges list used to count RNA sequencing reads)
- metadata how GRanges List was constructed and from what database etc.
- MIAME minimal information about microarray experiment

library(parathyroidSE)

```
## Loading required package: SummarizedExperiment
## Loading required package: MatrixGenerics
## Loading required package: matrixStats
##
## Attaching package: 'matrixStats'
  The following objects are masked from 'package:Biobase':
##
##
       anyMissing, rowMedians
##
## Attaching package: 'MatrixGenerics'
  The following objects are masked from 'package:matrixStats':
##
##
       colAlls, colAnyNAs, colAnys, colAvgsPerRowSet, colCollapse,
##
##
       colCounts, colCummaxs, colCummins, colCumprods, colCumsums,
##
       colDiffs, colIQRDiffs, colIQRs, colLogSumExps, colMadDiffs,
##
       colMads, colMaxs, colMeans2, colMedians, colMins, colOrderStats,
##
       colProds, colQuantiles, colRanges, colRanks, colSdDiffs, colSds,
```

```
##
       colSums2, colTabulates, colVarDiffs, colVars, colWeightedMads,
##
       colWeightedMeans, colWeightedMedians, colWeightedSds,
##
       colWeightedVars, rowAlls, rowAnyNAs, rowAnys, rowAvgsPerColSet,
       rowCollapse, rowCounts, rowCummaxs, rowCummins, rowCumprods,
##
##
       rowCumsums, rowDiffs, rowIQRDiffs, rowIQRs, rowLogSumExps,
       rowMadDiffs, rowMads, rowMaxs, rowMeans2, rowMedians, rowMins,
##
##
       rowOrderStats, rowProds, rowQuantiles, rowRanges, rowRanks,
       rowSdDiffs, rowSds, rowSums2, rowTabulates, rowVarDiffs, rowVars,
##
##
       rowWeightedMads, rowWeightedMeans, rowWeightedMedians,
##
       rowWeightedSds, rowWeightedVars
## The following object is masked from 'package:Biobase':
##
##
       rowMedians
## Loading required package: GenomicRanges
## Loading required package: stats4
## Loading required package: S4Vectors
##
## Attaching package: 'S4Vectors'
## The following object is masked from 'package:base':
##
       expand.grid
##
## Loading required package: IRanges
## Loading required package: GenomeInfoDb
## Warning: package 'GenomeInfoDb' was built under R version 4.0.4
data(parathyroidGenesSE)
se <- parathyroidGenesSE
se
## class: RangedSummarizedExperiment
## dim: 63193 27
## metadata(1): MIAME
## assays(1): counts
## rownames(63193): ENSG00000000003 ENSG0000000005 ... LRG_98 LRG_99
## rowData names(0):
## colnames: NULL
## colData names(8): run experiment ... study sample
# assay contains results of the assay
dim(se)
## [1] 63193
                27
assay(se)[1:3,1:3]
##
                   [,1] [,2] [,3]
## ENSG00000000003
                   792 1064
## ENSG00000000005
                      4
                           1
## ENSG00000000419 294 282
dim(assay(se))
                # rows = features (ranges), columns = samples
## [1] 63193
```

27

```
# colData contains sample information
colData(se)[1:3,1:6]
## DataFrame with 3 rows and 6 columns
##
            run experiment patient treatment
                                                  time submission
##
                  <factor> <factor> <factor> <factor>
     <character>
                                                         <factor>
      SRR479052 SRX140503
## 1
                                  1
                                      Control
                                                   24h
                                                        SRA051611
## 2
       SRR479053
                 SRX140504
                                      Control
                                                        SRA051611
                                  1
                                                   48h
## 3
      SRR479054 SRX140505
                                  1
                                      DPN
                                                   24h
                                                        SRA051611
dim(colData(se))
## [1] 27 8
names(colData(se))
## [1] "run"
                    "experiment" "patient"
                                              "treatment"
                                                          "time"
                                 "sample"
## [6] "submission" "study"
colData(se) $treatment
  [1] Control Control DPN
                               DPN
                                        OHT
                                               OHT
                                                        Control Control DPN
## [10] DPN
               DPN
                        ОНТ
                               ОНТ
                                        OHT
                                                                       DPN
                                               Control Control DPN
## [19] OHT
                OHT
                        Control DPN
                                       DPN
                                               DPN
                                                       OHT
                                                               OHT
                                                                       OHT
## Levels: Control DPN OHT
as.numeric(colData(se)$treatment)
# rowRanges contains feature information
rowRanges(se)[1]
## GRangesList object of length 1:
## $ENSG0000000003
   GRanges object with 17 ranges and 2 metadata columns:
##
          seqnames
                             ranges strand |
                                               exon_id
                                                             exon_name
##
             <Rle>
                          <IRanges>
                                     <Rle> | <integer>
                                                           <character>
##
      [1]
                X 99883667-99884983
                                         - |
                                                664095 ENSE00001459322
      [2]
##
                X 99885756-99885863
                                          - 1
                                                664096 ENSE00000868868
##
      [3]
                                                664097 ENSE00000401072
                X 99887482-99887565
##
      [4]
                X 99887538-99887565
                                         - 1
                                                664098 ENSE00001849132
                                         - |
##
      [5]
                X 99888402-99888536
                                                664099 ENSE00003554016
##
      . . .
                                        . . . .
##
     [13]
                X 99890555-99890743
                                                664106 ENSE00003512331
##
     [14]
                X 99891188-99891686
                                         - |
                                                664108 ENSE00001886883
                X 99891605-99891803
                                         - |
##
                                                664109 ENSE00001855382
     [15]
##
     Г16Т
                X 99891790-99892101
                                                664110 ENSE00001863395
##
     [17]
                X 99894942-99894988
                                                664111 ENSE00001828996
##
##
     seqinfo: 580 sequences (1 circular) from an unspecified genome
class(rowRanges(se))
## [1] "CompressedGRangesList"
## attr(,"package")
## [1] "GenomicRanges"
```

```
length(rowRanges(se)) # number of genes
## [1] 63193
length(rowRanges(se)[[1]]) # number of exons for first gene
## [1] 17
head(rownames(se))
## [1] "ENSG00000000003" "ENSG0000000005" "ENSG000000000419" "ENSG000000000457"
## [5] "ENSG0000000460" "ENSG00000000938"
metadata(rowRanges(se))
## $genomeInfo
## $genomeInfo$`Db type`
## [1] "TranscriptDb"
## $genomeInfo$`Supporting package`
## [1] "GenomicFeatures"
##
## $genomeInfo$`Data source`
## [1] "BioMart"
##
## $genomeInfo$Organism
## [1] "Homo sapiens"
## $genomeInfo$`Resource URL`
## [1] "www.biomart.org:80"
##
## $genomeInfo$`BioMart database`
## [1] "ensembl"
##
## $genomeInfo$`BioMart database version`
## [1] "ENSEMBL GENES 72 (SANGER UK)"
##
## $genomeInfo$`BioMart dataset`
## [1] "hsapiens_gene_ensembl"
## $genomeInfo$`BioMart dataset description`
## [1] "Homo sapiens genes (GRCh37.p11)"
##
## $genomeInfo$`BioMart dataset version`
## [1] "GRCh37.p11"
##
## $genomeInfo$`Full dataset`
## [1] "yes"
## $genomeInfo$`miRBase build ID`
## [1] NA
##
## $genomeInfo$transcript_nrow
## [1] "213140"
```

\$genomeInfo\$exon_nrow

```
## [1] "737783"
##
## $genomeInfo$cds_nrow
## [1] "531154"
## $genomeInfo$`Db created by`
## [1] "GenomicFeatures package from Bioconductor"
## $genomeInfo$`Creation time`
## [1] "2013-07-30 17:30:25 +0200 (Tue, 30 Jul 2013)"
## $genomeInfo$`GenomicFeatures version at creation time`
## [1] "1.13.21"
##
## $genomeInfo$`RSQLite version at creation time`
## [1] "0.11.4"
##
## $genomeInfo$DBSCHEMAVERSION
## [1] "1.0"
# additional metadata, including sample information
metadata(se)$MIAME
## Experiment data
##
    Experimenter name: Felix Haglund
##
    Laboratory: Science for Life Laboratory Stockholm
##
    Contact information: Mikael Huss
    Title: DPN and Tamoxifen treatments of parathyroid adenoma cells
    URL: http://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE37211
##
##
     PMIDs: 23024189
##
     Abstract: A 251 word abstract is available. Use 'abstract' method.
abstract(metadata(se)$MIAME)
```

[1] "Primary hyperparathyroidism (PHPT) is most frequently present in postmenopausal women. Although