

RNA-seq analysis: SLBP (EDA)

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This R Markdown document contains a walk-through for performing exploratory data analysis of pooled (single-end) RNA-seq on single *D.melanogaster* histone overexpression mutant embryos caused by a knock-down of *Slbp* (Stem loop binding protein) gene and corresponding wild-type/ control. Raw transcript count data obtained by mapping to a reference transcriptome using Salmon (slurm/bash scripts calling the relevant functions to preprocess and map are in another repository).

This document includes

- Importing and Normalizing the RNA-seq count data via DESeq2 and rlog transformation
- Visualizing sample similarity based on Euclidean distance and Principal components analysis (PCA)
- custom plotting/ visualization in base R, ggplot2 and pheatmap

“Desktop/RNAseq_output/” has been used as a local directory for this project, but that can be changed to any desired local or cloud based directory.

```
# Libraries for RNA-seq count data analysis
library(tximport)
library(DESeq2)

# Libraries for data handling and visualization
library(ggplot2)
library(dplyr)
library(pheatmap)
library(RColorBrewer)
library(genefilter)
library(dendsort)
library(reshape2)

#Libraries for database
library(TxDb.Dmelanogaster.UCSC.dm6.ensGene)
library(org.Dm.eg.db)
```

Loading Gene annotation datasets transcript to geneID to gene name mappings. This can also be obtained from an organism specific database (in this case <http://flybase.org/>) or can be imported from org.db (in this case org.Dm.eg.db obtained from Bioconductor)

```
setwd("~/Desktop/RNAseq_output/Abo_Wt_StagedNC_flybase_transcriptome/")
ttg.slbp <- read.table("scripts_samples_ttg/flybase_transcript_to_gene.txt", h=T)
head(ttg.slbp)
```

```
##           txId           Gene
## 1 FBtr0081624 dmel_7SLRNA:CR32864
## 2 FBtr0100521          dmel_a
## 3 FBtr0071764          dmel_a
## 4 FBtr0342981          dmel_a
## 5 FBtr0071763          dmel_a
## 6 FBtr0083388      dmel_abd-A
```

```
fbgn.gene.conv <- read.table("scripts_samples_ttg/flybase_fbgn_to_gene.tsv", h=T)
head(fbgn.gene.conv)
```

```
##           geneId           Gene
## 1 FBgn0262029      dmel_d
## 2 FBgn0052532 dmel_CG32532
## 3 FBgn0023536 dmel_CG3156
## 4 FBgn0029718 dmel_mRpL30
## 5 FBgn0031101 dmel_CG1631
## 6 FBgn0030952 dmel_CG12609
```

Exploratory Analysis

```
setwd("~/Desktop/RNAseq_output/Abo_Wt_StagedNC_flybase_transcriptome/data/SLBP/main/")
# Reading in the sample information file
sample.slbp.all <- read.csv("salmon_data_slbp_main_pilot_inc/samples_slbp_wt_main_pilot_inc.csv",h=T)
str(sample.slbp.all)
```

```
## 'data.frame':    28 obs. of  7 variables:
## $ Sample      : Factor w/ 28 levels "SLBP_NCO_Pre9_R1_B2",...: 1 2 3 4 5 6 7 8 9 10 ...
## $ Genotype    : Factor w/ 2 levels "SLBP","WT": 1 1 1 1 1 1 1 1 1 ...
## $ Cycle       : Factor w/ 5 levels "NCO_Pre9","NC13",...: 1 1 1 1 1 2 2 2 2 ...
## $ Replicate   : Factor w/ 6 levels "R1","R2","R3",...: 1 2 3 4 5 1 1 2 2 3 ...
## $ Gen_Rep     : Factor w/ 25 levels "SLBP_NCO_Pre9_R1",...: 1 2 3 4 5 6 6 7 7 8 ...
## $ Gen_Rep_Batch: Factor w/ 28 levels "SLBP_NCO_Pre9_R1_B2",...: 1 2 3 4 5 6 7 8 9 10 ...
## $ Gen_Cyc     : Factor w/ 5 levels "SLBP_NCO_Pre9",...: 1 1 1 1 1 2 2 2 2 2 ...
```

```
head(sample.slbp.all)
```

```
##           Sample Genotype   Cycle Replicate      Gen_Rep
## 1 SLBP_NCO_Pre9_R1_B2      SLBP NCO_Pre9      R1 SLBP_NCO_Pre9_R1
## 2 SLBP_NCO_Pre9_R2_B2      SLBP NCO_Pre9      R2 SLBP_NCO_Pre9_R2
## 3 SLBP_NCO_Pre9_R3_B2      SLBP NCO_Pre9      R3 SLBP_NCO_Pre9_R3
## 4 SLBP_NCO_Pre9_R4_B2      SLBP NCO_Pre9      R4 SLBP_NCO_Pre9_R4
## 5 SLBP_NCO_Pre9_R5_B2      SLBP NCO_Pre9      R5 SLBP_NCO_Pre9_R5
## 6      SLBP_NC13_R1_B1      SLBP      NC13      R1      SLBP_NC13_R1
##           Gen_Rep_Batch      Gen_Cyc
## 1 SLBP_NCO_Pre9_R1_B2 SLBP_NCO_Pre9
## 2 SLBP_NCO_Pre9_R2_B2 SLBP_NCO_Pre9
## 3 SLBP_NCO_Pre9_R3_B2 SLBP_NCO_Pre9
## 4 SLBP_NCO_Pre9_R4_B2 SLBP_NCO_Pre9
## 5 SLBP_NCO_Pre9_R5_B2 SLBP_NCO_Pre9
## 6      SLBP_NC13_R1_B1      SLBP_NC13
```

```
levels(sample.slbp.all$Gen_Cyc)
```

```
## [1] "SLBP_NCO_Pre9" "SLBP_NC13"      "WT_NCO_Pre9"   "WT_NC13"
## [5] "WT_NC14"
```

```

sample.slbp.all$Gen_Cyc <- releve1(sample.slbp.all$Gen_Cyc, ref="WT_NCO_Pre9")
# Ordering the dataset such that WT_NCO_Pre9
# i.e. the most initial developmental stages is the reference for all comparisons

# Reading in the raw count matrix files and converting it into a DESeq object
files.slbp.all <- file.path("salmon_data_slbp_main_pilot_inc",
                           sample.slbp.all$Sample, "quant.sf")
names(files.slbp.all) <- paste0("Sample", 1:28)
all(file.exists(files.slbp.all))

```

```
## [1] TRUE
```

```
txi.slbp.all <- tximport(files.slbp.all, type = "salmon", tx2gene = ttg.slbp)
```

```
## reading in files with read_tsv
```

```

## 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
## summarizing abundance
## summarizing counts
## summarizing length

```

```
names(txi.slbp.all)
```

```

## [1] "abundance"          "counts"              "length"
## [4] "countsFromAbundance"

```

```

rownames(sample.slbp.all) <- colnames(txi.slbp.all$counts)
ddsTxi.slbp.all <- DESeqDataSetFromTximport(txi.slbp.all,
                                           colData = sample.slbp.all,
                                           design = ~ Gen_Cyc)

```

```
## using counts and average transcript lengths from tximport
```

```

# The design here is Gen_Cyc == Genotype*Cycle == Genotype + Cycle + Genotype:Cycle
# main and interaction effects of Genotype and Cell cycle

```

There are a couple of other manipulations that can be performed before performing the actual analysis

- The same libraries were sequenced on multiple lanes. These form technical replicates and can be combined into the appropriate biological replicate by summing the counts, using the `collapseReplicates()` function
- The genes that have not received any reads or say below a threshold level of counts can be eliminated before analysis

```

# Collapsing the technical replicates
ddsColl.slbp.all <- collapseReplicates(ddsTxi.slbp.all,
                                       ddsTxi.slbp.all$Gen_Rep,
                                       ddsTxi.slbp.all$Gen_Rep_Batch)

colData(ddsColl.slbp.all)

```

```
## DataFrame with 25 rows and 8 columns
##
##           Sample Genotype   Cycle Replicate
##           <factor> <factor> <factor> <factor>
## SLBP_NCO_Pre9_R1 SLBP_NCO_Pre9_R1_B2      SLBP NCO_Pre9      R1
## SLBP_NCO_Pre9_R2 SLBP_NCO_Pre9_R2_B2      SLBP NCO_Pre9      R2
## SLBP_NCO_Pre9_R3 SLBP_NCO_Pre9_R3_B2      SLBP NCO_Pre9      R3
## SLBP_NCO_Pre9_R4 SLBP_NCO_Pre9_R4_B2      SLBP NCO_Pre9      R4
## SLBP_NCO_Pre9_R5 SLBP_NCO_Pre9_R5_B2      SLBP NCO_Pre9      R5
## ...
## WT_NC14_R1      WT_NC14_R1_B2      WT      NC14      R1
## WT_NC14_R2      WT_NC14_R2_B2      WT      NC14      R2
## WT_NC14_R3      WT_NC14_R3_B2      WT      NC14      R3
## WT_NC14_R4      WT_NC14_R4_B2      WT      NC14      R4
## WT_NC14_R5      WT_NC14_R5_B2      WT      NC15      R5
##
##           Gen_Rep      Gen_Rep_Batch      Gen_Cyc
##           <factor>      <factor>      <factor>
## SLBP_NCO_Pre9_R1 SLBP_NCO_Pre9_R1 SLBP_NCO_Pre9_R1_B2 SLBP_NCO_Pre9
## SLBP_NCO_Pre9_R2 SLBP_NCO_Pre9_R2 SLBP_NCO_Pre9_R2_B2 SLBP_NCO_Pre9
## SLBP_NCO_Pre9_R3 SLBP_NCO_Pre9_R3 SLBP_NCO_Pre9_R3_B2 SLBP_NCO_Pre9
## SLBP_NCO_Pre9_R4 SLBP_NCO_Pre9_R4 SLBP_NCO_Pre9_R4_B2 SLBP_NCO_Pre9
## SLBP_NCO_Pre9_R5 SLBP_NCO_Pre9_R5 SLBP_NCO_Pre9_R5_B2 SLBP_NCO_Pre9
## ...
## WT_NC14_R1      WT_NC14_R1      WT_NC14_R1_B2      WT_NC14
## WT_NC14_R2      WT_NC14_R2      WT_NC14_R2_B2      WT_NC14
## WT_NC14_R3      WT_NC14_R3      WT_NC14_R3_B2      WT_NC14
## WT_NC14_R4      WT_NC14_R4      WT_NC14_R4_B2      WT_NC14
## WT_NC14_R5      WT_NC14_R5      WT_NC14_R5_B2      WT_NC14
##
##           runsCollapsed
##           <character>
## SLBP_NCO_Pre9_R1 SLBP_NCO_Pre9_R1_B2
## SLBP_NCO_Pre9_R2 SLBP_NCO_Pre9_R2_B2
## SLBP_NCO_Pre9_R3 SLBP_NCO_Pre9_R3_B2
## SLBP_NCO_Pre9_R4 SLBP_NCO_Pre9_R4_B2
## SLBP_NCO_Pre9_R5 SLBP_NCO_Pre9_R5_B2
## ...
## WT_NC14_R1      WT_NC14_R1_B2
## WT_NC14_R2      WT_NC14_R2_B2
## WT_NC14_R3      WT_NC14_R3_B2
## WT_NC14_R4      WT_NC14_R4_B2
## WT_NC14_R5      WT_NC14_R5_B2
```

```
# Retaining a gene if it has over 1 reads in 2 or more samples
# This is a very permissive threshold to eliminate any unintentional filtration bias
ddsColl.slbp.all
```

```
## class: DESeqDataSet
## dim: 13728 25
## metadata(1): version
## assays(2): counts avgTxLength
## rownames(13728): dmel_1-Dec dmel_1-Sep ... dmel_zye dmel_Zyx
## rowData names(0):
## colnames(25): SLBP_NCO_Pre9_R1 SLBP_NCO_Pre9_R2 ... WT_NC14_R4
##           WT_NC14_R5
## colData names(8): Sample Genotype ... Gen_Cyc runsCollapsed
```

```
keep.slbp.all <- rowSums(counts(ddsColl.slbp.all) >1) >= 2
ddsColl.keep.slbp.all <- ddsColl.slbp.all[keep.slbp.all,]
ddsColl.keep.slbp.all # 10860 genes
```

```
## class: DESeqDataSet
## dim: 10860 25
## metadata(1): version
## assays(2): counts avgTxLength
## rownames(10860): dmel_1-Dec dmel_1-Sep ... dmel_zye dmel_Zyx
## rowData names(0):
## colnames(25): SLBP_NC0_Pre9_R1 SLBP_NC0_Pre9_R2 ... WT_NC14_R4
##   WT_NC14_R5
## colData names(8): Sample Genotype ... Gen_Cyc runsCollapsed
```

Perform the DESeq2 normalization followed by

- regularized log transformation
- similarity between samples based on Euclidean distance
- principal components analysis (PCA)

```
deseq.slbp.all <- DESeq(ddsColl.keep.slbp.all)
```

```
## estimating size factors
```

```
## using 'avgTxLength' from assays(dds), correcting for library size
```

```
## estimating dispersions
```

```
## gene-wise dispersion estimates
```

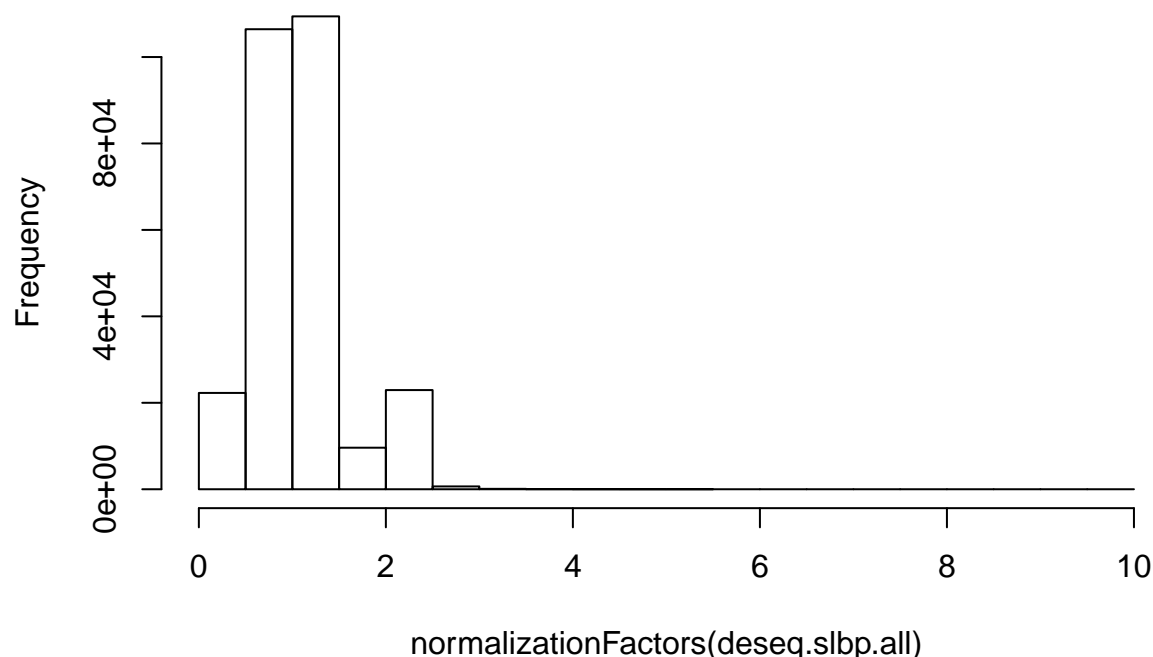
```
## mean-dispersion relationship
```

```
## final dispersion estimates
```

```
## fitting model and testing
```

```
hist(normalizationFactors(deseq.slbp.all))
```

Histogram of normalizationFactors(deseq.slbp.all)

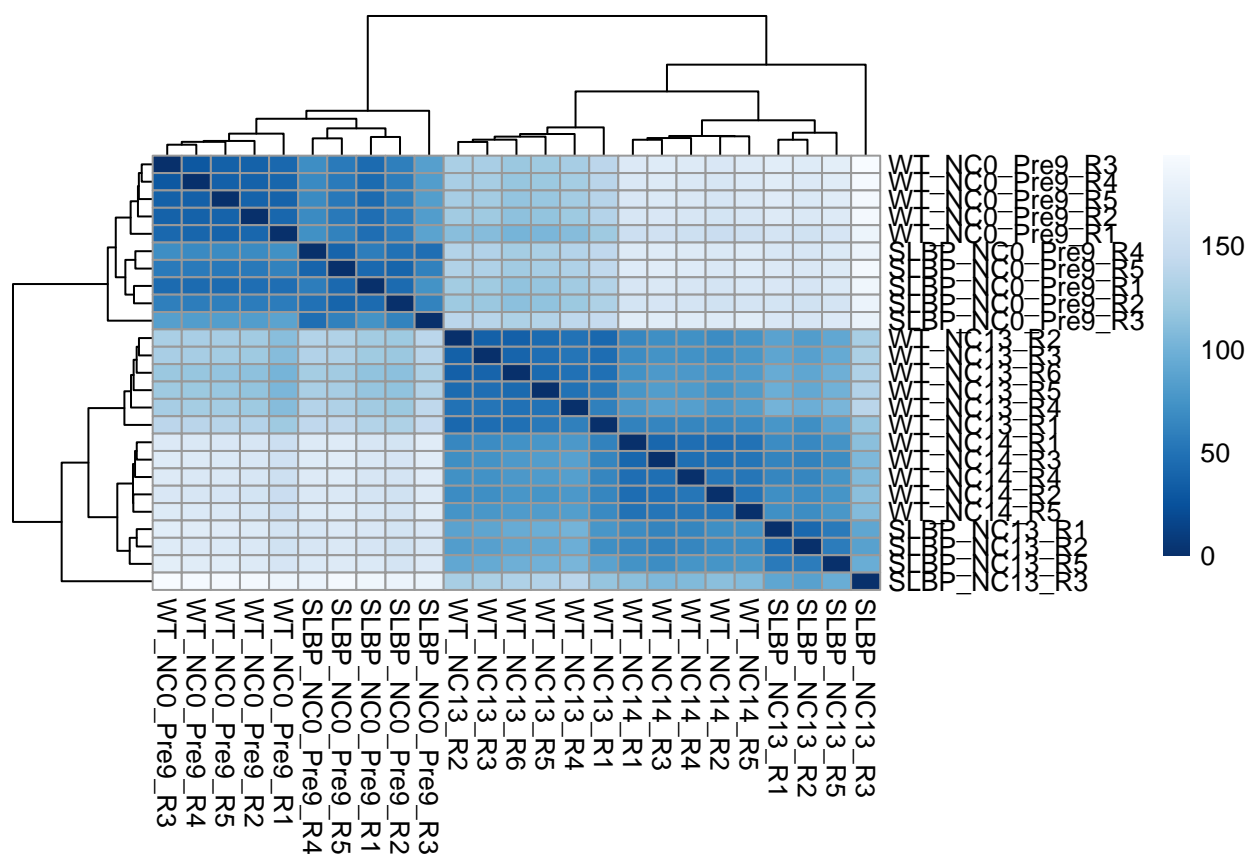


```
# histogram of normalization factors typically distributed with a mean/ median ~1.0
rld.slbp.all <- rlog(deseq.slbp.all, blind=T)

sampleDists.slbp.all <- dist(t(assay(rld.slbp.all)))
hm.mat.slbp.all <- as.matrix( sampleDists.slbp.all)
colors <- colorRampPalette( rev(brewer.pal(9, "Blues")) )(255)

# heirarchical clustering of the sample distances
hm.col.clust.slbp.all <- hclust(dist(t(hm.mat.slbp.all)))
sort.hclust <- function(...) as.hclust(dendsort(as.dendrogram(...)))
hm.col.clust.slbp.all <- sort.hclust(hclust(dist(t(hm.mat.slbp.all))))
hm.row.clust.slbp.all <- sort.hclust(hclust(dist(hm.mat.slbp.all)))

#visualizing the clustered sample distances
pheatmap(
  mat           = hm.mat.slbp.all,
  color         = colors,
  cluster_cols  = hm.col.clust.slbp.all,
  cluster_rows  = hm.row.clust.slbp.all,
  show_rownames = T
)
```



```
#plotting PCA
plotPCA(rld.slbp.all, intgroup=c("Gen_Cyc"), ntop=5000)
```

