Library analysis output

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This workflow brings together FastQ files containing barcodes and 5'/3' ends of a suitable insert and alignmen them using Bowtie2. It also includes starcode based false barcode reduction and a MapReduce based hierarchical clustering

```
suppressPackageStartupMessages(library(knitr))
suppressPackageStartupMessages(library(ShortRead))
```

```
## Creating a generic function for 'nchar' from package 'base' in package 'S4Vectors'
```

```
suppressPackageStartupMessages(library(ggplot2))
suppressPackageStartupMessages(library(ggbio))
suppressPackageStartupMessages(library(beanplot))
suppressPackageStartupMessages(library(parallel))
suppressPackageStartupMessages(library(doParallel))
suppressPackageStartupMessages(library(data.table))
suppressPackageStartupMessages(library(scales)) #Gives the log2 ability to ggplot2
suppressPackageStartupMessages(library(formatR))
suppressPackageStartupMessages(library(BSgenome))
suppressPackageStartupMessages(library(Rsamtools))
suppressPackageStartupMessages(library(rtracklayer))
suppressPackageStartupMessages(library(GenomicFeatures))
suppressPackageStartupMessages(library(GenomicAlignments))
suppressPackageStartupMessages(library(GenomicRanges))
suppressPackageStartupMessages(library(biovizBase))
suppressPackageStartupMessages(library(Gviz))
suppressPackageStartupMessages(library(plyr))
suppressPackageStartupMessages(library(devtools))
suppressPackageStartupMessages(library(Hmisc))
```

Sequencing files

```
knitr::kable(config, format = "markdown")
```

Parameter	Value
dataDir	../../Shared/NGS\ data/Original\ sequencing\ files/TB20151026-26037026
in.name.P5	psc-lib-2_S1-2_L001_R1_001.fastq.gz
in.name.P7	psc-lib-2_S1-2_L001_R2_001.fastq.gz
name.out	2015-11-04_AAVlibrary
paired.alignment	TRUE
bb.dir	../Templates/adapters/pscAAV_firstLib
fragmentTemplate	../../Shared/NGS\ data/bowtieIndices/libIndex
sc.param	0
run.subset	FALSE
align.P7	FALSE
max.cores	32
subset.count	500000

```
dataDir <- config$Value[1]
in.name.P5 <- file.path(dataDir, config$Value[2])
in.name.P7 <- file.path(dataDir, config$Value[3])
name.out <- config$Value[4]
paired.alignment <- as.logical(config$Value[5])
```

Analysis parameters

```
bb.dir <- config$Value[6]
fragmentTemplate  <- config$Value[7]
output.table$SC <- config$Value[8]
run.subset <- as.logical(config$Value[9])
align.p7 <- as.logical(config$Value[10])
max.cores <- as.integer(config$Value[11])
subset.count <- as.integer(config$Value[12])
```

Script execution

```
strt<-Sys.time()

id.backbone.L <- file.path(bb.dir, "Ltrim.fa")
id.backbone.R <- file.path(bb.dir, "Rtrim.fa")
id.BC.L <- file.path(bb.dir, "BC-L.fa")
id.BC.R <- file.path(bb.dir, "BC-R.fa")
id.uncut <- file.path(bb.dir, "uncut.fa")
```

Selection of real amplicons

```
out.name.P5 <- tempfile(pattern = "P5_", tmpdir = tempdir(), fileext = ".fastq.gz")
out.name.P7 <- tempfile(pattern = "P7_", tmpdir = tempdir(), fileext = ".fastq.gz")
command.args <- paste("-Xmx12g overwrite=true k=15 rcomp=f skipr2=t qhdist=0 maskmiddle=f hammingdistance=2
                      " in=", in.name.P5,
                      " in2=", in.name.P7,
                      " outm=", out.name.P5,
                      " outm2=", out.name.P7,
                      " fliteral=", "GTATGTTGTTCTGGAGCGGGAGGGTGCTATTTTGCCTAGCGATAA", sep = "") #Length 48-7
# postLoxP on P5: GTATGTTGTTCTGGAGCGGGAGGGTGCTATTTTGCCTAGCGATAAGCTGATGTAGCC
# GFP from P7: CCTGCTGGAGTTCGTGACCGCCGCCGGGATCACTCTCGGCATGGACGAGCTGTACAAGTAA
# Cap from P7: AGACAAGCAGCTACCGCAGATGTCAACACACAAGGCGTTCTTCCAGGCATGGTCTGG

sys.out <- system2(path.expand("~/bbmap/bbduk2.sh"), args=command.args, stdout=TRUE, stderr=TRUE) #

sys.out <- as.data.frame(sys.out)


colnames(sys.out) <- c("bbduk2 Identification of real amplicons")
invisible(sys.out[" "] <- " ")
lengthOut <- (nrow(sys.out))
knitr::kable(sys.out[3:lengthOut,], format = "markdown")
```

bbduk2 Identification of real amplicons

```
3
4   BBDuk2 version 34.79
5   Set ORDERED to true
6   Set threads to 32
7   k=15
8   hamming distance=2
9   kfiltering using 1 literal.
10
11  Initial:
12  Memory: free=12090m, used=258m
13
14  Added 30721 kmers; time: 0.073 seconds.
15  Memory: free=11639m, used=709m
16
17  Input is being processed as paired
18  Started output streams: 0.031 seconds.
19  Processing time: 34.652 seconds.
20
21  Input: 9864252 reads 1485018643 bases.
22  Contaminants: 9769054 reads (99.03%) 1470711327 bases (99.04%)
23  Result: 95198 reads (0.97%) 14307316 bases (0.96%)
24
25  Time: 34.764 seconds.
26  Reads Processed: 9864k 283.75k reads/sec
27  Bases Processed: 1485m 42.72m bases/sec
```

```
in.name.P5 <- out.name.P5
in.name.P7 <- out.name.P7
```

Extraction of a subset

```
if (run.subset){
  suppressWarnings(sampler <- FastqSampler(gsub("([\\])", "", in.name.P5), subset.count, readerBlockSize=1e9
  set.seed(123); tmp.P5 <- yield(sampler)
  in.name.P5 <- tempfile(pattern = "P5_", tmpdir = tempdir(), fileext = ".fastq.gz")
  writeFastq(tmp.P5,in.name.P5, compress=TRUE)
  rm(tmp.P5)
  suppressWarnings(sampler <- FastqSampler(gsub("([\\])", "", in.name.P7), subset.count, readerBlockSize=1e9
  set.seed(123); tmp.P7 <- yield(sampler)
  in.name.P7 <- tempfile(pattern = "P7_", tmpdir = tempdir(), fileext = ".fastq.gz")
  writeFastq(tmp.P7,in.name.P7, compress=TRUE)
  rm(tmp.P7)
}

output.table$Reads <- as.integer(system(paste("gunzip -c ",shQuote(gsub("([\\])", "", in.name.P5)),
                                              " | echo $((`wc -l`/4)) 2>&1", sep = ""), intern = TRUE,
                                         ignore.stdout = FALSE)) #Stores the read count utilized
print(paste("Utilized sequences:", output.table$Reads[1]))
```

```
[1] "Utilized sequences: 4884527"
```

Extraction of barcodes

```
out.name.P5 <- tempfile(pattern = "P5_", tmpdir = tempdir(), fileext = ".fastq.gz")
out.name.P7 <- tempfile(pattern = "P7_", tmpdir = tempdir(), fileext = ".fastq.gz")
command.args <- paste("-Xmx12g overwrite=true k=10 rcomp=f skipr2=t qhdist=0 maskmiddle=t hammingdistance=1
                      " in=", in.name.P5,
                      " in2=", in.name.P7,
                      " outm=", out.name.P5,
                      " outm2=", out.name.P7,
                      " fliteral=", "ATAACTTCGTATAATGTATGC", sep = "") #Length 48-72 bp k=18 mink=10 qhdist=

sys.out <- system2(path.expand("~/bbmap/bbduk2.sh"), args=command.args, stdout=TRUE, stderr=TRUE) #

sys.out <- as.data.frame(sys.out)


colnames(sys.out) <- c("bbduk2 Identification of real barcodes")
invisible(sys.out[" "] <- " ")
lengthOut <- (nrow(sys.out))
knitr::kable(sys.out[3:lengthOut,], format = "markdown")
```

	bbduk2 Identification of real barcodes
3	
4	BBDuk2 version 34.79
5	Set ORDERED to true
6	Set threads to 32
7	k=10
8	maskMiddle=true
9	hamming distance=1
10	kfiltering using 1 literal.
11	
12	Initial:
13	Memory: free=12090m, used=258m
14	
15	Added 336 kmers; time: 0.029 seconds.
16	Memory: free=11639m, used=709m
17	
18	Input is being processed as paired
19	Started output streams: 0.020 seconds.
20	Processing time: 34.044 seconds.
21	
22	Input: 9769054 reads 1470711327 bases.
23	Contaminants: 9765270 reads (99.96%) 1470141763 bases (99.96%)
24	Result: 3784 reads (0.04%) 569564 bases (0.04%)
25	
26	Time: 34.102 seconds.
27	Reads Processed: 9769k 286.47k reads/sec
28	Bases Processed: 1470m 43.13m bases/sec

```
in.name.P5 <- out.name.P5
in.name.P7 <- out.name.P7


out.name.P5 <- tempfile(pattern = "BC_", tmpdir = tempdir(), fileext = ".fastq.gz")
```

```
sys.out <- system(paste("~/bbmap/bbduk2.sh overwrite=true k=15 mink=15 hammingdistance=1 findbestmatch=t ",
                        "rcomp=f findbestmatch=f qhdist=0 minavgquality=0 maxns=0 minlength=18 ",
                        "maxlength=22 threads=", detectCores()," in=", shQuote(in.name.P5),
                        " out=", out.name.P5," lliteral=", "GGCCTAGCGGCCGCTTTACTT",
                        " rliteral=", "ATAACTTCGTATAATGTATGC",
                        " 2>&1", sep = ""), intern = TRUE, ignore.stdout = FALSE) #" fliteral=",id.uncut,
sys.out <- as.data.frame(sys.out)

in.name.P5 <- out.name.P5


colnames(sys.out) <- c("bbduk2 Extraction of barcodes")
invisible(sys.out[" "] <- " ")
lengthOut <- (nrow(sys.out))
knitr::kable(sys.out[3:lengthOut,], format = "markdown")
```

	bbduk2 Extraction of barcodes
3	
4	BBDuk2 version 34.79
5	Set threads to 32
6	k=15
7	maskMiddle=true
8	hamming distance=1
9	right-ktrimming using 1 literal.
10	left-ktrimming using 1 literal.
11	
12	Initial:
13	Memory: free=77297m, used=2500m
14	
15	Added 301 kmers; time: 0.046 seconds.
16	Memory: free=74383m, used=5414m
17	
18	Added 301 kmers; time: 0.004 seconds.
19	Memory: free=73966m, used=5831m
20	
21	Input is being processed as unpaired
22	Started output streams: 0.047 seconds.
23	Processing time: 12.583 seconds.
24	
25	Input: 4882635 reads 735139725 bases.
26	KTrimmed: 9746540 reads (199.62%) 637135332 bases (86.67%)
27	Low quality discards: 0 reads (0.00%) 0 bases (0.00%)
28	Result: 4803041 reads (98.37%) 95977260 bases (13.06%)
29	
30	Time: 12.695 seconds.
31	Reads Processed: 4882k 384.61k reads/sec
32	Bases Processed: 735m 57.91m bases/sec

```
rm(sys.out)

reads.BC <- readFastq(in.name.P5)
sread(reads.BC)
```

```
  A DNAStringSet instance of length 4803041
```

```
          width seq
      [1]    20 GTAGATTGCCGGGAGTCAGG
      [2]    20 GTTGGAGCATTCCTTCATGT
      [3]    20 CCAGGCTTACTGCTGCAATG
      [4]    20 GTTTATAGATGTGCGTGTTC
      [5]    20 GAAGCTGGGCAGGTTCGCTG
      ...   ... ...
[4803037]    20 GTGGCAGGGTGGCCGGGCAC
[4803038]    20 GAGCGTGGGCGTCCGCGCGC
[4803039]    20 GTACGTATACGGATTTGCGG
[4803040]    20 GTTTGCTCGAAGACGGGTGT
[4803041]    20 GCGTGTTTGCGTGATTATAC
```

```
output.table$OrigBC <- length(unique(sread(reads.BC)))
unique(sread(reads.BC))
```

```
  A DNAStringSet instance of length 2172414
          width seq
      [1]    20 GTAGATTGCCGGGAGTCAGG
      [2]    20 GTTGGAGCATTCCTTCATGT
      [3]    20 CCAGGCTTACTGCTGCAATG
      [4]    20 GTTTATAGATGTGCGTGTTC
      [5]    20 GAAGCTGGGCAGGTTCGCTG
      ...   ... ...
[2172410]    20 CCACGAGTCTGGACATGCGT
[2172411]    20 GCATCAATCTTCGTTCCAGT
[2172412]    20 ATTTGATGAAACCAGTGATG
[2172413]    20 GTGCACACCCTTGATTGTAG
[2172414]    20 GCGTGTTTGCGTGATTATAC
```

```
barcodeTable <- data.table(ID=as.character(ShortRead::id(reads.BC)), BC=as.character(sread(reads.BC)))

##"CATTACGCGCTCGCGTAAGC" %in% names(frag.ranges.matched)
```

Extraction of fragments

```
out.name.P7 <- tempfile(pattern = "P7_", tmpdir = tempdir(), fileext = ".fastq.gz")
command.args <- paste("-Xmx12g overwrite=true k=10 mink=18 rcomp=f qhdist=0 maskmiddle=t hammingdistance=1 i
                      " in=", in.name.P7,
                      " out=", out.name.P7,
                      " lliteral=", "AGCAACCTCCAGAGAGGCAAC",
                      " rliteral=", "AGACAAGCAGCTACCGCAGATGTCAACACACAAGGCGTTCTTCCAGGCATGGTCTGG", sep = "") #

sys.out <- system2(path.expand("~/bbmap/bbduk2.sh"), args=command.args, stdout=TRUE, stderr=TRUE) #

sys.out <- as.data.frame(sys.out)

colnames(sys.out) <- c("bbduk2 Identification of real amplicons")
invisible(sys.out[" "] <- " ")
lengthOut <- (nrow(sys.out))
knitr::kable(sys.out[3:lengthOut,], format = "markdown")
```

bbduk2 Identification of real amplicons

```
3
4   BBDuk2 version 34.79
5   Set ORDERED to true
6   Set threads to 32
7   k=10
8   maskMiddle=true
9   hamming distance=1
10  right-ktrimming using 1 literal.
11  left-ktrimming using 1 literal.
12
13  Initial:
14  Memory: free=11959m, used=389m
15
16  Added 1344 kmers; time: 0.038 seconds.
17  Memory: free=11508m, used=840m
18
19  Added 336 kmers; time: 0.004 seconds.
20  Memory: free=11508m, used=840m
21
22  Input is being processed as unpaired
23  Started output streams: 0.029 seconds.
24  Processing time: 14.027 seconds.
25
26  Input: 4882635 reads 735002038 bases.
27  KTrimmed: 9288363 reads (190.23%) 538889479 bases (73.32%)
28  Result: 3608520 reads (73.91%) 193033355 bases (26.26%)
29
30  Time: 14.108 seconds.
31  Reads Processed: 4882k 346.08k reads/sec
32  Bases Processed: 735m 52.10m bases/sec
```

```
in.name.P7 <- out.name.P7


source("retrieveFASTAQID.R")

FastQ1 <- readFastq(out.name.P5)
FastQ2 <- readFastq(out.name.P7)
FastQ1ID <- retrieveFASTAQID(FastQ1, PE=TRUE)
FastQ2ID <- retrieveFASTAQID(FastQ2, PE=TRUE)


hits <- intersect(FastQ2ID,FastQ1ID)

FastQ1Subset <- FastQ1[match(hits,FastQ1ID)]
FastQ2Subset <- FastQ2[match(hits,FastQ2ID)]

system(paste("mv ", out.name.P7, " ./data/fragments_", name.out, ".fastq.gz", sep=""))
system(paste("mv ", out.name.P5, " ./data/barcodes_", name.out, ".fastq.gz", sep=""))

unlink(paste(tempdir(), "/*", sep = ""), recursive = FALSE, force = FALSE) #Cleanup of temp files

print("Total execution time:")
```

```
[1] "Total execution time:"
```

```
print(Sys.time()-strt)
```

```
Time difference of 3.748013 mins
```

```
devtools::session_info()
```

```
Session info -------------------------------------------------------------
```

```
 setting  value
 version  R version 3.2.2 (2015-08-14)
 system   x86_64, linux-gnu
 ui       X11
 language (EN)
 collate  en_US.UTF-8
 tz       <NA>
 date     2015-11-04
```

```
Packages -----------------------------------------------------------------
```

```
 package           * version  date       source
 acepack             1.3-3.3  2014-11-24 CRAN (R 3.2.0)
 AnnotationDbi     * 1.30.1   2015-09-04 Bioconductor
 beanplot          * 1.2      2014-09-19 CRAN (R 3.2.0)
 Biobase           * 2.28.0   2015-04-21 Bioconductor
 BiocGenerics      * 0.14.0   2015-04-21 Bioconductor
 BiocParallel      * 1.2.20   2015-09-04 Bioconductor
 biomaRt             2.24.0   2015-04-21 Bioconductor
 Biostrings        * 2.36.4   2015-09-04 Bioconductor
 biovizBase        * 1.16.0   2015-04-21 Bioconductor
 bitops              1.0-6    2013-08-17 CRAN (R 3.2.0)
 BSgenome          * 1.36.3   2015-09-04 Bioconductor
 chron               2.3-47   2015-06-24 CRAN (R 3.2.2)
 cluster             2.0.3    2015-07-21 CRAN (R 3.2.2)
 codetools           0.2-14   2015-07-15 CRAN (R 3.2.2)
 colorspace          1.2-6    2015-03-11 CRAN (R 3.2.0)
 data.table        * 1.9.4    2014-10-02 CRAN (R 3.2.0)
 DBI                 0.3.1    2014-09-24 CRAN (R 3.2.0)
 devtools          * 1.9.1    2015-09-11 CRAN (R 3.2.2)
 dichromat           2.0-0    2013-01-24 CRAN (R 3.2.0)
 digest              0.6.8    2014-12-31 CRAN (R 3.2.0)
 doParallel        * 1.0.8    2014-02-28 CRAN (R 3.2.0)
 evaluate            0.7.2    2015-08-13 CRAN (R 3.2.2)
 foreach           * 1.4.2    2014-04-11 CRAN (R 3.2.0)
 foreign             0.8-66   2015-08-19 CRAN (R 3.2.2)
 formatR           * 1.2      2015-04-21 CRAN (R 3.2.0)
 Formula           * 1.2-1    2015-04-07 CRAN (R 3.2.0)
 futile.logger       1.4.1    2015-04-20 CRAN (R 3.2.0)
 futile.options      1.0.0    2010-04-06 CRAN (R 3.2.0)
 GenomeInfoDb      * 1.4.2    2015-09-04 Bioconductor
 GenomicAlignments * 1.4.1    2015-09-04 Bioconductor
 GenomicFeatures   * 1.20.3   2015-09-04 Bioconductor
 GenomicRanges     * 1.20.6   2015-09-04 Bioconductor
 GGally              0.5.0    2014-12-02 CRAN (R 3.2.0)
 ggbio             * 1.16.1   2015-09-04 Bioconductor
 ggplot2           * 1.0.1    2015-03-17 CRAN (R 3.2.0)
```

```
graph               1.46.0   2015-04-21 Bioconductor
gridExtra           2.0.0    2015-07-14 CRAN (R 3.2.2)
gtable              0.1.2    2012-12-05 CRAN (R 3.2.0)
Gviz              * 1.12.1   2015-09-04 Bioconductor
highr               0.5      2015-04-21 CRAN (R 3.2.0)
Hmisc             * 3.16-0   2015-04-30 CRAN (R 3.2.2)
htmltools           0.2.6    2014-09-08 CRAN (R 3.2.0)
hwriter             1.3.2    2014-09-10 CRAN (R 3.2.0)
IRanges           * 2.2.7    2015-09-04 Bioconductor
iterators         * 1.0.7    2014-04-11 CRAN (R 3.2.0)
knitr             * 1.11     2015-08-14 CRAN (R 3.2.2)
lambda.r            1.1.7    2015-03-20 CRAN (R 3.2.0)
lattice           * 0.20-33  2015-07-14 CRAN (R 3.2.2)
latticeExtra        0.6-26   2013-08-15 CRAN (R 3.2.0)
magrittr            1.5      2014-11-22 CRAN (R 3.2.2)
MASS                7.3-44   2015-08-30 CRAN (R 3.2.2)
matrixStats         0.14.2   2015-06-24 CRAN (R 3.2.2)
memoise             0.2.1    2014-04-22 CRAN (R 3.2.2)
munsell             0.4.2    2013-07-11 CRAN (R 3.2.0)
nnet                7.3-11   2015-08-30 CRAN (R 3.2.2)
OrganismDbi         1.10.0   2015-04-21 Bioconductor
plyr              * 1.8.3    2015-06-12 CRAN (R 3.2.2)
proto               0.3-10   2012-12-22 CRAN (R 3.2.0)
RBGL                1.44.0   2015-04-21 Bioconductor
RColorBrewer        1.1-2    2014-12-07 CRAN (R 3.2.0)
Rcpp                0.12.0   2015-07-25 CRAN (R 3.2.2)
RCurl               1.95-4.7 2015-06-30 CRAN (R 3.2.2)
reshape             0.8.5    2014-04-23 CRAN (R 3.2.0)
reshape2            1.4.1    2014-12-06 CRAN (R 3.2.0)
rmarkdown           0.8      2015-08-30 CRAN (R 3.2.2)
rpart               4.1-10   2015-06-29 CRAN (R 3.2.2)
Rsamtools         * 1.20.4   2015-09-04 Bioconductor
RSQLite             1.0.0    2014-10-25 CRAN (R 3.2.0)
rtracklayer       * 1.28.10  2015-09-04 Bioconductor
S4Vectors         * 0.6.5    2015-09-04 Bioconductor
scales            * 0.3.0    2015-08-25 CRAN (R 3.2.2)
ShortRead         * 1.26.0   2015-04-21 Bioconductor
stringi             0.5-5    2015-06-29 CRAN (R 3.2.2)
stringr             1.0.0    2015-04-30 CRAN (R 3.2.2)
survival          * 2.38-3   2015-07-02 CRAN (R 3.2.2)
VariantAnnotation   1.14.13  2015-09-04 Bioconductor
XML                 3.98-1.3 2015-06-30 CRAN (R 3.2.2)
XVector           * 0.8.0    2015-04-21 Bioconductor
yaml                2.1.13   2014-06-12 CRAN (R 3.2.0)
zlibbioc            1.14.0   2015-04-21 Bioconductor
```