

An Introduction to *GenomeInfoDb*

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1 Introduction

The *GenomeInfoDb* provides an interface to access seqlevelsStyles (such as UCSC, NCBI, Ensembl) and their supported mappings for organisms. For instance, for Homo sapiens, seqlevelsStyle "UCSC" maps to "chr1", "chr2", ..., "chrX", "chrY". The section below introduces these functions with examples.

2 Functionality for all existing organisms

2.1 genomeStyles

The `genomeStyles` lists out for each organism, the seqlevelsStyles and their mappings.

```
seqmap <- genomeStyles()
head(seqmap, n=2)

## $Arabidopsis_thaliana
##   circular auto   sex NCBI TAIR9 Ensembl
## 1  FALSE  TRUE FALSE   1 Chr1     1
## 2  FALSE  TRUE FALSE   2 Chr2     2
## 3  FALSE  TRUE FALSE   3 Chr3     3
## 4  FALSE  TRUE FALSE   4 Chr4     4
## 5  FALSE  TRUE FALSE   5 Chr5     5
## 6   TRUE FALSE FALSE  MT ChrM     Mt
## 7   TRUE FALSE  TRUE Pltd ChrC     Pt
##
## $Caenorhabditis_elegans
##   circular auto   sex NCBI  UCSC Ensembl
## 1  FALSE  TRUE FALSE   I  chrI     I
## 2  FALSE  TRUE FALSE  II  chrII    II
## 3  FALSE  TRUE FALSE III chrIII   III
## 4  FALSE  TRUE FALSE  IV  chrIV   IV
## 5  FALSE  TRUE FALSE   V  chrV     V
## 6  FALSE FALSE  TRUE   X  chrX     X
## 7   TRUE  TRUE FALSE  MT  chrM   MtdNA
```

Organism's supported by GenomeInfoDb can be found by :

```
names(genomeStyles())

## [1] "Arabidopsis_thaliana"      "Caenorhabditis_elegans"
## [3] "Canis_familiaris"         "Cyanidioschyzon_merolae"
## [5] "Drosophila_melanogaster"  "Homo_sapiens"
## [7] "Mus_musculus"            "Oryza_sativa"
## [9] "Populus_trichocarpa"     "Rattus_norvegicus"
## [11] "Saccharomyces_cerevisiae" "Zea_mays"
```

An Introduction to *GenomeInfoDb*

If one knows the organism one is interested in, then we can directly access the information for the given organism along. Each function accepts an argument called species which as "genus species", the default is "Homo sapiens". In the following example we list out only the first five entries returned by the code snippet.

```
head(genomeStyles("Homo_sapiens"),5)

##   circular auto   sex NCBI UCSC dbSNP Ensembl
## 1   FALSE TRUE FALSE   1 chr1  ch1     1
## 2   FALSE TRUE FALSE   2 chr2  ch2     2
## 3   FALSE TRUE FALSE   3 chr3  ch3     3
## 4   FALSE TRUE FALSE   4 chr4  ch4     4
## 5   FALSE TRUE FALSE   5 chr5  ch5     5
```

We can also check if a given style is supported by GenomeInfoDb for a given species. For example, if we want to know if "UCSC" mapping is supported for "Homo sapiens" we can ask :

```
"UCSC" %in% names(genomeStyles("Homo_sapiens"))
## [1] TRUE
```

2.2 extractSeqlevels

We can also extract the desired seqlevelsStyle from a given organism using the `extractSeqlevels`

```
extractSeqlevels(species="Arabidopsis_thaliana", style="NCBI")
## [1] "1" "2" "3" "4" "5" "MT" "Pltd"
```

2.3 extractSeqlevelsByGroup

We can also extract the desired seqlevelsStyle from a given organism based on a group (Group - 'auto' denotes autosomes, 'circular' denotes circular chromosomes and 'sex' denotes sex chromosomes; the default is all chromosomes are returned).

```
extractSeqlevelsByGroup(species="Arabidopsis_thaliana", style="NCBI",
                        group="auto")
## [1] "1" "2" "3" "4" "5"
```

2.4 seqlevelsStyle

We can find the seqname Style for a given character vector by using the `seqlevelsStyle`

```
seqlevelsStyle(paste0("chr",c(1:30)))
## [1] "UCSC"

seqlevelsStyle(c("2L","2R","X","Xhet"))
```

```
## [1] "NCBI"
```

2.5 seqlevelsInGroup

We can also subset a given character vector containing seqnames using the `seqlevelsInGroup`. We currently support 3 groups: 'auto' for autosomes, 'sex' for allosomes/sex chromosomes and circular for 'circular' chromosomes. The user can also provide the style and species they are working with. In the following examples, we extract the sex, auto and circular chromosomes for Homo sapiens :

```
newchr <- paste0("chr",c(1:22, "X", "Y", "M", "1_gl000192_random", "4_ctg9_hap1"))
seqlevelsInGroup(newchr, group="sex")
## [1] "chrX" "chrY"

seqlevelsInGroup(newchr, group="auto")
## [1] "chr1" "chr2" "chr3" "chr4" "chr5" "chr6" "chr7" "chr8" "chr9"
## [10] "chr10" "chr11" "chr12" "chr13" "chr14" "chr15" "chr16" "chr17" "chr18"
## [19] "chr19" "chr20" "chr21" "chr22"

seqlevelsInGroup(newchr, group="circular")
## [1] "chrM"

seqlevelsInGroup(newchr, group="sex", "Homo_sapiens", "UCSC")
## [1] "chrX" "chrY"
```

if we have a vector containing seqnames and we want to verify the species and style for them , we can use:

```
seqnames <- c("chr1", "chr9", "chr2", "chr3", "chr10")
all(seqnames %in% extractSeqlevels("Homo_sapiens", "UCSC"))
## [1] TRUE
```

2.6 orderSeqlevels

The `orderSeqlevels` can return the order of a given character vector which contains seqnames. In the following example, we show how you can find the order for a given seqnames character vector.

```
seqnames <- c("chr1", "chr9", "chr2", "chr3", "chr10")
orderSeqlevels(seqnames)
## [1] 1 3 4 2 5

seqnames[orderSeqlevels(seqnames)]
## [1] "chr1" "chr2" "chr3" "chr9" "chr10"
```

2.7 rankSeqlevels

The `rankSeqlevels` can return the rank of a given character vector which contains seqnames. In the following example, we show how you can find the rank for a given seqnames character vector.

```
seqnames <- c("chr1", "chr9", "chr2", "chr3", "chr10")
rankSeqlevels(seqnames)
## [1] 1 4 2 3 5
```

2.8 mapSeqlevels

Returns a matrix with 1 column per supplied sequence name and 1 row per sequence renaming map compatible with the specified style. If `best.only` is TRUE (the default), only the "best" renaming maps (i.e. the rows with less NAs) are returned.

```
mapSeqlevels(c("chrII", "chrIII", "chrM"), "NCBI")
## chrII chrIII chrM
## "II" "III" "MT"
```

We also have several seqlevel utility functions. Let us construct a basic GRanges and show how these functions can be used. .

```
gr <- GRanges(paste0("ch", 1:35), IRanges(1:35, width=5))
gr
## GRanges object with 35 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
## [1]      ch1         1-5      *
## [2]      ch2         2-6      *
## [3]      ch3         3-7      *
## [4]      ch4         4-8      *
## [5]      ch5         5-9      *
## ...           ...           ...      ...
## [31]     ch31        31-35     *
## [32]     ch32        32-36     *
## [33]     ch33        33-37     *
## [34]     ch34        34-38     *
## [35]     ch35        35-39     *
## -----
## seqinfo: 35 sequences from an unspecified genome; no seqlengths
```

As you can see, we have "ch" instead of "chr" for chromosome names. We can use `renameSeqlevels` to change the "ch" to "chr"

2.9 renameSeqlevels

As the first argument - it takes the object whose seqlevels we need to change, and as the second argument it takes a named vector which has the changes.

```

newnames <- paste0("chr",1:35)
names(newnames) <- paste0("ch",1:35)
head(newnames)

##   ch1   ch2   ch3   ch4   ch5   ch6
## "chr1" "chr2" "chr3" "chr4" "chr5" "chr6"

gr <- renameSeqlevels(gr,newnames)
gr

## GRanges object with 35 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
##   [1]   chr1         1-5      *
##   [2]   chr2         2-6      *
##   [3]   chr3         3-7      *
##   [4]   chr4         4-8      *
##   [5]   chr5         5-9      *
##   ...     ...         ...     ...
##  [31]  chr31        31-35     *
##  [32]  chr32        32-36     *
##  [33]  chr33        33-37     *
##  [34]  chr34        34-38     *
##  [35]  chr35        35-39     *
##  -----
## seqinfo: 35 sequences from an unspecified genome; no seqlengths

```

Humans have just 22 primary chromosomes - but here we have some extra seqlevels which we want to remove - there are several ways we can achieve this:

2.10 dropSeqlevels

Here the second argument is the seqlevels that you want to drop. Because these seqlevels are in use (i.e. have ranges on them), the ranges on these sequences need to be removed before the seqlevels can be dropped. We call this *pruning*. The `pruning.mode` argument controls how to prune `gr`. Unlike for list-like objects (e.g. `GRangesList`) for which pruning can be done in various ways, pruning a `GRanges` object is straightforward and achieved by specifying `pruning.mode="coarse"`.

```

dropSeqlevels(gr, paste0("chr",23:35), pruning.mode="coarse")

## GRanges object with 22 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
##   [1]   chr1         1-5      *
##   [2]   chr2         2-6      *
##   [3]   chr3         3-7      *

```

```
## [4] chr4 4-8 *
## [5] chr5 5-9 *
## ... .. ... ..
## [18] chr18 18-22 *
## [19] chr19 19-23 *
## [20] chr20 20-24 *
## [21] chr21 21-25 *
## [22] chr22 22-26 *
## -----
## seqinfo: 22 sequences from an unspecified genome; no seqlengths
```

2.11 keepSeqlevels

Here the second argument is the seqlevels that you want to keep.

```
keepSeqlevels(gr, paste0("chr",1:22), pruning.mode="coarse")

## GRanges object with 22 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
## [1] chr1      1-5      *
## [2] chr2      2-6      *
## [3] chr3      3-7      *
## [4] chr4      4-8      *
## [5] chr5      5-9      *
## ... .. ... ..
## [18] chr18 18-22 *
## [19] chr19 19-23 *
## [20] chr20 20-24 *
## [21] chr21 21-25 *
## [22] chr22 22-26 *
## -----
## seqinfo: 22 sequences from an unspecified genome; no seqlengths
```

2.12 keepStandardChromosomes

This function internally uses the pre-defined tables inside GenomeInfoDb to find the correct seqlevels according to the sequence style of the object.

```
keepStandardChromosomes(gr, pruning.mode="coarse")

## GRanges object with 35 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
## [1] chr1      1-5      *
## [2] chr2      2-6      *
## [3] chr3      3-7      *
## [4] chr4      4-8      *
## [5] chr5      5-9      *
```

```
##      ...      ...      ...      ...
## [31] chr31    31-35    *
## [32] chr32    32-36    *
## [33] chr33    33-37    *
## [34] chr34    34-38    *
## [35] chr35    35-39    *
## -----
## seqinfo: 35 sequences from an unspecified genome; no seqlengths
```

One can also specify the optional species argument to be more precise.

```
plantgr <- GRanges(c(1:5,"MT","Pltd"), IRanges(1:7,width=5))
keepStandardChromosomes(plantgr, species="Arabidopsis thaliana",
  pruning.mode="coarse")

## GRanges object with 7 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
## [1]      1         1-5      *
## [2]      2         2-6      *
## [3]      3         3-7      *
## [4]      4         4-8      *
## [5]      5         5-9      *
## [6]      MT         6-10     *
## [7]      Pltd       7-11     *
## -----
## seqinfo: 7 sequences from an unspecified genome; no seqlengths
```

3 Classes inside GenomeInfoDb package

3.1 Genome-Description class

We also provide a Genome Description class which can be used in the following way:

```
library(BSgenome.Celegans.UCSC.ce2)
class(Celegans)

## [1] "BSgenome"
## attr(,"package")
## [1] "BSgenome"

is(Celegans, "GenomeDescription")

## [1] TRUE

provider(Celegans)

## [1] "UCSC"

seqinfo(Celegans)

## Seqinfo object with 7 sequences (1 circular) from ce2 genome:
```



```
## seqnames seqlengths isCircular genome
## chrI      15080483      FALSE   ce2
## chrII     15279308      FALSE   ce2
## chrIII    13783313      FALSE   ce2
## chrIV     17493791      FALSE   ce2
## chrV     20922231      FALSE   ce2
## chrX     17718849      FALSE   ce2
## chrM       13794        TRUE    ce2

gendesc <- as(Celegans, "GenomeDescription")
class(gendesc)

## [1] "GenomeDescription"
## attr(,"package")
## [1] "GenomeInfoDb"

gendesc

## | organism: Caenorhabditis elegans (Worm)
## | provider: UCSC
## | provider version: ce2
## | release date: Mar. 2004
## | release name: WormBase v. WS120
## | ---
## | seqlengths:
## |   chrI   chrII   chrIII   chrIV   chrV   chrX   chrM
## | 15080483 15279308 13783313 17493791 20922231 17718849 13794

provider(gendesc)

## [1] "UCSC"

seqinfo(gendesc)

## Seqinfo object with 7 sequences (1 circular) from ce2 genome:
## seqnames seqlengths isCircular genome
## chrI      15080483      FALSE   ce2
## chrII     15279308      FALSE   ce2
## chrIII    13783313      FALSE   ce2
## chrIV     17493791      FALSE   ce2
## chrV     20922231      FALSE   ce2
## chrX     17718849      FALSE   ce2
## chrM       13794        TRUE    ce2

bsgenomeName(gendesc)

## [1] "BSgenome.Celegans.UCSC.ce2"
```

3.2 Seqinfo class

```
## Note that all the arguments (except 'genome') must have the
## same length. 'genome' can be of length 1, whatever the lengths
## of the other arguments are.
x <- Seqinfo(seqnames=c("chr1", "chr2", "chr3", "chrM"),
```

```

seqlengths=c(100, 200, NA, 15),
isCircular=c(NA, FALSE, FALSE, TRUE),
genome="toy")

length(x)
## [1] 4

seqnames(x)
## [1] "chr1" "chr2" "chr3" "chrM"

names(x)
## [1] "chr1" "chr2" "chr3" "chrM"

seqlevels(x)
## [1] "chr1" "chr2" "chr3" "chrM"

seqlengths(x)
## chr1 chr2 chr3 chrM
## 100 200 NA 15

isCircular(x)
## chr1 chr2 chr3 chrM
## NA FALSE FALSE TRUE

genome(x)
## chr1 chr2 chr3 chrM
## "toy" "toy" "toy" "toy"

x[c("chrY", "chr3", "chr1")] # subset by names

## Seqinfo object with 3 sequences from 2 genomes (NA, toy):
## seqnames seqlengths isCircular genome
## chrY NA NA <NA>
## chr3 NA FALSE toy
## chr1 100 NA toy

## Rename, drop, add and/or reorder the sequence levels:
xx <- x
seqlevels(xx) <- sub("chr", "ch", seqlevels(xx)) # rename
xx

## Seqinfo object with 4 sequences (1 circular) from toy genome:
## seqnames seqlengths isCircular genome
## ch1 100 NA toy
## ch2 200 FALSE toy
## ch3 NA FALSE toy
## chM 15 TRUE toy

seqlevels(xx) <- rev(seqlevels(xx)) # reorder
xx

## Seqinfo object with 4 sequences (1 circular) from toy genome:
## seqnames seqlengths isCircular genome
## chM 15 TRUE toy

```

```
## ch3          NA      FALSE  toy
## ch2          200     FALSE  toy
## ch1          100      NA     toy

seqlevels(xx) <- c("ch1", "ch2", "chY") # drop/add/reorder
xx

## Seqinfo object with 3 sequences from 2 genomes (toy, NA):
## seqnames seqlengths isCircular genome
## ch1          100      NA     toy
## ch2          200     FALSE  toy
## chY          NA       NA    <NA>

seqlevels(xx) <- c(chY="Y", ch1="1", "22") # rename/reorder/drop/add
xx

## Seqinfo object with 3 sequences from 2 genomes (NA, toy):
## seqnames seqlengths isCircular genome
## Y          NA       NA    <NA>
## 1          100     NA     toy
## 22         NA       NA    <NA>

y <- Seqinfo(seqnames=c("chr3", "chr4", "chrM"),
              seqlengths=c(300, NA, 15))
y

## Seqinfo object with 3 sequences from an unspecified genome:
## seqnames seqlengths isCircular genome
## chr3          300      NA    <NA>
## chr4          NA       NA    <NA>
## chrM          15       NA    <NA>

merge(x, y) # rows for chr3 and chrM are merged

## Warning in .Seqinfo.mergexy(x, y): Each of the 2 combined objects has sequence
## levels not in the other:
## - in 'x': chr1, chr2
## - in 'y': chr4
## Make sure to always combine/compare objects based on the same reference
## genome (use suppressWarnings() to suppress this warning).

## Seqinfo object with 5 sequences (1 circular) from 2 genomes (toy, NA):
## seqnames seqlengths isCircular genome
## chr1          100      NA     toy
## chr2          200     FALSE  toy
## chr3          300     FALSE  toy
## chrM          15      TRUE   toy
## chr4          NA       NA    <NA>

suppressWarnings(merge(x, y))

## Seqinfo object with 5 sequences (1 circular) from 2 genomes (toy, NA):
## seqnames seqlengths isCircular genome
## chr1          100      NA     toy
## chr2          200     FALSE  toy
## chr3          300     FALSE  toy
```

```
## chrM      15      TRUE   toy
## chr4      NA      NA     <NA>

## Note that, strictly speaking, merging 2 Seqinfo objects is not
## a commutative operation, i.e., in general 'z1 <- merge(x, y)'
## is not identical to 'z2 <- merge(y, x)'. However 'z1' and 'z2'
## are guaranteed to contain the same information (i.e. the same
## rows, but typically not in the same order):
suppressWarnings(merge(y, x))

## Seqinfo object with 5 sequences (1 circular) from 2 genomes (toy, NA):
## seqnames seqlengths isCircular genome
## chr3      300      FALSE   toy
## chr4      NA      NA     <NA>
## chrM      15      TRUE   toy
## chr1      100      NA     toy
## chr2      200      FALSE   toy

## This contradicts what 'x' says about circularity of chr3 and chrM:
isCircular(y)[c("chr3", "chrM")] <- c(TRUE, FALSE)
y

## Seqinfo object with 3 sequences (1 circular) from an unspecified genome:
## seqnames seqlengths isCircular genome
## chr3      300      TRUE   <NA>
## chr4      NA      NA     <NA>
## chrM      15      FALSE  <NA>

if (interactive()) {
  merge(x, y) # raises an error
}
```

4 Examples

4.1 converting seqlevel styles (eg:UCSC to NCBI)

A quick example using *Drosophila Melanogaster*. The txdb object contains seqlevels in UCSC style, we want to convert them to NCBI

```
txdb <- TxDb.Dmelanogaster.UCSC.dm3.ensGene
seqlevels(txdb)

## [1] "chr2L"      "chr2R"      "chr3L"      "chr3R"      "chr4"      "chrX"
## [7] "chrU"       "chrM"       "chr2LHet"   "chr2RHet"   "chr3LHet"   "chr3RHet"
## [13] "chrXHet"    "chrYHet"    "chrUextra"

genomeStyles("Drosophila melanogaster")

##   circular sex auto  NCBI   UCSC           Ensembl
## 1   FALSE FALSE TRUE   2L   chr2L           2L
## 2   FALSE FALSE TRUE   2R   chr2R           2R
## 3   FALSE FALSE TRUE   3L   chr3L           3L
```

```
## 4    FALSE FALSE TRUE    3R    chr3R                    3R
## 5    FALSE FALSE TRUE    4    chr4                      4
## 6    FALSE TRUE  FALSE   X    chrX                      X
## 7    FALSE TRUE  FALSE   Y    chrY                      Y
## 8    TRUE  FALSE FALSE   MT    chrM dmel_mitochondrion_genome
## 9    FALSE FALSE FALSE  2LHet chr2LHet                    2LHet
## 10   FALSE FALSE FALSE  2Rhet chr2RHet                    2RHet
## 11   FALSE FALSE FALSE  3LHet chr3LHet                    3LHet
## 12   FALSE FALSE FALSE  3RHet chr3RHet                    3RHet
## 13   FALSE FALSE FALSE  Xhet  chrXHet                    XHet
## 14   FALSE FALSE FALSE  Yhet  chrYHet                    YHet
## 15   FALSE FALSE FALSE   Un    chrU                      U
## 16   FALSE FALSE FALSE <NA> chrUextra                  Uextra

mapSeqlevels(seqlevels(txdb), "NCBI")

##      chr2L      chr2R      chr3L      chr3R      chr4      chrX      chrU
##      "2L"      "2R"      "3L"      "3R"      "4"      "X"      "Un"
##      chrM chr2LHet chr2RHet chr3LHet chr3RHet chrXHet chrYHet
##      "MT"  "2LHet"  "2Rhet" "3LHet" "3RHet" "Xhet"  "Yhet"
## chrUextra
##      NA
```

4.2 converting styles and removing unwanted seqlevels

Suppose we read in a Bam file or a BED file and the resulting GRanges have a lot of seqlevels which are not required by your analysis or you want to rename the seqlevels from the current style to your own style (eg:USCS to NCBI), we can use the functionality provided by GenomeInfoDb to do that.

Let us say that we have extracted the seqlevels of the Seqinfo object(say GRanges from a BED file) in a variable called "sequence".

```
sequence <- seqlevels(x)

## sequence is in UCSC format and we want NCBI style
newStyle <- mapSeqlevels(sequence,"NCBI")
newStyle <- newStyle[complete.cases(newStyle)] # removing NA cases.

## rename the seqlevels
x <- renameSeqlevels(x,newStyle)

## keep only the seqlevels you want (say autosomes)
auto <- extractSeqlevelsByGroup(species="Homo sapiens", style="NCBI",
                               group="auto")
x <- keepSeqlevels(x,auto)
```

5 Session Information

Here is the output of `sessionInfo` on the system on which this document was compiled:

```
toLatex(sessionInfo())
```

- R version 3.6.0 (2019-04-26), x86_64-pc-linux-gnu
- Locale: LC_CTYPE=en_US.UTF-8, LC_NUMERIC=C, LC_TIME=en_US.UTF-8, LC_COLLATE=C, LC_MONETARY=en_US.UTF-8, LC_MESSAGES=en_US.UTF-8, LC_PAPER=en_US.UTF-8, LC_NAME=C, LC_ADDRESS=C, LC_TELEPHONE=C, LC_MEASUREMENT=en_US.UTF-8, LC_IDENTIFICATION=C
- Running under: Ubuntu 18.04.2 LTS
- Matrix products: default
- BLAS: /home/biocbuild/bbs-3.9-bioc/R/lib/libRblas.so
- LAPACK: /home/biocbuild/bbs-3.9-bioc/R/lib/libRlapack.so
- Base packages: base, datasets, grDevices, graphics, methods, parallel, stats, stats4, utils
- Other packages: AnnotationDbi 1.46.0, BSgenome 1.52.0, BSgenome.Celegans.UCSC.ce2 1.4.0, Biobase 2.44.0, BiocGenerics 0.30.0, Biostrings 2.52.0, GenomeInfoDb 1.20.0, GenomicFeatures 1.36.0, GenomicRanges 1.36.0, IRanges 2.18.0, S4Vectors 0.22.0, TxDb.Dmelanogaster.UCSC.dm3.ensGene 3.2.2, XVector 0.24.0, rtracklayer 1.44.0
- Loaded via a namespace (and not attached): BiocManager 1.30.4, BiocParallel 1.18.0, BiocStyle 2.12.0, DBI 1.0.0, DelayedArray 0.10.0, GenomeInfoDbData 1.2.1, GenomicAlignments 1.20.0, Matrix 1.2-17, R6 2.4.0, RCurl 1.95-4.12, RSQLite 2.1.1, Rcpp 1.0.1, Rsamtools 2.0.0, SummarizedExperiment 1.14.0, XML 3.98-1.19, assertthat 0.2.1, biomaRt 2.40.0, bit 1.1-14, bit64 0.9-7, bitops 1.0-6, blob 1.1.1, compiler 3.6.0, crayon 1.3.4, digest 0.6.18, evaluate 0.13, grid 3.6.0, highr 0.8, hms 0.4.2, htmltools 0.3.6, httr 1.4.0, knitr 1.22, lattice 0.20-38, magrittr 1.5, matrixStats 0.54.0, memoise 1.1.0, pkgconfig 2.0.2, prettyunits 1.0.2, progress 1.2.0, rlang 0.3.4, rmarkdown 1.12, stringi 1.4.3, stringr 1.4.0, tools 3.6.0, xfun 0.6, yaml 2.2.0, zlibbioc 1.30.0