

# Package ‘tximeta’

November 15, 2024

**Version** 1.24.0

**Title** Transcript Quantification Import with Automatic Metadata

**Description** Transcript quantification import from Salmon and other quantifiers with automatic attachment of transcript ranges and release information, and other associated metadata. De novo transcriptomes can be linked to the appropriate sources with linkedTxomes and shared for computational reproducibility.

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**License** GPL-2

**VignetteBuilder** knitr

**Imports** SummarizedExperiment, tximport, jsonlite, S4Vectors, IRanges, GenomicRanges, AnnotationDbi, GenomicFeatures, txdbmaker, ensemblDb, BiocFileCache, AnnotationHub, Biostrings, tibble, GenomeInfoDb, tools, utils, methods, Matrix

**Suggests** knitr, rmarkdown, testthat, tximportData, org.Dm.eg.db, DESeq2, fishpond, edgeR, limma, devtools

**URL** <https://github.com/thelovelab/tximeta>

**biocViews** Annotation, GenomeAnnotation, DataImport, Preprocessing, RNASeq, SingleCell, Transcriptomics, Transcription, GeneExpression, FunctionalGenomics, ReproducibleResearch, ReportWriting, ImmunoOncology

**RoxygenNote** 7.3.2

**Encoding** UTF-8

**git\_url** <https://git.bioconductor.org/packages/tximeta>

**git\_branch** RELEASE\_3\_20

**git\_last\_commit** 9a98a8d

**git\_last\_commit\_date** 2024-10-29

**Repository** Bioconductor 3.20

**Date/Publication** 2024-11-14

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tximeta-package	<i>Import transcript quantification with metadata</i>
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## Description

The tximeta package imports abundances (TPM), estimated counts, and effective lengths from Salmon, alevin, piscem or other quantification tools, and will output a SummarizedExperiment object. For Salmon / alevin / piscem quantification data, tximeta will try to identify the correct provenance of the reference transcripts and automatically attach the transcript ranges to the SummarizedExperiment, to facilitate downstream integration with other datasets. The automatic identification of reference transcripts should work out-of-the-box for human or mouse transcriptomes from the sources: GENCODE, Ensembl, or RefSeq.

## Details

The main functions are:

- `tximeta` - with key argument: `coldata`
- `summarizeToGene,SummarizedExperiment-method` - summarize quants to gene-level
- `retrieveDb` - retrieve the transcript database
- `addIds` - add transcript or gene ID (see gene argument)

All software-related questions should be posted to the Bioconductor Support Site:

<https://support.bioconductor.org>

The code can be viewed at the GitHub repository, which also lists the contributor code of conduct:

<https://github.com/thelovelab/tximeta>

## Author(s)

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## References

**tximeta** reference:

Michael I. Love, Charlotte Soneson, Peter F. Hickey, Lisa K. Johnson N. Tessa Pierce, Lori Shepherd, Martin Morgan, Rob Patro (2020) Tximeta: reference sequence checksums for provenance identification in RNA-seq. PLOS Computational Biology. <https://doi.org/10.1371/journal.pcbi.1007664>

**tximport** reference (the effective length offset and counts-from-abundance):

Charlotte Soneson, Michael I. Love, Mark D. Robinson (2015) Differential analyses for RNA-seq: transcript-level estimates improve gene-level inferences. F1000Research. <http://doi.org/10.12688/f1000research.7563>

## See Also

Useful links:

- <https://github.com/thelovelab/tximeta>

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addCDS

*Add CDS to rowRanges of a transcript-level SummarizedExperiment*

---

## Description

Working similarly to [addExons](#), this function can be used to add information about CDS (coding sequence) to the SummarizedExperiment object. As not all transcripts are coding, we have CDS information for only a subset of the rows of the object. For this reason, a logical indicator for whether the transcript is coding, `mcols(se)$coding`, is added as a column to the metadata columns of the `rowRanges` of the object. An additional column, `mcols(se)$cds`, is added to the metadata columns, which is a `GRangesList` with either the CDS regions (if the transcript is coding), or the original transcript/exon ranges (if the transcript is non-coding). This is necessary, as `GRangesList` cannot have NA elements. As with [addExons](#), this function is designed only for transcript-level objects.

## Usage

```
addCDS(se)
```

## Arguments

`se`                    the SummarizedExperiment

## Value

a SummarizedExperiment

---

addExons	<i>Add exons to rowRanges of a transcript-level SummarizedExperiment</i>
----------	--------------------------------------------------------------------------

---

### Description

After running `tximeta`, the `SummarizedExperiment` output will have `GRanges` representing the transcript locations attached as `rowRanges` to the object. These provide the start and end of the transcript in the genomic coordinates, and strand information. However, the exonic locations are not provided. This function, `addExons`, swaps out the `GRanges` with a `GRangesList`, essentially a list along the rows of the `SummarizedExperiment`, where each element of the list is a `GRanges` providing the locations of the exons for that transcript.

### Usage

```
addExons(se)
```

### Arguments

`se`                    the `SummarizedExperiment`

### Details

This function is designed only for transcript-level objects. This "lack of a feature" reflects a belief on the part of the package author that it makes more sense to think about exons belonging to transcripts than to genes. For users desiring exonic information alongside gene-level objects, for example, which exons are associated with a particular gene, it is recommended to pull out the relevant `GRangesList` for the transcripts of this gene, while the object represents transcript-level data, such that the exons are still associated with transcripts.

For an example of `addExons`, please see the `tximeta` vignette.

### Value

a `SummarizedExperiment`

---

addIds	<i>Add IDs to rowRanges of a SummarizedExperiment</i>
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### Description

For now this function just works with `SummarizedExperiments` with Ensembl gene or transcript IDs. See example of usage in `tximeta` vignette. For obtaining multiple matching IDs for each row of the `SummarizedExperiment` set `multiVals="list"`. See `select` for documentation on use of `multiVals`.

### Usage

```
addIds(se, column, fromDb = FALSE, gene = FALSE, ...)
```

**Arguments**

se	the SummarizedExperiment
column	the name of the new ID to add (a column of the org package database or of the TxDb/EnsDb is fromDb=TRUE)
fromDb	logical, whether to use the TxDb/EnsDb that is associated with se. Default is FALSE, and an org package is used. Currently only implemented for transcript level (gene=FALSE). Column names can be viewed with <code>columns(retrieveDb(se))</code>
gene	logical, whether to map by genes or transcripts (default is FALSE). if rows are genes, and easily detected as such (ENSG or ENSMUSG), it will automatically switch to TRUE. if rows are transcripts and gene=TRUE, then it will try to use a gene_id column to map IDs to column
...	arguments passed to mapIds

**Value**

a SummarizedExperiment

**Examples**

```
example(tximeta)
library(org.Dm.eg.db)
se <- addIds(se, "REFSEQ", gene=FALSE)
```

---

getTximetaBFC

*Get or set the directory of the BiocFileCache used by tximeta*


---

**Description**

Running `getTximetaBFC` will report the saved directory, if it has been determined, or will return NULL. Running `setTximetaBFC` will ask the user to specify a BiocFileCache directory for accessing and saving TxDb sqlite files. Note that tximeta's BiocFileCache can be set by the environmental variable TXIMETA\_HUB\_CACHE, which will reset the cache location.

**Usage**

```
getTximetaBFC()

setTximetaBFC(dir, quiet = FALSE)
```

**Arguments**

dir	the location for tximeta's BiocFileCache. can be missing in which case the function will call <code>file.choose</code> for choosing location interactively
quiet	whether to suppress feedback message

**Value**

the directory of the BiocFileCache used by tximeta (or nothing, in the case of `setTximetaBFC`)

**Examples**

```
# getting the BiocFileCache used by tximeta
# (may not be set, which uses BiocFileCache default or temp directory)
getTximetaBFC()

# don't want to actually change user settings so this is not run:
# setTximetaBFC()
```

---

linkedTxome

---

*Make and load linked transcriptomes ("linkedTxome")*


---

**Description**

makeLinkedTxome reads the digest associated with a Salmon index at indexDir, and links it to key information about the transcriptome, including the source, organism, release, and genome (these are custom character strings), as well as the locations (e.g. local, HTTP, or FTP) for one or more fasta files and one gtf file. loadLinkedTxome loads this information from a JSON file. See Details.

**Usage**

```
makeLinkedTxome(
  indexDir,
  source,
  organism,
  release,
  genome,
  fasta,
  gtf,
  write = TRUE,
  jsonFile
)

loadLinkedTxome(jsonFile)
```

**Arguments**

indexDir	the local path to the Salmon index
source	the source of transcriptome (e.g. "de-novo"). Note: if you specify "GENCODE" or "Ensembl", this will trigger behavior by tximeta that may not be desired: e.g. attempts to download canonical transcriptome data from AnnotationHub (unless useHub=FALSE when running tximeta) and parsing of Ensembl GTF using ensemblldb (which may fail if the GTF file has been modified). For transcriptomes that are defined by local GTF files, it is recommended to use the terms "LocalGENCODE" or "LocalEnsembl". Setting "LocalEnsembl" will also strip version numbers from the FASTA transcript IDs to enable matching with the Ensembl GTF.
organism	organism (e.g. "Homo sapiens")
release	release number (e.g. "27")

genome	genome (e.g. "GRCh38", or "none")
fasta	location(s) for the FASTA transcript sequences (of which the transcripts used to build the index is equal or a subset). This can be a local path, or an HTTP or FTP URL
gtf	location for the GTF/GFF file (of which the transcripts used to build the index is equal or a subset). This can be a local path, or an HTTP or FTP URL While the fasta argument can take a vector of length greater than one (more than one FASTA file containing transcripts used in indexing), the gtf argument has to be a single GTF/GFF file. This can also be a serialized GRanges object (location of a .rds file) imported with rtracklayer. If transcripts were added to a standard set of reference transcripts (e.g. fusion genes, or pathogen transcripts), it is recommended that the tximeta user would manually add these to the GTF/GFF file, and post the modified GTF/GFF publicly, such as on Zenodo. This enables consistent annotation and downstream annotation tasks, such as by summarizeToGene.
write	logical, should a JSON file be written out which documents the transcriptome digest and metadata? (default is TRUE)
jsonFile	the path to the json file for the linkedTxome

## Details

makeLinkedTxome links the information about the transcriptome used for quantification in two ways: 1) the function will store a record in tximeta's cache such that future import of quantification data will automatically access and parse the GTF as if the transcriptome were one of those automatically detected by tximeta. Then all features of tximeta (e.g. summarization to gene, programmatic adding of IDs or metadata) will be available; 2) it will by default write out a JSON file that can be shared, or posted online, and which can be read by loadLinkedTxome which will store the information in tximeta's cache. This should make the full quantification-import pipeline computationally reproducible / auditable even for transcriptomes which differ from those provided by references (GENCODE, Ensembl, RefSeq).

For further details please see the "Linked transcriptomes" section of the tximeta vignette.

## Value

nothing, the function is run for its side effects

## Examples

```
# point to a Salmon quantification file with an additional artificial transcript
dir <- system.file("extdata/salmon_dm", package="tximportData")
file <- file.path(dir, "SRR1197474.plus", "quant.sf")
coldata <- data.frame(files=file, names="SRR1197474", sample="1",
                      stringsAsFactors=FALSE)

# now point to the Salmon index itself to create a linkedTxome
# as the index will not match a known txome
indexDir <- file.path(dir, "Dm.BDGP6.22.98.plus_salmon-0.14.1")

# point to the source FASTA and GTF:
fastaFTP <- c("ftp://ftp.ensembl.org/pub/release-98/fasta/drosophila_melanogaster/cdna/Drosophila_melanogas
            "ftp://ftp.ensembl.org/pub/release-98/fasta/drosophila_melanogaster/ncrna/Drosophila_melanogaster
            "extra_transcript.fa.gz")
gtfPath <- file.path(dir, "Drosophila_melanogaster.BDGP6.22.98.plus.gtf.gz")
```

```
# now create a linkedTxome, linking the Salmon index to its FASTA and GTF sources
makeLinkedTxome(indexDir=indexDir, source="Ensembl", organism="Drosophila melanogaster",
                 release="98", genome="BDGP6.22", fasta=fastaFTP, gtf=gtfPath, write=FALSE)

# to clear the entire linkedTxome table
# (don't run unless you want to clear this table!)
# bfcloc <- getTximetaBFC()
# bfc <- BiocFileCache(bfcloc)
# bfcremove(bfc, bfcquery(bfc, "linkedTxomeTbl")$rid)
```

---

makeDGEList	<i>Make a DGEList from tximeta output</i>
-------------	-------------------------------------------

---

### Description

A simple wrapper function for constructing a DGEList for use with edgeR. See vignette for an example. Requires installation of the edgeR package from Bioconductor.

### Usage

```
makeDGEList(se)
```

### Arguments

se                    a SummarizedExperiment produced by tximeta

### Value

a DGEList

---

retrieveCDNA	<i>Retrieve the cDNA transcript sequence for a SummarizedExperiment</i>
--------------	-------------------------------------------------------------------------

---

### Description

This helper function retrieves the cDNA sequence of the transcripts used for expression quantification. This function either downloads or loads the transcript sequence from cache, it does not re-order or check against the rows of the SummarizedExperiment (which could be already summarized to genes for example).

### Usage

```
retrieveCDNA(se, quiet = FALSE)
```

### Arguments

se                    the SummarizedExperiment  
quiet                logical, suppress messages



**Value**

a DNStringSet object

**Examples**

```
## Not run:  
# this example is not run because it requires access to Ensembl ftp  
example(tximeta)  
cdna <- retrieveCDNA(se)  
  
## End(Not run)
```

---

retrieveDb

*Retrieve the TxDb or EnsDb associated with a SummarizedExperiment*

---

**Description**

SummarizedExperiment objects returned by `tximeta` have associated TxDb or EnsDb databases which are cached locally and used to perform various metadata related tasks. This helper function retrieves the database itself for the user to perform any additional operations.

**Usage**

```
retrieveDb(se)
```

**Arguments**

se                    the SummarizedExperiment

**Value**

a database object

**Examples**

```
example(tximeta)  
edb <- retrieveDb(se)
```

splitSE

*Split SummarizedExperiment by gene categories***Description**

Construct a new `SummarizedExperiment` by splitting one of the assays into a list of assays, each of which contains features of a given 'type'. It is assumed that there is a one-to-one correspondence between feature sets of different types; for example, these can be spliced and unspliced variants of the same transcripts. The type of each feature in the original `SummarizedExperiment`, and the correspondence between the features of different types, are given in a `data.frame`.

**Usage**

```
splitSE(se, splitDf, assayName)
```

**Arguments**

<code>se</code>	A <code>SummarizedExperiment</code> object.
<code>splitDf</code>	A <code>data.frame</code> with feature IDs. Each column represents a separate feature type, and the features in a given row are considered representatives of the same feature (and will be represented as one feature in the output object).
<code>assayName</code>	A character scalar, indicating the assay of <code>se</code> that will be split. Must be one of <code>assayNames(se)</code> .

**Value**

A `SummarizedExperiment` object with the same columns as the input object, and the same number of assays as the number of columns in `splitDf`. The assays will be named by the column names of `splitDf`. The `colData` and `metadata` of the input `SummarizedExperiment` object are copied to the output object. The row names are set to the feature IDs in the first column of `splitDf`.

**Examples**

```
se <- SummarizedExperiment::SummarizedExperiment(
  assays = S4Vectors::SimpleList(
    counts = as(matrix(1:15, nrow = 5), "sparseMatrix"),
    logcounts = log2(matrix(1:15, nrow = 5))
  ),
  colData = S4Vectors::DataFrame(sID = paste0("S", 1:3),
    condition = c("A", "A", "B")),
  metadata = list(md1 = "annotation")
)
rownames(se) <- paste0("G", 1:5)
colnames(se) <- paste0("P", 1:3)
splitDf <- data.frame(spliced = c("G1", "G2", "G6"),
  unspliced = c("G3", "G5", "G4"),
  stringsAsFactors = FALSE)

splse <- splitSE(se = se, splitDf = splitDf, assayName = "counts")
```

---

summarizeToGene, SummarizedExperiment-method

*Summarize estimated quantities to gene-level*


---

## Description

Summarizes abundances, counts, lengths, (and inferential replicates or variance) from transcript-to gene-level. Transcript IDs are stored as a CharacterList in the `mcols` of the output object. This function operates on SummarizedExperiment objects, and will automatically access the relevant TxDb (by either finding it in the BiocFileCache or by building it from an ftp location). This function uses the tximport package to perform summarization, where a method is defined that works on simple lists.

## Usage

```
## S4 method for signature 'SummarizedExperiment'
summarizeToGene(
  object,
  assignRanges = c("range", "abundant"),
  varReduce = FALSE,
  ...
)
```

## Arguments

<code>object</code>	a SummarizedExperiment produced by tximeta
<code>assignRanges</code>	"range" or "abundant", this argument controls the way that the rowRanges of the output object are assigned (note that this argument does not affect data aggregation at all). The default is to just output the entire range of the gene, i.e. the leftmost basepair to the rightmost basepair across all isoforms. Alternatively, for expressed genes, one can obtain the start and end of the most abundant isoform (averaging over all samples). Non-expressed genes will have range-based positions. For abundant, for expressed genes, the name of the range-assigned isoform, <code>max_prop</code> (maximum isoform proportion), and <code>iso_prop</code> (numeric values for isoform proportions) are also returned in <code>mcols</code>
<code>varReduce</code>	whether to reduce per-sample inferential replicates information into a matrix of sample variances variance (default FALSE)
<code>...</code>	arguments passed to tximport

## Value

a SummarizedExperiment with summarized quantifications and transcript IDs as a CharacterList in the `mcols`

## Examples

```
example(tximeta)
gse <- summarizeToGene(se)
```

tximeta

*Import transcript quantification with metadata***Description**

tximeta leverages the hashed digest of the Salmon or pisces index, in addition to a number of core Bioconductor packages (GenomicFeatures, ensemblDb, AnnotationHub, GenomeInfoDb, BiocFileCache) to automatically populate metadata for the user, without additional effort from the user. For other quantifiers see the customMetaInfo argument below.

**Usage**

```
tximeta(
  coldata,
  type = NULL,
  txOut = TRUE,
  skipMeta = FALSE,
  skipSeqinfo = FALSE,
  useHub = TRUE,
  markDuplicateTxps = FALSE,
  cleanDuplicateTxps = FALSE,
  customMetaInfo = NULL,
  skipFtp = FALSE,
  ...
)
```

**Arguments**

coldata	<p>a data.frame with at least two columns (others will propagate to object):</p> <ul style="list-style-type: none"> <li>files - character, paths of quantification files</li> <li>names - character, sample names</li> </ul> <p>if coldata is a vector, it is assumed to be the paths of quantification files and unique sample names are created</p>
type	what quantifier was used (see <a href="#">tximport</a> )
txOut	whether to output transcript-level data. tximeta is designed to have transcript-level output with Salmon, so default is TRUE, and it's recommended to use <a href="#">summarizeToGene</a> following tximeta for gene-level summarization. For an alevin file, tximeta will import the gene level counts ignoring this argument (alevin produces only gene-level quantification).
skipMeta	whether to skip metadata generation (e.g. to avoid errors if not connected to internet). This calls tximport directly and so either txOut=TRUE or tx2gene should be specified.
skipSeqinfo	whether to skip the addition of Seqinfo, which requires an internet connection to download the relevant chromosome information table from UCSC
useHub	whether to first attempt to download a TxDb/EnsDb object from AnnotationHub, rather than creating from a GTF file from FTP (default is TRUE). If FALSE, it will force tximeta to download and parse the GTF

<code>markDuplicateTxps</code>	whether to mark the status ( <code>hasDuplicate</code> ) and names of duplicate transcripts ( <code>duplicates</code> ) in the <code>rowData</code> of the <code>SummarizedExperiment</code> output. Subsequent summarization to gene level will keep track of the number of transcripts sets per gene ( <code>numDupSets</code> )
<code>cleanDuplicateTxps</code>	whether to try to clean duplicate transcripts (exact sequence duplicates) by replacing the transcript names that do not appear in the GTF with those that do appear in the GTF
<code>customMetaInfo</code>	the relative path to a custom metadata information JSON file, relative to the paths in files of <code>coldata</code> . For example, <code>customMetaInfo="meta_info.json"</code> would indicate that in the same directory as the quantification files in <code>files</code> , there are custom metadata information JSON files. These should contain the SHA-256 hash of the reference transcripts with the <code>index_seq_hash</code> tag (see details in vignette).
<code>skipFtp</code>	whether to avoid <code>ftp://</code> in case of firewall, default is <code>FALSE</code>
<code>...</code>	arguments passed to <code>tximport</code>

## Details

Most of the code in `tximeta` works to add metadata and transcript ranges when the quantification was performed with Salmon. However, `tximeta` can be used with any quantification type that is supported by `tximport`, where it will return a non-ranged `SummarizedExperiment`.

`tximeta` performs a lookup of the hashed digest of the index (stored in an auxiliary information directory of the Salmon output) against a database of known transcriptomes, which lives within the `tximeta` package and is continually updated on Bioconductor's release schedule. In addition, `tximeta` performs a lookup of the digest against a locally stored table of `linkedTxome`'s (see `link{makeLinkedTxome}`). If `tximeta` detects a match, it will automatically populate, e.g. the transcript locations, the transcriptome release, the genome with correct chromosome lengths, etc. It allows for automatic and correct summarization of transcript-level quantifications to the gene-level via `summarizeToGene` without the need to manually build a `tx2gene` table.

`tximeta` on the first run will ask where the `BiocFileCache` for this package should be kept, either using a default location or a temporary directory. At any point, the user can specify a location using `setTximetaBFC` and this choice will be saved for future sessions. Multiple users can point to the same `BiocFileCache`, such that transcript databases (`TxDb` or `EnsDb`) associated with certain Salmon indices and `linkedTxomes` can be accessed by different users without additional effort or time spent downloading and building the relevant `TxDb` / `EnsDb`. Note that, if the `TxDb` or `EnsDb` is present in `AnnotationHub`, `tximeta` will use this object instead of downloading and building a `TxDb/EnsDb` from GTF (to disable this set `useHub=FALSE`).

In order to allow that multiple users can read and write to the same location, one should set the `BiocFileCache` directory to have group write permissions (`g+w`).

## Value

a `SummarizedExperiment` with metadata on the `rowRanges`. (if the hashed digest in the Salmon or Sailfish index does not match any known transcriptomes, or any locally saved `linkedTxome`, `tximeta` will just return a non-ranged `SummarizedExperiment`)

## Examples

```
# point to a Salmon quantification file:
```

```
dir <- system.file("extdata/salmon_dm", package="tximportData")
files <- file.path(dir, "SRR1197474", "quant.sf")
coldata <- data.frame(files, names="SRR1197474", condition="A", stringsAsFactors=FALSE)

# normally we would just run the following which would download the appropriate metadata
# se <- tximeta(coldata)

# for this example, we instead point to a local path where the GTF can be found
# by making a linkedTxome:
indexDir <- file.path(dir, "Dm.BDGP6.22.98_salmon-0.14.1")
fastaFTP <- c("ftp://ftp.ensembl.org/pub/release-98/fasta/drosophila_melanogaster/cdna/Drosophila_melanogaster",
             "ftp://ftp.ensembl.org/pub/release-98/fasta/drosophila_melanogaster/ncrna/Drosophila_melanogaster")
gtfPath <- file.path(dir, "Drosophila_melanogaster.BDGP6.22.98.gtf.gz")
makeLinkedTxome(indexDir=indexDir, source="LocalEnsembl", organism="Drosophila melanogaster",
                release="98", genome="BDGP6.22", fasta=fastaFTP, gtf=gtfPath, write=FALSE)
se <- tximeta(coldata)

# to clear the entire linkedTxome table
# (don't run unless you want to clear this table!)
# bfcloc <- getTximetaBFC()
# bfc <- BiocFileCache(bfcloc)
# bfcremove(bfc, bfcquery(bfc, "linkedTxomeTbl")$rid)
```

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