

# Package ‘tximeta’

April 12, 2022

**Version** 1.12.4

**Title** Transcript Quantification Import with Automatic Metadata

**Description** Transcript quantification import from Salmon and alevin 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, ensemblDb, BiocFileCache, AnnotationHub, Biostrings, tibble, GenomeInfoDb, tools, utils, methods, Matrix

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

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

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

**RoxygenNote** 7.1.2

**Encoding** UTF-8

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

**git\_branch** RELEASE\_3\_14

**git\_last\_commit** 78d1a79

**git\_last\_commit\_date** 2021-12-20

**Date/Publication** 2022-04-12

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

The tximeta package imports abundances (TPM), estimated counts, and effective lengths from Salmon, alevin, or other quantification tools, and will output a SummarizedExperiment object. For Salmon and alevin quantification directories, 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` - summarize quants to gene-level
- `retrieveDb` - retrieve the transcript database
- `addIds` - add transcript or gene ID (see `gene` argument)
- `addExons` - convert from GRanges to GRangesList

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/mikelove/tximeta>

### Author(s)

Michael I. Love, Charlotte Soneson, Peter Hickey, Rob Patro

### 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>

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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>
--------	---

---

### 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 columns(retrieveDb(se))
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 `file.choose` 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 checksum 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**

<code>indexDir</code>	the local path to the Salmon index
<code>source</code>	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 <code>useHub=FALSE</code> when running tximeta) and parsing of Ensembl GTF using <code>ensemldb</code> (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"
<code>organism</code>	organism (e.g. "Homo sapiens")
<code>release</code>	release number (e.g. "27")
<code>genome</code>	genome (e.g. "GRCh38", or "none")
<code>fasta</code>	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
<code>gtf</code>	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 <code>fasta</code> argument can take a vector of length greater than one (more than one FASTA file containing transcripts used in indexing), the <code>gtf</code> argument has to be a single GTF/GFF file. 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 <code>summarizeToGene</code> .
<code>write</code>	logical, should a JSON file be written out which documents the transcriptome checksum and metadata? (default is TRUE)
<code>jsonFile</code>	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_melanogaster.
             "ftp://ftp.ensembl.org/pub/release-98/fasta/drosophila_melanogaster/ncrna/Drosophila_melanogaster.BDGP6.22.98.
             "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

*Make a DGEList from tximeta output*


---

**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 DNASTringSet object

**Examples**

```
example(tximeta)
cdna <- retrieveCDNA(se)
```

---

retrieveDb	<i>Retrieve the TxDb or EnsDb associated with a SummarizedExperiment</i>
------------	--

---

**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**

se	A SummarizedExperiment object.
splitDf	A data.frame 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).
assayName	A character scalar, indicating the assay of se that will be split. Must be one of assayNames(se).

**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, varReduce = FALSE, ...)

```

## Arguments

<code>object</code>	a <code>SummarizedExperiment</code> produced by <code>tximeta</code>
<code>varReduce</code>	whether to reduce per-sample inferential replicates information into a matrix of sample variances <code>variance</code> (default <code>FALSE</code> )
<code>...</code>	arguments passed to <code>tximport</code>

## Value

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

## Examples

```

example(tximeta)
gse <- summarizeToGene(se)

```

---

tximeta

*tximeta: Transcript quantification import with automatic metadata*


---

## Description

tximeta leverages the hashed checksum of the Salmon 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. Note that tximeta requires that the entire output directory of Salmon or alevin is present and unmodified in order to identify the provenance of the reference transcripts.

## Usage

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

## Arguments

coldata	a data.frame with at least two columns (others will propagate to object): <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
markDuplicateTxps	whether to mark the status (hasDuplicate) and names of duplicate transcripts (duplicates) in the rowData of the SummarizedExperiment output. Subsequent summarization to gene level will keep track of the number of transcripts sets per gene (numDupSets)
cleanDuplicateTxps	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
customMetaInfo	the relative path to a custom metadata information JSON file, relative to the paths in files of coldata. For example, customMetaInfo="meta_info.json" would indicate that in the same directory as the quantification files in files, there are custom metadata information JSON files. These should contain the SHA-256 hash of the reference transcripts with the index_seq_hash tag (see details in vignette).
...	arguments passed to tximport

## 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 checksum 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 checksum 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 checksum 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.BDG
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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