

# Package ‘GenomicFeatures’

November 26, 2023

**Title** Conveniently import and query gene models

**Description** A set of tools and methods for making and manipulating transcript centric annotations. With these tools the user can easily download the genomic locations of the transcripts, exons and cds of a given organism, from either the UCSC Genome Browser or a BioMart database (more sources will be supported in the future). This information is then stored in a local database that keeps track of the relationship between transcripts, exons, cds and genes. Flexible methods are provided for extracting the desired features in a convenient format.

**biocViews** Genetics, Infrastructure, Annotation, Sequencing, GenomeAnnotation

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**BugReports** <https://github.com/Bioconductor/GenomicFeatures/issues>

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**Depends** R (>= 3.5.0), BiocGenerics (>= 0.1.0), S4Vectors (>= 0.17.29), IRanges (>= 2.13.23), GenomeInfoDb (>= 1.35.8), GenomicRanges (>= 1.31.17), AnnotationDbi (>= 1.41.4)

**Imports** methods, utils, stats, tools, DBI, RSQLite (>= 2.0), RCurl, XVector (>= 0.19.7), Biostrings (>= 2.47.6), BiocIO, rtracklayer (>= 1.51.5), biomaRt (>= 2.17.1), Biobase (>= 2.15.1)

**Suggests** RMariaDB, org.Mm.eg.db, org.Hs.eg.db, BSgenome, BSgenome.Hsapiens.UCSC.hg19 (>= 1.3.17), BSgenome.Celegans.UCSC.ce11, BSgenome.Dmelanogaster.UCSC.dm3 (>= 1.3.17), mirbase.db, FDb.UCSC.tRNAs, TxDb.Hsapiens.UCSC.hg19.knownGene, TxDb.Celegans.UCSC.ce11.ensGene, TxDb.Dmelanogaster.UCSC.dm3.ensGene (>= 2.7.1),

TxDb.Mmusculus.UCSC.mm10.knownGene (>= 3.4.7),  
 TxDb.Hsapiens.UCSC.hg19.lincRNAsTranscripts,  
 TxDb.Hsapiens.UCSC.hg38.knownGene (>= 3.4.6),  
 SNPlocs.Hsapiens.dbSNP144.GRCh38, Rsamtools, pasillaBamSubset  
 (>= 0.0.5), GenomicAlignments (>= 1.15.7), ensemblDb,  
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**VignetteBuilder** knitr

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 Ensembl-utils.R findCompatibleMarts.R TxDb-class.R  
 FeatureDb-class.R makeTxDb.R makeTxDbFromUCSC.R  
 makeTxDbFromBiomart.R makeTxDbFromEnsembl.R  
 makeTxDbFromGRanges.R makeTxDbFromGFF.R makeFeatureDbFromUCSC.R  
 mapIdsToRanges.R id2name.R transcripts.R transcriptsBy.R  
 transcriptsByOverlaps.R transcriptLengths.R exonicParts.R  
 extendExonsIntoIntrons.R features.R microRNAs.R  
 extractTranscriptSeqs.R extractUpstreamSeqs.R  
 getPromoterSeq-methods.R makeTxDbPackage.R select-methods.R  
 nearest-methods.R transcriptLocs2refLocs.R  
 coordinate-mapping-methods.R proteinToGenome.R  
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as-format-methods	<i>Coerce to file format structures</i>
-------------------	---

---

**Description**

These functions coerce a [TxDb](#) object to a [GRanges](#) object with metadata columns encoding transcript structures according to the model of a standard file format. Currently, BED and GFF models are supported. If a [TxDb](#) is passed to [export](#), when targeting a BED or GFF file, this coercion occurs automatically.

**Usage**

```
## S4 method for signature 'TxDb'
asBED(x)
## S4 method for signature 'TxDb'
asGFF(x)
```

**Arguments**

x                    A TxDb object to coerce to a GRanges, structured as BED or GFF.

**Value**

For asBED, a GRanges, with the columns name, thickStart, thickEnd, blockStarts, blockSizes added. The thick regions correspond to the CDS regions, and the blocks represent the exons. The transcript IDs are stored in the name column. The ranges are the transcript bounds.

For asGFF, a GRanges, with columns type, Name, ID,, and Parent. The gene structures are expressed according to the conventions defined by the GFF3 spec. There are elements of each type of feature: “gene”, “mRNA” “exon” and “cds”. The Name column contains the gene\_id for genes, tx\_name for transcripts, and exons and cds regions are NA. The ID column uses gene\_id and tx\_id, with the prefixes “GeneID” and “TxID” to ensure uniqueness across types. The exons and cds regions have NA for ID. The Parent column contains the IDs of the parent features. A feature may have multiple parents (the column is a CharacterList). Each exon belongs to one or more mRNAs, and mRNAs belong to a gene.

**Author(s)**

Michael Lawrence

**Examples**

```
txdb_file <- system.file("extdata", "hg19_knownGene_sample.sqlite",
                        package="GenomicFeatures")
txdb <- loadDb(txdb_file)

asBED(txdb)
asGFF(txdb)
```

---

coverageByTranscript    *Compute coverage by transcript (or CDS) of a set of ranges*

---

**Description**

coverageByTranscript computes the transcript (or CDS) coverage of a set of ranges.

pcoverageByTranscript is a version of coverageByTranscript that operates element-wise.

**Usage**

```
coverageByTranscript(x, transcripts, ignore.strand=FALSE)
```

```
pcoverageByTranscript(x, transcripts, ignore.strand=FALSE, ...)
```

**Arguments**

- x** An object representing a set of ranges (typically aligned reads). [GRanges](#), [GRangesList](#), [GAlignments](#), [GAlignmentPairs](#), and [GAlignmentsList](#) objects are supported.
- More generally, for `coverageByTranscript` `x` can be any object for which `seqinfo()` and `coverage()` are supported (e.g. a [BamFile](#) object). Note that, for such objects, `coverage()` is expected to return an [RleList](#) object whose names are `seqlevels(x)`.
- More generally, for `pcoverageByTranscript` `x` can be any object for which `grglist()` is supported. It should have the length of `transcripts` or length 1. If the latter, it is recycled to the length of `transcripts`.
- transcripts** A [GRangesList](#) object representing the exons of each transcript for which to compute coverage. For each transcript, the exons must be ordered by *ascending rank*, that is, by their position in the transcript. This means that, for a transcript located on the minus strand, the exons should typically be ordered by descending position on the reference genome. If `transcripts` was obtained with `exonsBy`, then the exons are guaranteed to be ordered by ascending rank. See `?exonsBy` for more information.
- Alternatively, `transcripts` can be a [TxDb](#) object, or any [TxDb](#)-like object that supports the `exonsBy()` extractor (e.g. an [EnsDb](#) object). In this case it is replaced with the [GRangesList](#) object returned by `exonsBy(transcripts, by="tx", use.names=TRUE)`.
- For `pcoverageByTranscript`, `transcripts` should have the length of `x` or length 1. If the latter, it is recycled to the length of `x`.
- ignore.strand** TRUE or FALSE. If FALSE (the default) then the strand of a range in `x` and exon in `transcripts` must be the same in order for the range to contribute coverage to the exon. If TRUE then the strand is ignored.
- ...** Additional arguments passed to the internal call to `grglist()`. More precisely, when `x` is not a [GRanges](#) or [GRangesList](#) object, `coverageByTranscript` replace it with the [GRangesList](#) object returned by `grglist(x, ...)`.

**Value**

An [RleList](#) object *parallel* to `transcripts`, that is, the *i*-th element in it is an integer-[Rle](#) representing the coverage of the *i*-th transcript in `transcripts`. Its `lengths()` is guaranteed to be identical to `sum(width(transcripts))`. The names and metadata columns on `transcripts` are propagated to it.

**Author(s)**

Hervé Pagès

## See Also

- [transcripts](#), [transcriptsBy](#), and [transcriptsByOverlaps](#), for extracting genomic feature locations from a [TxDb](#)-like object.
- [transcriptLengths](#) for extracting the transcript lengths (and other metrics) from a [TxDb](#) object.
- [extractTranscriptSeqs](#) for extracting transcript (or CDS) sequences from chromosome sequences.
- The [RleList](#) class defined and documented in the [IRanges](#) package.
- The [GRangesList](#) class defined and documented in the [GenomicRanges](#) package.
- The [coverage](#) methods defined in the [GenomicRanges](#) package.
- The [exonsBy](#) function for extracting exon ranges grouped by transcript.
- [findCompatibleOverlaps](#) in the [GenomicAlignments](#) package for finding which reads are *compatible* with the splicing of which transcript.

## Examples

```
## -----
## 1. A SIMPLE ARTIFICIAL EXAMPLE WITH ONLY ONE TRANSCRIPT
## -----

## Get some transcripts:
library(TxDb.Dmelanogaster.UCSC.dm3.ensGene)
txdb <- TxDb.Dmelanogaster.UCSC.dm3.ensGene
dm3_transcripts <- exonsBy(txdb, by="tx", use.names=TRUE)
dm3_transcripts

## Let's pick up the 1st transcript: FBtr0300689. It as 2 exons and 1
## intron:
my_transcript <- dm3_transcripts["FBtr0300689"]

## Let's create 3 artificial aligned reads. We represent them as a
## GRanges object of length 3 that contains the genomic positions of
## the 3 reads. Note that these reads are simple alignments i.e. each
## of them can be represented with a single range. This would not be
## the case if they were junction reads.
my_reads <- GRanges(c("chr2L:7531-7630",
                     "chr2L:8101-8200",
                     "chr2L:8141-8240"))

## The coverage of the 3 reads on the reference genome is:
coverage(my_reads)

## As you can see, all the genomic positions in the 3 ranges participate
## to the coverage. This can be confirmed by comparing:
sum(coverage(my_reads))
## with:
sum(width(my_reads))
## They should always be the same.
```

```

## When computing the coverage on a transcript, only the part of the
## read that overlaps with the transcript participates to the coverage.
## Let's look at the individual coverage of each read on transcript
## FBtr0300689:

## The 1st read is fully contained within the 1st exon:
coverageByTranscript(my_reads[1], my_transcript)

## Note that the length of the Rle (1880) is the length of the transcript.

## The 2nd and 3rd reads overlap the 2 exons and the intron. Only the
## parts that overlap the exons participate to coverage:
coverageByTranscript(my_reads[2], my_transcript)
coverageByTranscript(my_reads[3], my_transcript)

## The coverage of the 3 reads together is:
coverageByTranscript(my_reads, my_transcript)

## Note that this is the sum of the individual coverages. This can be
## checked with:
stopifnot(all(
  coverageByTranscript(my_reads, my_transcript)
  ==
  Reduce("+", lapply(seq_along(my_reads),
    function(i) coverageByTranscript(my_reads[i], my_transcript)), 0L)
))

## -----
## 2. COMPUTE THE FULL TRANSCRIPTOME COVERAGE OF A SET OF ALIGNED READS
## -----

## Load the aligned reads:
library(pasillaBamSubset)
library(GenomicAlignments)
reads <- readGAlignments(untreated1_chr4())

## Compute the full transcriptome coverage by calling
## coverageByTranscript() on 'dm3_transcripts':
tx_cvg <- coverageByTranscript(reads, dm3_transcripts, ignore.strand=TRUE)
tx_cvg

## A sanity check:
stopifnot(identical(lengths(tx_cvg), sum(width(dm3_transcripts))))

## We can also use pcoverageByTranscript() to compute 'tx_cvg'.
## For this we first create a GAlignmentsList object "parallel" to
## 'dm3_transcripts' where the i-th list element contains the aligned
## reads that overlap with the i-th transcript:
hits <- findOverlaps(reads, dm3_transcripts, ignore.strand=TRUE)
tx2reads <- setNames(as(t(hits), "List"), names(dm3_transcripts))
reads_by_tx <- extractList(reads, tx2reads) # GAlignmentsList object
reads_by_tx

```

```

## Call pcoverageByTranscript():
tx_cvg2 <- pcoverageByTranscript(reads_by_tx, dm3_transcripts,
                                ignore.strand=TRUE)
stopifnot(identical(tx_cvg, tx_cvg2))

## A more meaningful coverage is obtained by counting for each
## transcript only the reads that are *compatible* with its splicing:
compat_hits <- findCompatibleOverlaps(reads, dm3_transcripts)
tx2reads <- setNames(as(t(compat_hits), "List"), names(dm3_transcripts))
compat_reads_by_tx <- extractList(reads, tx2reads)

tx_compat_cvg <- pcoverageByTranscript(compat_reads_by_tx,
                                       dm3_transcripts,
                                       ignore.strand=TRUE)

## A sanity check:
stopifnot(all(all(tx_compat_cvg <= tx_cvg)))

## -----
## 3. COMPUTE CDS COVERAGE OF A SET OF ALIGNED READS
## -----

## coverageByTranscript() can also be used to compute CDS coverage:
cds <- cdsBy(txdb, by="tx", use.names=TRUE)
cds_cvg <- coverageByTranscript(reads, cds, ignore.strand=TRUE)
cds_cvg

## A sanity check:
stopifnot(identical(lengths(cds_cvg), sum(width(cds))))

## -----
## 4. ALTERNATIVELY, THE CDS COVERAGE CAN BE OBTAINED FROM THE
##     TRANSCRIPT COVERAGE BY TRIMMING THE 5' AND 3' UTRS
## -----

tx_lens <- transcriptLengths(txdb, with.utr5_len=TRUE, with.utr3_len=TRUE)
stopifnot(identical(tx_lens$tx_name, names(tx_cvg))) # sanity

## Keep the rows in 'tx_lens' that correspond to a list element in
## 'cds_cvg' and put them in the same order as in 'cds_cvg':
m <- match(names(cds_cvg), names(tx_cvg))
tx_lens <- tx_lens[m, ]
utr5_width <- tx_lens$utr5_len
utr3_width <- tx_lens$utr3_len
cds_cvg2 <- windows(tx_cvg[m], start=1L+utr5_width, end=-1L-utr3_width)

## A sanity check:
stopifnot(identical(cds_cvg2, cds_cvg))

```



## Description

exonicParts and intronicParts extract the non-overlapping (a.k.a. disjoint) exonic or intronic parts from a [TxDb](#)-like object.

## Usage

```
exonicParts(txdb, linked.to.single.gene.only=FALSE)
intronicParts(txdb, linked.to.single.gene.only=FALSE)
```

```
## 3 helper functions used internally by exonicParts() and intronicParts():
tidyTranscripts(txdb, drop.geneless=FALSE)
tidyExons(txdb, drop.geneless=FALSE)
tidyIntrons(txdb, drop.geneless=FALSE)
```

## Arguments

**txdb** A [TxDb](#) object, or any [TxDb](#)-like object that supports the [transcripts\(\)](#) and [exonsBy\(\)](#) extractors (e.g. an [EnsDb](#) object).

**linked.to.single.gene.only**  
TRUE or FALSE.

If FALSE (the default), then the disjoint parts are obtained by calling [disjoin\(\)](#) on all the exons (or introns) in txdb, including on exons (or introns) not linked to a gene or linked to more than one gene.

If TRUE, then the disjoint parts are obtained in 2 steps:

1. call [disjoin\(\)](#) on the exons (or introns) linked to *at least one gene*,
2. then drop the parts linked to more than one gene from the set of exonic (or intronic) parts obtained previously.

**drop.geneless** If FALSE (the default), then all the transcripts (or exons, or introns) get extracted from the [TxDb](#) object.

If TRUE, then only the transcripts (or exons, or introns) that are linked to a gene get extracted from the [TxDb](#) object.

Note that drop.geneless also impacts the order in which the features are returned:

- **Transcripts:** If drop.geneless is FALSE then transcripts are returned in the same order as with [transcripts](#), which is expected to be by internal transcript id (tx\_id). Otherwise they are ordered first by gene id (gene\_id), then by internal transcript id.
- **Exons:** If drop.geneless is FALSE then exons are ordered first by internal transcript id (tx\_id), then by exon rank (exon\_rank). Otherwise they are ordered first by gene id (gene\_id), then by internal transcript id, and then by exon rank.
- **Introns:** If drop.geneless is FALSE then introns are ordered by internal transcript id (tx\_id). Otherwise they are ordered first by gene id (gene\_id), then by internal transcript id.

**Value**

exonicParts returns a disjoint and strictly sorted [GRanges](#) object with 1 range per exonic part and with metadata columns tx\_id, tx\_name, gene\_id, exon\_id, exon\_name, and exon\_rank. If linked.to.single.gene.only was set to TRUE, an additional exonic\_part metadata column is added that indicates the rank of each exonic part within all the exonic parts linked to the same gene.

intronicParts returns a disjoint and strictly sorted [GRanges](#) object with 1 range per intronic part and with metadata columns tx\_id, tx\_name, and gene\_id. If linked.to.single.gene.only was set to TRUE, an additional intronic\_part metadata column is added that indicates the rank of each intronic part within all the intronic parts linked to the same gene.

tidyTranscripts returns a [GRanges](#) object with 1 range per transcript and with metadata columns tx\_id, tx\_name, and gene\_id.

tidyExons returns a [GRanges](#) object with 1 range per exon and with metadata columns tx\_id, tx\_name, gene\_id, exon\_id, exon\_name, and exon\_rank.

tidyIntrons returns a [GRanges](#) object with 1 range per intron and with metadata columns tx\_id, tx\_name, and gene\_id.

**Author(s)**

Hervé Pagès

**See Also**

- [disjoin](#) in the **IRanges** package.
- [transcripts](#), [transcriptsBy](#), and [transcriptsByOverlaps](#), for extracting genomic feature locations from a [TxDb](#)-like object.
- [transcriptLengths](#) for extracting the transcript lengths (and other metrics) from a [TxDb](#) object.
- [extendExonsIntoIntrons](#) for extending exons into their adjacent introns.
- [extractTranscriptSeqs](#) for extracting transcript (or CDS) sequences from chromosome sequences.
- [coverageByTranscript](#) for computing coverage by transcript (or CDS) of a set of ranges.
- The [TxDb](#) class.

**Examples**

```
library(TxDb.Hsapiens.UCSC.hg19.knownGene)
txdb <- TxDb.Hsapiens.UCSC.hg19.knownGene

## -----
## exonicParts()
## -----

exonic_parts1 <- exonicParts(txdb)
exonic_parts1

## Mapping from exonic parts to genes is many-to-many:
```

```

gene_id1 <- mcols(exonic_parts1)$gene_id
gene_id1 # CharacterList object
table(lengths(gene_id1))
## The number of known genes a Human exonic part can be linked to
## varies from 0 to 22!

exonic_parts2 <- exonicParts(txdb, linked.to.single.gene.only=TRUE)
exonic_parts2

## Mapping from exonic parts to genes now is many-to-one:
gene_id2 <- mcols(exonic_parts2)$gene_id
gene_id2[1:20] # character vector

## Select exonic parts for a given gene:
exonic_parts2[gene_id2 %in% "643837"]

## Sanity checks:
stopifnot(isDisjoint(exonic_parts1), isStrictlySorted(exonic_parts1))
stopifnot(isDisjoint(exonic_parts2), isStrictlySorted(exonic_parts2))
stopifnot(all(exonic_parts2 %within% reduce(exonic_parts1)))
stopifnot(identical(
  lengths(gene_id1) == 1L,
  exonic_parts1 %within% exonic_parts2
))

## -----
## intronicParts()
## -----

intronic_parts1 <- intronicParts(txdb)
intronic_parts1

## Mapping from intronic parts to genes is many-to-many:
mcols(intronic_parts1)$gene_id
table(lengths(mcols(intronic_parts1)$gene_id))
## A Human intronic part can be linked to 0 to 22 known genes!

intronic_parts2 <- intronicParts(txdb, linked.to.single.gene.only=TRUE)
intronic_parts2

## Mapping from intronic parts to genes now is many-to-one:
class(mcols(intronic_parts2)$gene_id) # character vector

## Sanity checks:
stopifnot(isDisjoint(intronic_parts1), isStrictlySorted(intronic_parts1))
stopifnot(isDisjoint(intronic_parts2), isStrictlySorted(intronic_parts2))
stopifnot(all(intronic_parts2 %within% reduce(intronic_parts1)))
stopifnot(identical(
  lengths(mcols(intronic_parts1)$gene_id) == 1L,
  intronic_parts1 %within% intronic_parts2
))

## -----

```

```

## Helper functions
## -----

tidyTranscripts(txdb)           # Ordered by 'tx_id'.
tidyTranscripts(txdb, drop.geneless=TRUE) # Ordered first by 'gene_id',
                                         # then by 'tx_id'.

tidyExons(txdb)                 # Ordered first by 'tx_id',
                                         # then by 'exon_rank'.
tidyExons(txdb, drop.geneless=TRUE) # Ordered first by 'gene_id',
                                         # then by 'tx_id',
                                         # then by 'exon_rank'.

tidyIntrons(txdb)              # Ordered by 'tx_id'.
tidyIntrons(txdb, drop.geneless=TRUE) # Ordered first by 'gene_id',
                                         # then by 'tx_id'.

```

---

extendExonsIntoIntrons

*Extend exons by a given number of bases into their adjacent introns*

---

## Description

extendExonsIntoIntrons extends the supplied exons by a given number of bases into their adjacent introns.

## Usage

```
extendExonsIntoIntrons(ex_by_tx, extent=2)
```

## Arguments

ex_by_tx	<p>A <a href="#">GRangesList</a> object containing exons grouped by transcript. This must be an object as returned by <code>exonsBy(txdb, by="tx")</code>, that is:</p> <ul style="list-style-type: none"> <li>• each list element in <code>ex_by_tx</code> must be a <a href="#">GRanges</a> object representing the exons of a given transcript;</li> <li>• the exons in each list element must be ordered by ascending rank with respect to their transcript.</li> </ul>
extent	<p>Size of the extent in number of bases. 2 by default.</p> <p>The first exon in a transcript will be extended by that amount on its 3' side only. The last exon in a transcript will be extended by that amount on its 5' side only. All other exons (i.e. intermediate exons) will be extended by that amount on <i>each</i> side.</p> <p>Note that exons that belong to a single-exon transcript don't get extended.</p> <p>The default value of 2 corresponds to inclusion of the donor/acceptor intronic regions (typically GT/AG).</p>

**Value**

A copy of [GRangesList](#) object `ex_by_tx` where the original exon ranges have been extended.

Names and metadata columns on `ex_by_tx` are propagated to the result.

**Author(s)**

Hervé Pagès

**See Also**

- [transcripts](#), [transcriptsBy](#), and [transcriptsByOverlaps](#), for extracting genomic feature locations from a [TxDb](#)-like object.
- [exonicParts](#) and [intronicParts](#) for extracting non-overlapping exonic or intronic parts from a [TxDb](#)-like object.
- [extractTranscriptSeqs](#) for extracting transcript (or CDS) sequences from chromosome sequences.
- The [TxDb](#) class.

**Examples**

```
## With toy transcripts:
ex_by_tx <- GRangesList(
  TX1="chr1:10-20:+",
  TX2=c("chr1:10-20:+", "chr1:50-75:+"),
  TX3=c("chr1:10-20:+", "chr1:50-75:+", "chr1:100-120:+"),
  TX4="chr1:10-20:-",
  TX5=c("chr1:10-20:-", "chr1:50-75:-"),
  TX6=c("chr1:10-20:-", "chr1:50-75:-", "chr1:100-120:-")
)

extended <- extendExonsIntoIntrons(ex_by_tx, extent=2)
extended[1:3]
extended[4:6]

## With real-world transcripts:
library(TxDb.Celegans.UCSC.ce11.ensGene)
txdb <- TxDb.Celegans.UCSC.ce11.ensGene
ex_by_tx <- exonsBy(txdb, by="tx")
ex_by_tx

extendExonsIntoIntrons(ex_by_tx, extent=2)

## Sanity check:
stopifnot(identical(extendExonsIntoIntrons(ex_by_tx, extent=0), ex_by_tx))
```

---

extractTranscriptSeqs *Extract transcript (or CDS) sequences from chromosome sequences*

---

### Description

extractTranscriptSeqs extracts transcript (or CDS) sequences from an object representing a single chromosome or a collection of chromosomes.

### Usage

```
extractTranscriptSeqs(x, transcripts, ...)

## S4 method for signature 'DNAString'
extractTranscriptSeqs(x, transcripts, strand="+")

## S4 method for signature 'ANY'
extractTranscriptSeqs(x, transcripts, ...)
```

### Arguments

- |             |  |
|-------------|--|
| x           | <p>An object representing a single chromosome or a collection of chromosomes. More precisely, x can be a <a href="#">DNAString</a> object (single chromosome), or a <a href="#">BSgenome</a> object (collection of chromosomes). Other objects representing a collection of chromosomes are supported (e.g. <a href="#">FaFile</a> objects in the <b>Rsamtools</b> package) as long as <a href="#">seqinfo</a> and <a href="#">getSeq</a> work on them.</p>  |
| transcripts | <p>An object representing the exon ranges of each transcript to extract. More precisely:</p> <ul style="list-style-type: none"> <li>• If x is a <a href="#">DNAString</a> object, then transcripts must be an <a href="#">IntegerRangesList</a> object.</li> <li>• If x is a <a href="#">BSgenome</a> object or any object representing a collection of chromosomes, then transcripts must be a <a href="#">GRangesList</a> object or any object for which <a href="#">exonsBy</a> is implemented (e.g. a <a href="#">TxDb</a> or <a href="#">EnsDb</a> object). If the latter, then it's first turned into a <a href="#">GRangesList</a> object with <a href="#">exonsBy</a>(transcripts, by="tx", ...).</li> </ul> |

Note that, for each transcript, the exons must be ordered by ascending *rank*, that is, by ascending position *in the transcript* (when going in the 5' to 3' direction). This generally means (but not always) that they are also ordered from 5' to 3' on the reference genome. More precisely:

- For a transcript located on the plus strand, the exons will typically (but not necessarily) be ordered by ascending position on the reference genome.
- For a transcript located on the minus strand, the exons will typically (but not necessarily) be ordered by descending position on the reference genome.

If transcripts was obtained with [exonsBy](#) (see above), then the exons are guaranteed to be ordered by ascending rank. See [?exonsBy](#) for more information.

...	<p>Additional arguments, for use in specific methods.</p> <p>For the default method, additional arguments are allowed only when transcripts is not a <a href="#">GRangesList</a> object, in which case they are passed to the internal call to <a href="#">exonsBy</a> (see above).</p>
strand	<p>Only supported when x is a <a href="#">DNAStrng</a> object.</p> <p>Can be an atomic vector, a factor, or an <a href="#">Rle</a> object, in which case it indicates the strand of each transcript (i.e. all the exons in a transcript are considered to be on the same strand). More precisely: it's turned into a factor (or factor-<a href="#">Rle</a>) that has the "standard strand levels" (this is done by calling the <a href="#">strand</a> function on it). Then it's recycled to the length of <a href="#">IntegerRangesList</a> object transcripts if needed. In the resulting object, the i-th element is interpreted as the strand of all the exons in the i-th transcript.</p> <p>strand can also be a list-like object, in which case it indicates the strand of each exon, individually. Thus it must have the same <i>shape</i> as <a href="#">IntegerRangesList</a> object transcripts (i.e. same length plus strand[[i]] must have the same length as transcripts[[i]] for all i).</p> <p>strand can only contain "+" and/or "-" values. "*" is not allowed.</p>

**Value**

A [DNAStrngSet](#) object *parallel* to transcripts, that is, the i-th element in it is the sequence of the i-th transcript in transcripts.

**Author(s)**

Hervé Pagès

**See Also**

- [coverageByTranscript](#) for computing coverage by transcript (or CDS) of a set of ranges.
- [transcriptLengths](#) for extracting the transcript lengths (and other metrics) from a [TxDb](#) object.
- [extendExonsIntoIntrons](#) for extending exons into their adjacent introns.
- The [transcriptLocs2refLocs](#) function for converting transcript-based locations into reference-based locations.
- The [available.genomes](#) function in the **BSgenome** package for checking availability of BSgenome data packages (and installing the desired one).
- The [DNAStrng](#) and [DNAStrngSet](#) classes defined and documented in the **Biostrings** package.
- The [translate](#) function in the **Biostrings** package for translating DNA or RNA sequences into amino acid sequences.
- The [GRangesList](#) class defined and documented in the **GenomicRanges** package.
- The [IntegerRangesList](#) class defined and documented in the **IRanges** package.
- The [exonsBy](#) function for extracting exon ranges grouped by transcript.
- The [TxDb](#) class.

**Examples**

```

## -----
## 1. A TOY EXAMPLE
## -----

library(Biostrings)

## A chromosome of length 30:
x <- DNASTring("ATTTAGGACACTCCCTGAGGACAAGACCCC")

## 2 transcripts on 'x':
tx1 <- IRanges(1, 8)          # 1 exon
tx2 <- c(tx1, IRanges(12, 30)) # 2 exons
transcripts <- IRangesList(tx1=tx1, tx2=tx2)
extractTranscriptSeqs(x, transcripts)

## By default, all the exons are considered to be on the plus strand.
## We can use the 'strand' argument to tell extractTranscriptSeqs()
## to extract them from the minus strand.

## Extract all the exons from the minus strand:
extractTranscriptSeqs(x, transcripts, strand="-")

## Note that, for a transcript located on the minus strand, the exons
## should typically be ordered by descending position on the reference
## genome in order to reflect their rank in the transcript:
extractTranscriptSeqs(x, IRangesList(tx1=tx1, tx2=rev(tx2)), strand="-")

## Extract the exon of the 1st transcript from the minus strand:
extractTranscriptSeqs(x, transcripts, strand=c("-", "+"))

## Extract the 2nd exon of the 2nd transcript from the minus strand:
extractTranscriptSeqs(x, transcripts, strand=list("-", c("+", "-")))

## -----
## 2. A REAL EXAMPLE
## -----

## Load a genome:
library(BSgenome.Hsapiens.UCSC.hg19)
genome <- BSgenome.Hsapiens.UCSC.hg19

## Load a TxDb object:
txdb_file <- system.file("extdata", "hg19_knownGene_sample.sqlite",
                        package="GenomicFeatures")
txdb <- loadDb(txdb_file)

## Check that 'txdb' is based on the hg19 assembly:
txdb

## Extract the exon ranges grouped by transcript from 'txdb':
transcripts <- exonsBy(txdb, by="tx", use.names=TRUE)

```





---

extractUpstreamSeqs    *Extract sequences upstream of a set of genes or transcripts*

---

### Description

extractUpstreamSeqs is a generic function for extracting sequences upstream of a supplied set of genes or transcripts.

### Usage

```
extractUpstreamSeqs(x, genes, width=1000, ...)

## Dispatch is on the 2nd argument!

## S4 method for signature 'GenomicRanges'
extractUpstreamSeqs(x, genes, width=1000)

## S4 method for signature 'TxDb'
extractUpstreamSeqs(x, genes, width=1000, exclude.seqlevels=NULL)
```

### Arguments

x	An object containing the chromosome sequences from which to extract the upstream sequences. It can be a <a href="#">BSgenome</a> , <a href="#">TwoBitFile</a> , or <a href="#">FaFile</a> object, or any <i>genome sequence container</i> . More formally, x must be an object for which <a href="#">seqinfo</a> and <a href="#">getSeq</a> are defined.
genes	An object containing the locations (i.e. chromosome name, start, end, and strand) of the genes or transcripts with respect to the reference genome. Only <a href="#">GenomicRanges</a> and <a href="#">TxDb</a> objects are supported at the moment. If the latter, the gene locations are obtained by calling the <a href="#">genes</a> function on the <a href="#">TxDb</a> object internally.
width	How many bases to extract upstream of each TSS (transcription start site).
...	Additional arguments, for use in specific methods.
exclude.seqlevels	A character vector containing the chromosome names (a.k.a. sequence levels) to exclude when the genes are obtained from a <a href="#">TxDb</a> object.

### Value

A [DNAStringSet](#) object containing one upstream sequence per gene (or per transcript if genes is a [GenomicRanges](#) object containing transcript ranges).

More precisely, if genes is a [GenomicRanges](#) object, the returned object is *parallel* to it, that is, the i-th element in the returned object is the upstream sequence corresponding to the i-th gene (or transcript) in genes. Also the names on the [GenomicRanges](#) object are propagated to the returned object.

If `genes` is a `TxDb` object, the names on the returned object are the gene IDs found in the `TxDb` object. To see the type of gene IDs (i.e. Entrez gene ID or Ensembl gene ID or ...), you can display genes with `show(genes)`.

In addition, the returned object has the following metadata columns (accessible with `mcols`) that provide some information about the gene (or transcript) corresponding to each upstream sequence:

- `gene_seqnames`: the chromosome name of the gene (or transcript);
- `gene_strand`: the strand of the gene (or transcript);
- `gene_TSS`: the transcription start site of the gene (or transcript).

### Note

IMPORTANT: Always make sure to use a `TxDb` package (or `TxDb` object) that contains a gene model compatible with the *genome sequence container* `x`, that is, a gene model based on the exact same reference genome as `x`.

See [http://bioconductor.org/packages/release/BiocViews.html#\\_\\_\\_TxDb](http://bioconductor.org/packages/release/BiocViews.html#___TxDb) for the list of `TxDb` packages available in the current release of Bioconductor. Note that you can make your own custom `TxDb` object from various annotation resources by using one of the `makeTxDbFrom*`(`)` functions listed in the "See also" section below.

### Author(s)

Hervé Pagès

### See Also

- `makeTxDbFromUCSC`, `makeTxDbFromBiomart`, and `makeTxDbFromEnsembl`, for making a `TxDb` object from online resources.
- `makeTxDbFromGRanges` and `makeTxDbFromGFF` for making a `TxDb` object from a `GRanges` object, or from a GFF or GTF file.
- The `available.genomes` function in the **BSgenome** package for checking availability of BSgenome data packages (and installing the desired one).
- The **BSgenome**, `TwoBitFile`, and `FaFile` classes, defined and documented in the **BSgenome**, **rtracklayer**, and **Rsamtools** packages, respectively.
- The `TxDb` class.
- The `genes` function for extracting gene ranges from a `TxDb` object.
- The `GenomicRanges` class defined and documented in the **GenomicRanges** package.
- The `DNAStringSet` class defined and documented in the **Biostrings** package.
- The `seqinfo` getter defined and documented in the **GenomeInfoDb** package.
- The `getSeq` function for extracting subsequences from a sequence container.

## Examples

```
## Load a genome:
library(BSgenome.Dmelanogaster.UCSC.dm3)
genome <- BSgenome.Dmelanogaster.UCSC.dm3
genome

## Use a TxDb object:
library(TxDb.Dmelanogaster.UCSC.dm3.ensGene)
txdb <- TxDb.Dmelanogaster.UCSC.dm3.ensGene
txdb # contains Ensembl gene IDs

## Because the chrU and chrUextra sequences are made of concatenated
## scaffolds (see https://genome.ucsc.edu/cgi-bin/hgGateway?db=dm3),
## extracting the upstream sequences for genes located on these
## scaffolds is not reliable. So we exclude them:
exclude <- c("chrU", "chrUextra")
up1000seqs <- extractUpstreamSeqs(genome, txdb, width=1000,
                                  exclude.seqlevels=exclude)
up1000seqs # the names are Ensembl gene IDs
mcols(up1000seqs)

## Upstream sequences for genes close to the chromosome bounds can be
## shorter than 1000 (note that this does not happen for circular
## chromosomes like chrM):
table(width(up1000seqs))
mcols(up1000seqs)[width(up1000seqs) != 1000, ]
```

---

FeatureDb-class

*FeatureDb objects*

---

## Description

**WARNING:** The FeatureDb/makeFeatureDbFromUCSC/features code base is no longer actively maintained and FeatureDb-related functionalities might get deprecated in the near future. Please use [makeFeatureDbFromUCSC](#) for a convenient way to import transcript annotations from UCSC online resources into Bioconductor.

The FeatureDb class is a generic container for storing genomic locations of an arbitrary type of genomic features.

See [?TxDb](#) for a container for storing transcript annotations.

See [?makeFeatureDbFromUCSC](#) for a convenient way to make FeatureDb objects from BioMart online resources.

## Methods

In the code snippets below, `x` is a FeatureDb object.

`metadata(x)`: Return `x`'s metadata in a data frame.

**Author(s)**

Marc Carlson

**See Also**

- The [TxDb](#) class for storing transcript annotations.
- [makeFeatureDbFromUCSC](#) for a convenient way to make a FeatureDb object from UCSC online resources.
- [saveDb](#) and [loadDb](#) for saving and loading the database content of a FeatureDb object.
- [features](#) for how to extract genomic features from a FeatureDb object.

**Examples**

```
fdb_file <- system.file("extdata", "FeatureDb.sqlite",  
                        package="GenomicFeatures")  
fdb <- loadDb(fdb_file)  
fdb
```

---

features

*Extract simple features from a FeatureDb object*

---

**Description**

WARNING: The FeatureDb/makeFeatureDbFromUCSC/features code base is no longer actively maintained and FeatureDb-related functionalities might get deprecated in the near future. Please use [makeFeatureDbFromUCSC](#) for a convenient way to import transcript annotations from UCSC online resources into Bioconductor.

Generic function to extract genomic features from a FeatureDb object.

**Usage**

```
features(x)  
## S4 method for signature 'FeatureDb'  
features(x)
```

**Arguments**

x                   A [FeatureDb](#) object.

**Value**

a GRanges object

**Author(s)**

M. Carlson

**See Also**[FeatureDb](#)**Examples**

```
fdb <- loadDb(system.file("extdata", "FeatureDb.sqlite",
                        package="GenomicFeatures"))
features(fdb)
```

---

getPromoterSeq	<i>Get gene promoter sequences</i>
----------------	------------------------------------

---

**Description**

Extract sequences for the genes or transcripts specified in the query (a [GRanges](#) or [GRangesList](#) object) from a [BSgenome](#) object or an [FaFile](#).

**Usage**

```
## S4 method for signature 'GRangesList'
getPromoterSeq(query, subject, upstream=2000, downstream=200, ...)
## S4 method for signature 'GRangesList'
getPromoterSeq(query, subject, upstream=2000, downstream=200, ...)
## S4 method for signature 'GRanges'
getPromoterSeq(query, subject, upstream=2000, downstream=200, ...)
```

**Arguments**

query	A <a href="#">GRanges</a> or <a href="#">GRangesList</a> object containing genes grouped by transcript.
subject	A <a href="#">BSgenome</a> object or a <a href="#">FaFile</a> from which the sequences will be taken.
upstream	The number of DNA bases to include upstream of the TSS (transcription start site)
downstream	The number of DNA bases to include downstream of the TSS (transcription start site)
...	Additional arguments

**Details**

getPromoterSeq is an overloaded method dispatching on query, which is either a [GRanges](#) or a [GRangesList](#). It is a wrapper for the promoters and getSeq functions. The purpose is to allow sequence extraction from either a [BSgenome](#) or [FaFile](#).

Default values for upstream and downstream were chosen based on our current understanding of gene regulation. On average, promoter regions in the mammalian genome are 5000 bp upstream and downstream of the transcription start site.

**Value**

A [DNASTringSet](#) or [DNASTringSetList](#) instance corresponding to the GRanges or GRangesList supplied in the query.

**Author(s)**

Paul Shannon

**See Also**

[intra-range-methods](#) ## promoters method for IntegerRanges objects [intra-range-methods](#) ## promoters method for GenomicRanges objects [getSeq](#)

**Examples**

```
library(TxDb.Hsapiens.UCSC.hg19.knownGene)
library(BSgenome.Hsapiens.UCSC.hg19)

e2f3 <- "1871" # entrez geneID for a cell cycle control transcription
           # factor, chr6 on the plus strand

transcriptCoordsByGene.GRangesList <-
  transcriptsBy (TxDb.Hsapiens.UCSC.hg19.knownGene, by = "gene") [e2f3]
  # a GRangesList of length one, describing three transcripts

promoter.seqs <- getPromoterSeq (transcriptCoordsByGene.GRangesList,
                                Hsapiens, upstream=10, downstream=0)
  # DNASTringSetList of length 1
  # [["1871"]] GCTTCCTGGA GCTTCCTGGA CGGAGCCAGG
```

---

id2name

*Map internal ids to external names for a given feature type*


---

**Description**

Utility function for retrieving the mapping from the internal ids to the external names of a given feature type.

**Usage**

```
id2name(txdb, feature.type=c("tx", "exon", "cds"))
```

**Arguments**

txdb            A [TxDb](#) object.

feature.type    The feature type for which the mapping must be retrieved.

## Details

Transcripts, exons and CDS parts in a [TxDb](#) object are stored in separate tables where the primary key is an integer called *feature internal id*. This id is stored in the "tx\_id" column for transcripts, in the "exon\_id" column for exons, and in the "cds\_id" column for CDS parts. Unlike other commonly used ids like Entrez Gene IDs or Ensembl IDs, this internal id was generated at the time the [TxDb](#) object was created and has no meaning outside the scope of this object.

The `id2name` function can be used to translate this internal id into a more informative id or name called *feature external name*. This name is stored in the "tx\_name" column for transcripts, in the "exon\_name" column for exons, and in the "cds\_name" column for CDS parts.

Note that, unlike the feature internal id, the feature external name is not guaranteed to be unique or even defined (the column can contain NAs).

## Value

A named character vector where the names are the internal ids and the values the external names.

## Author(s)

Hervé Pagès

## See Also

- [transcripts](#), [transcriptsBy](#), and [transcriptsByOverlaps](#), for how to extract genomic features from a [TxDb](#) object.
- The [TxDb](#) class.

## Examples

```
txdb1_file <- system.file("extdata", "hg19_knownGene_sample.sqlite",
                          package="GenomicFeatures")
txdb1 <- loadDb(txdb1_file)
id2name(txdb1, feature.type="tx")[1:4]
id2name(txdb1, feature.type="exon")[1:4]
id2name(txdb1, feature.type="cds")[1:4]

txdb2_file <- system.file("extdata", "Biomart_Ensembl_sample.sqlite",
                          package="GenomicFeatures")
txdb2 <- loadDb(txdb2_file)
id2name(txdb2, feature.type="tx")[1:4]
id2name(txdb2, feature.type="exon")[1:4]
id2name(txdb2, feature.type="cds")[1:4]
```



---

makeFeatureDbFromUCSC *Making a FeatureDb object from annotations available at the UCSC Genome Browser*

---

## Description

WARNING: The FeatureDb/makeFeatureDbFromUCSC/features code base is no longer actively maintained and FeatureDb-related functionalities might get deprecated in the near future. Please use [makeFeatureDbFromUCSC](#) for a convenient way to import transcript annotations from UCSC online resources into Bioconductor.

The makeFeatureDbFromUCSC function allows the user to make a [FeatureDb](#) object from simple annotation tracks at UCSC. The tracks in question must (at a minimum) have a start, end and a chromosome affiliation in order to be made into a [FeatureDb](#). This function requires a precise declaration of its first three arguments to indicate which genome, track and table wish to be imported. There are discovery functions provided to make this process go smoothly.

## Usage

```
supportedUCSCFeatureDbTracks(genome)
```

```
supportedUCSCFeatureDbTables(genome, track)
```

```
UCSCFeatureDbTableSchema(genome,
                           track,
                           tablename)
```

```
makeFeatureDbFromUCSC(
  genome,
  track,
  tablename,
  columns = UCSCFeatureDbTableSchema(genome, track, tablename),
  url="https://genome.ucsc.edu/cgi-bin/",
  goldenPath.url=getOption("UCSC.goldenPath.url"),
  chromCol,
  chromStartCol,
  chromEndCol,
  taxonomyId=NA)
```

## Arguments

genome genome abbreviation used by UCSC and obtained by [ucscGenomes\(\)](#)[ , "db"]. For example: "hg18".

track name of the UCSC track. Use supportedUCSCFeatureDbTracks to get the list of available tracks for a particular genome

tablename name of the UCSC table containing the annotations to retrieve. Use the supportedUCSCFeatureDbTables utility function to get the list of supported tables for a track.

columns	a named character vector to list out the names and types of the other columns that the downloaded track should have. Use UCSCFeatureDbTableSchema to retrieve this information for a particular table.
url, goldenPath.url	use to specify the location of an alternate UCSC Genome Browser.
chromCol	If the schema comes back and the 'chrom' column has been labeled something other than 'chrom', use this argument to indicate what that column has been labeled as so we can properly designate it. This could happen (for example) with the knownGene track tables, which has no 'chromStart' or 'chromEnd' columns, but which DOES have columns that could reasonably substitute for these columns under particular circumstances. Therefore we allow these three columns to have arguments so that their definition can be re-specified
chromStartCol	Same thing as chromCol, but for renames of 'chromStart'
chromEndCol	Same thing as chromCol, but for renames of 'chromEnd'
taxonomyId	By default this value is NA and the organism inferred will be used to look up the correct value for this. But you can use this argument to override that and supply your own valid taxId here.

## Details

makeFeatureDbFromUCSC is a convenience function that builds a tiny database from one of the UCSC track tables. supportedUCSCFeatureDbTracks a convenience function that returns potential track names that could be used to make FeatureDb objects supportedUCSCFeatureDbTables a convenience function that returns potential table names for FeatureDb objects (table names go with a track name) UCSCFeatureDbTableSchema A convenience function that creates a named vector of types for all the fields that can potentially be supported for a given track. By default, this will be called on your specified tablename to include all of the fields in a track.

## Value

A [FeatureDb](#) object for makeFeatureDbFromUCSC. Or in the case of supportedUCSCFeatureDbTracks and UCSCFeatureDbTableSchema a named character vector

## Author(s)

M. Carlson

## See Also

[ucscGenomes](#),

## Examples

```
## Display the list of genomes available at UCSC:
library(GenomicFeatures)
library(rtracklayer)
ucscGenomes()[ , "db"]

## Display the list of Tracks supported by makeFeatureDbFromUCSC():
```

```

# supportedUCSCFeatureDbTracks("mm10")

## Display the list of tables supported by your track:
supportedUCSCFeatureDbTables(genome="mm10",
                             track="qPCR Primers")

## Display fields that could be passed in to colnames:
UCSCFeatureDbTableSchema(genome="mm10",
                          track="qPCR Primers",
                          tablename="qPcrPrimers")

## Retrieving a full transcript dataset for Mouse from UCSC:
fdb <- makeFeatureDbFromUCSC(genome="mm10",
                             track="qPCR Primers",
                             tablename="qPcrPrimers")

fdb

```

---

makeTxDb

*Making a TxDb object from user supplied annotations*


---

## Description

makeTxDb is a low-level constructor for making a [TxDb](#) object from user supplied transcript annotations.

Note that the end user will rarely need to use makeTxDb directly but will typically use one of the high-level constructors [makeTxDbFromUCSC](#), [makeTxDbFromEnsembl](#), or [makeTxDbFromGFF](#).

## Usage

```

makeTxDb(transcripts, splicings, genes=NULL,
          chrominfo=NULL, metadata=NULL,
          reassign.ids=FALSE, on.foreign.transcripts=c("error", "drop"))

```

## Arguments

transcripts	Data frame containing the genomic locations of a set of transcripts.
splicings	Data frame containing the genomic locations of exons and CDS parts of the transcripts in transcripts.
genes	Data frame containing the genes associated to a set of transcripts.
chrominfo	Data frame containing information about the chromosomes hosting the set of transcripts.
metadata	2-column data frame containing meta information about this set of transcripts like organism, genome, UCSC table, etc... The names of the columns must be "name" and "value" and their type must be character.

- `reassign.ids` TRUE or FALSE. Controls how internal ids should be assigned for each type of feature i.e. for transcripts, exons, and CDS parts. For each type, if `reassign.ids` is FALSE (the default) and if the ids are supplied, then they are used as the internal ids, otherwise the internal ids are assigned in a way that is compatible with the order defined by ordering the features first by chromosome, then by strand, then by start, and finally by end.
- `on.foreign.transcripts` Controls what to do when the input contains *foreign transcripts* i.e. transcripts that are on sequences not in `chrominfo`. If set to "error" (the default)

## Details

The `transcripts` (required), `splicings` (required) and `genes` (optional) arguments must be data frames that describe a set of transcripts and the genomic features related to them (exons, CDS parts, and genes at the moment). The `chrominfo` (optional) argument must be a data frame containing chromosome information like the length of each chromosome.

`transcripts` must have 1 row per transcript and the following columns:

- `tx_id`: Transcript ID. Integer vector. No NAs. No duplicates.
- `tx_chrom`: Transcript chromosome. Character vector (or factor) with no NAs.
- `tx_strand`: Transcript strand. Character vector (or factor) with no NAs where each element is either "+" or "-".
- `tx_start`, `tx_end`: Transcript start and end. Integer vectors with no NAs.
- `tx_name`: [optional] Transcript name. Character vector (or factor). NAs and/or duplicates are ok.
- `tx_type`: [optional] Transcript type (e.g. mRNA, ncRNA, snoRNA, etc...). Character vector (or factor). NAs and/or duplicates are ok.
- `gene_id`: [optional] Associated gene. Character vector (or factor). NAs and/or duplicates are ok.

Other columns, if any, are ignored (with a warning).

`splicings` must have N rows per transcript, where N is the nb of exons in the transcript. Each row describes an exon plus, optionally, the CDS part associated with this exon. Its columns must be:

- `tx_id`: Foreign key that links each row in the `splicings` data frame to a unique row in the `transcripts` data frame. Note that more than 1 row in `splicings` can be linked to the same row in `transcripts` (many-to-one relationship). Same type as `transcripts$tx_id` (integer vector). No NAs. All the values in this column must be present in `transcripts$tx_id`.
- `exon_rank`: The rank of the exon in the transcript. Integer vector with no NAs. (`tx_id`, `exon_rank`) pairs must be unique.
- `exon_id`: [optional] Exon ID. Integer vector with no NAs.
- `exon_name`: [optional] Exon name. Character vector (or factor). NAs and/or duplicates are ok.
- `exon_chrom`: [optional] Exon chromosome. Character vector (or factor) with no NAs. If missing then `transcripts$tx_chrom` is used. If present then `exon_strand` must also be present.

- `exon_strand`: [optional] Exon strand. Character vector (or factor) with no NAs. If missing then `transcripts$tx_strand` is used and `exon_chrom` must also be missing.
- `exon_start`, `exon_end`: Exon start and end. Integer vectors with no NAs.
- `cds_id`: [optional] ID of the CDS part associated with the exon. Integer vector. If present then `cds_start` and `cds_end` must also be present. NAs are allowed and must match those in `cds_start` and `cds_end`.
- `cds_name`: [optional] Name of the CDS part. Character vector (or factor). If present then `cds_start` and `cds_end` must also be present. NAs and/or duplicates are ok. Must contain NAs at least where `cds_start` and `cds_end` contain them.
- `cds_start`, `cds_end`: [optional] Start/end of the CDS part. Integer vectors. If one of the 2 columns is missing then all `cds_*` columns must be missing. NAs are allowed and must occur at the same positions in `cds_start` and `cds_end`.
- `cds_phase`: [optional] Phase of the CDS part. Integer vector. If present then `cds_start` and `cds_end` must also be present. NAs are allowed and must match those in `cds_start` and `cds_end`.

Other columns, if any, are ignored (with a warning).

`genes` should not be supplied if `transcripts` has a `gene_id` column. If supplied, it must have N rows per transcript, where N is the nb of genes linked to the transcript (N will be 1 most of the time). Its columns must be:

- `tx_id`: [optional] `genes` must have either a `tx_id` or a `tx_name` column but not both. Like `splittings$tx_id`, this is a foreign key that links each row in the `genes` data frame to a unique row in the `transcripts` data frame.
- `tx_name`: [optional] Can be used as an alternative to the `genes$tx_id` foreign key.
- `gene_id`: Gene ID. Character vector (or factor). No NAs.

Other columns, if any, are ignored (with a warning).

`chrominfo` must have 1 row per chromosome and the following columns:

- `chrom`: Chromosome name. Character vector (or factor) with no NAs and no duplicates.
- `length`: Chromosome length. Integer vector with either all NAs or no NAs.
- `is_circular`: [optional] Chromosome circularity flag. Logical vector. NAs are ok.

Other columns, if any, are ignored (with a warning).

### Value

A `TxDb` object.

### Author(s)

Hervé Pagès

**See Also**

- [makeTxDbFromUCSC](#), [makeTxDbFromBiomart](#), and [makeTxDbFromEnsembl](#), for making a [TxDb](#) object from online resources.
- [makeTxDbFromGRanges](#) and [makeTxDbFromGFF](#) for making a [TxDb](#) object from a [GRanges](#) object, or from a GFF or GTF file.
- The [TxDb](#) class.
- [saveDb](#) and [loadDb](#) in the [AnnotationDbi](#) package for saving and loading a [TxDb](#) object as an SQLite file.

**Examples**

```
transcripts <- data.frame(
  tx_id=1:3,
  tx_chrom="chr1",
  tx_strand=c("-", "+", "+"),
  tx_start=c(1, 2001, 2001),
  tx_end=c(999, 2199, 2199))
splittings <- data.frame(
  tx_id=c(1L, 2L, 2L, 2L, 3L, 3L),
  exon_rank=c(1, 1, 2, 3, 1, 2),
  exon_start=c(1, 2001, 2101, 2131, 2001, 2131),
  exon_end=c(999, 2085, 2144, 2199, 2085, 2199),
  cds_start=c(1, 2022, 2101, 2131, NA, NA),
  cds_end=c(999, 2085, 2144, 2193, NA, NA),
  cds_phase=c(0, 0, 2, 0, NA, NA))

txdb <- makeTxDb(transcripts, splittings)
```

---

`makeTxDbFromBiomart`    *Make a TxDb object from annotations available on a BioMart database*

---

**Description**

The `makeTxDbFromBiomart` function allows the user to make a [TxDb](#) object from transcript annotations available on a BioMart database.

Note that `makeTxDbFromBiomart` is being phased out in favor of [makeTxDbFromEnsembl](#).

**Usage**

```
makeTxDbFromBiomart(biomart="ENSEMBL_MART_ENSEMBL",
  dataset="hsapiens_gene_ensembl",
  transcript_ids=NULL,
  circ_seqs=NULL,
  filter=NULL,
  id_prefix="ensembl_",
  host="https://www.ensembl.org",
```

```

        port,
        taxonomyId=NA,
        miRBaseBuild=NA)

getChromInfoFromBiomart(biomart="ENSEMBL_MART_ENSEMBL",
                        dataset="hsapiens_gene_ensembl",
                        id_prefix="ensembl_",
                        host="https://www.ensembl.org",
                        port)

```

## Arguments

biomart	which BioMart database to use. Get the list of all available BioMart databases with the <a href="#">listMarts</a> function from the <code>biomaRt</code> package. See the details section below for a list of BioMart databases with compatible transcript annotations.
dataset	which dataset from BioMart. For example: "hsapiens_gene_ensembl", "mmusculus_gene_ensembl", "dmelanogaster_gene_ensembl", "celegans_gene_ensembl", "scerevisiae_gene_ensembl", etc in the ensembl database. See the examples section below for how to discover which datasets are available in a given BioMart database.
transcript_ids	optionally, only retrieve transcript annotation data for the specified set of transcript ids. If this is used, then the meta information displayed for the resulting <a href="#">TxDb</a> object will say 'Full dataset: no'. Otherwise it will say 'Full dataset: yes'.
circ_seqs	a character vector to list out which chromosomes should be marked as circular.
filter	Additional filters to use in the BioMart query. Must be a named list. An example is <code>filter=list(source="entrez")</code>
id_prefix	Specifies the prefix used in BioMart attributes. For example, some BioMarts may have an attribute specified as "ensembl_transcript_id" whereas others have the same attribute specified as "transcript_id". Defaults to "ensembl_".
host	The host URL of the BioMart. Defaults to <code>www.ensembl.org</code> .
port	The port to use in the HTTP communication with the host. This argument has been deprecated. It is handled by <code>useEnsembl</code> depending on the host input.
taxonomyId	By default this value is NA and the dataset selected will be used to look up the correct value for this. But you can use this argument to override that and supply your own taxId here (which will be independently checked to make sure its a real taxonomy id). Normally you should never need to use this.
miRBaseBuild	specify the string for the appropriate build information from <code>mirbase.db</code> to use for microRNAs. This can be learned by calling <code>supportedMiRBaseBuildValues</code> . By default, this value will be set to NA, which will inactivate the microRNAs accessor.

## Details

`makeTxDbFromBiomart` is a convenience function that feeds data from a BioMart database to the lower level `makeTxDb` function. See [?makeTxDbFromUCSC](#) for a similar function that feeds data from the UCSC source.

Here is a list of datasets known to be compatible with `makeTxDbFromBiomart` (list updated on September 18, 2017):

1. All the datasets in the main Ensembl database. Get the list with:

```
mart <- biomaRt::useEnsembl(biomart="ENSEMBL_MART_ENSEMBL",
                           host="https://www.ensembl.org")
biomaRt::listDatasets(mart)
```

2. All the datasets in the Ensembl Fungi database. Get the list with:

```
mart <- biomaRt::useEnsemblGenomes(biomart="fungi_mart")
biomaRt::listDatasets(mart)
```

3. All the datasets in the Ensembl Metazoa database. Get the list with:

```
mart <- biomaRt::useEnsemblGenomes(biomart="metazoa_mart")
biomaRt::listDatasets(mart)
```

4. All the datasets in the Ensembl Plants database. Get the list with:

```
mart <- biomaRt::useEnsemblGenomes(biomart="plants_mart")
biomaRt::listDatasets(mart)
```

5. All the datasets in the Ensembl Protists database. Get the list with:

```
mart <- biomaRt::useEnsemblGenomes(biomart="protists_mart")
biomaRt::listDatasets(mart)
```

6. All the datasets in the Gramene Mart. Get the list with:

```
mart <- biomaRt::useEnsembl(biomart="ENSEMBL_MART_PLANT",
                           host="https://ensembl.gramene.org")
biomaRt::listDatasets(mart)
```

Note that BioMart is not currently available for Ensembl Bacteria.

Also please note that not all these datasets have CDS information.

### Value

A [TxDb](#) object for `makeTxDbFromBiomart`.

A data frame with 1 row per chromosome (or scaffold) and with columns `chrom` and `length` for `getChromInfoFromBiomart`.

### Author(s)

M. Carlson and H. Pagès

### See Also

- [makeTxDbFromUCSC](#) and [makeTxDbFromEnsembl](#) for making a [TxDb](#) object from other online resources.
- [makeTxDbFromGRanges](#) and [makeTxDbFromGFF](#) for making a [TxDb](#) object from a [GRanges](#) object, or from a GFF or GTF file.
- The [listMarts](#), [useEnsembl](#), [listDatasets](#), and [listFilters](#) functions in the **biomaRt** package.



- The [supportedMiRBaseBuildValues](#) function for listing all the possible values for the `miRBaseBuild` argument.
- The [TxDb](#) class.
- [makeTxDb](#) for the low-level function used by the `makeTxDbFrom*` functions to make the [TxDb](#) object returned to the user.

## Examples

```
## -----
## A. BASIC USAGE
## -----

## We can use listDatasets() from the biomaRt package to list the
## datasets available in the "ENSEMBL_MART_ENSEMBL" BioMart database:
library(biomaRt)
listMarts(host="https://www.ensembl.org")
mart <- useEnsembl(biomart="ENSEMBL_MART_ENSEMBL", host="https://www.ensembl.org")
datasets <- listDatasets(mart)
head(datasets)
subset(datasets, grepl("elegans", dataset, ignore.case=TRUE))

## Retrieve the full transcript dataset for Worm:
txdb1 <- makeTxDbFromBiomart(dataset="celegans_gene_ensembl")
txdb1

## Retrieve an incomplete transcript dataset for Human:
transcript_ids <- c(
  "ENST00000013894",
  "ENST000000268655",
  "ENST000000313243",
  "ENST000000435657",
  "ENST000000384428",
  "ENST000000478783"
)

if (interactive()) {
  txdb2 <- makeTxDbFromBiomart(dataset="hsapiens_gene_ensembl",
                             transcript_ids=transcript_ids)
  txdb2 # note that these annotations match the GRCh38 genome assembly
}

## -----
## B. ACCESSING THE EnsemblGenomes MARTS
## -----

library(biomaRt)

## Note that BioMart is not currently available for Ensembl Bacteria.

## -----
## --- Ensembl Fungi ---
```

```

mart <- useEnsemblGenomes(biomart="fungi_mart")
datasets <- listDatasets(mart)
datasets$dataset
yeast_txdb <- makeTxDbFromBiomart(biomart="fungi_mart",
                                dataset="scerevisiae_eg_gene",
                                host="https://fungi.ensembl.org")

yeast_txdb

## Note that the dataset for Yeast on Ensembl Fungi is not necessarily
## the same as on the main Ensembl database:
yeast_txdb0 <- makeTxDbFromBiomart(dataset="scerevisiae_gene_ensembl")
all(transcripts(yeast_txdb0) %in% transcripts(yeast_txdb))
all(transcripts(yeast_txdb) %in% transcripts(yeast_txdb0))

## -----
## --- Ensembl Metazoa ---

## The metazoa mart is slow and at the same time it doesn't seem to
## support requests that take more than 1 min at the moment. So a call to
## biomart::getBM() will fail with a "Timeout was reached" error if the
## requested data takes more than 1 min to download. This unfortunately
## happens with the example below so we don't try to run it for now.

## Not run:
mart <- useEnsemblGenomes(biomart="metazoa_mart")
datasets <- listDatasets(mart)
datasets$dataset
worm_txdb <- makeTxDbFromBiomart(biomart="metazoa_mart",
                                dataset="celegans_eg_gene",
                                host="https://metazoa.ensembl.org")

worm_txdb

## Note that even if the dataset for Worm on Ensembl Metazoa contains
## the same transcript as on the main Ensembl database, the transcript
## type might be annotated with slightly different terms (e.g. antisense
## vs antisense_RNA):
filter <- list(tx_name="Y71G12B.44")
transcripts(worm_txdb, filter=filter, columns=c("tx_name", "tx_type"))
transcripts(txdb1, filter=filter, columns=c("tx_name", "tx_type"))

## End(Not run)
## -----
## --- Ensembl Plants ---

## Like the metazoa mart (see above), the plants mart is also slow and
## doesn't seem to support requests that take more than 1 min either.
## So we don't try to run the example below for now.

## Not run:
mart <- useEnsemblGenomes(biomart="plants_mart")
datasets <- listDatasets(mart)
datasets[, 1:2]
athaliana_txdb <- makeTxDbFromBiomart(biomart="plants_mart",

```

```

                                dataset="athaliana_eg_gene",
                                host="https://plants.ensembl.org")
athaliana_txdb

## End(Not run)
## -----
## --- Ensembl Protists ---

mart <- useEnsemblGenomes(biomart="protists_mart")
datasets <- listDatasets(mart)
datasets$dataset
tgondii_txdb <- makeTxDbFromBiomart(biomart="protists_mart",
                                dataset="tgondii_eg_gene",
                                host="https://protists.ensembl.org")
tgondii_txdb

## -----
## C. USING AN Ensembl MIRROR
## -----

## You can use the 'host' argument to access the "ENSEMBL_MART_ENSEMBL"
## BioMart database at a mirror (e.g. at uswest.ensembl.org). A gotcha
## when doing this is that the name of the database on the mirror might
## be different! We can check this with listMarts() from the biomaRt
## package:
if (interactive()) {

  listMarts(host="https://useast.ensembl.org")

  txdb3 <- makeTxDbFromBiomart(biomart="ENSEMBL_MART_ENSEMBL",
                              dataset="hsapiens_gene_ensembl",
                              transcript_ids=transcript_ids,
                              host="https://useast.ensembl.org")
  txdb3
}
## Therefore in addition to setting 'host' to "uswest.ensembl.org", we
## might also need to specify the 'biomart' argument.

## -----
## D. USING FILTERS
## -----

## We can use listFilters() from the biomaRt package to get valid filter
## names:
mart <- useEnsembl(biomart="ENSEMBL_MART_ENSEMBL",
                  dataset="hsapiens_gene_ensembl",
                  host="https://www.ensembl.org")
head(listFilters(mart))

## Retrieve transcript dataset for Ensembl gene ENSG0000011198:
my_filter <- list(ensembl_gene_id="ENSG0000011198")

```

```

if (interactive()) {
  txdb4 <- makeTxDbFromBiomart(dataset="hsapiens_gene_ensembl",
                              filter=my_filter)

  txdb4
  transcripts(txdb4, columns=c("tx_id", "tx_name", "gene_id"))
  transcriptLengths(txdb4)
}

## -----
## E. RETRIEVING CHROMOSOME INFORMATION ONLY
## -----

chrominfo <- getChromInfoFromBiomart(dataset="celegans_gene_ensembl")
chrominfo

```

---

makeTxDbFromEnsembl    *Make a TxDb object from an Ensembl database*

---

## Description

The `makeTxDbFromEnsembl` function creates a [TxDb](#) object for a given organism by importing the genomic locations of its transcripts, exons, CDS, and genes from an Ensembl database.

Note that it uses the **RMariaDB** package internally so make sure that this package is installed.

## Usage

```

makeTxDbFromEnsembl(organism="Homo sapiens",
                    release=NA,
                    circ_seqs=NULL,
                    server="ensemldb.ensembl.org",
                    username="anonymous", password=NULL, port=0L,
                    tx_attrib=NULL)

```

## Arguments

organism	The <i>scientific name</i> (i.e. genus and species, or genus and species and subspecies) of the organism for which to import the data. Case is not sensitive. Underscores can be used instead of white spaces e.g. "homo_sapiens" is accepted.
release	The Ensembl release to query e.g. 89. If set to NA (the default), the current release is used.
circ_seqs	A character vector to list out which chromosomes should be marked as circular.
server	The name of the MySQL server to query. See <a href="https://www.ensembl.org/info/data/mysql.html">https://www.ensembl.org/info/data/mysql.html</a> for the list of Ensembl public MySQL servers. Make sure to use the server nearest to you. It can make a big difference!
username	Login username for the MySQL server.
password	Login password for the MySQL server.

port	Port of the MySQL server.
tx_attr	If not NULL, only select transcripts with an attribute of the given code, a string, like "gencode_basic".

**Value**

A [TxDb](#) object.

**Note**

makeTxDbFromEnsembl tends to be faster and more reliable than [makeTxDbFromBiomart](#).

**Author(s)**

H. Pagès

**See Also**

- [makeTxDbFromUCSC](#) and [makeTxDbFromBiomart](#) for making a [TxDb](#) object from other online resources.
- [makeTxDbFromGRanges](#) and [makeTxDbFromGFF](#) for making a [TxDb](#) object from a [GRanges](#) object, or from a GFF or GTF file.
- The [TxDb](#) class.
- [makeTxDb](#) for the low-level function used by the makeTxDbFrom\* functions to make the [TxDb](#) object returned to the user.

**Examples**

```
## Not run:
txdb <- makeTxDbFromEnsembl("Saccharomyces cerevisiae",
                           server="useastdb.ensembl.org")
txdb

## End(Not run)
```

---

makeTxDbFromGFF	<i>Make a TxDb object from annotations available as a GFF3 or GTF file</i>
-----------------	--

---

**Description**

The makeTxDbFromGFF function allows the user to make a [TxDb](#) object from transcript annotations available as a GFF3 or GTF file.

**Usage**

```
makeTxDbFromGFF(file,
                 format=c("auto", "gff3", "gtf"),
                 dataSource=NA,
                 organism=NA,
                 taxonomyId=NA,
                 circ_seqs=NULL,
                 chrominfo=NULL,
                 miRBaseBuild=NA,
                 metadata=NULL,
                 dbxrefTag)
```

**Arguments**

file	Input GFF3 or GTF file. Can be a path to a file, or an URL, or a connection object, or a <a href="#">GFF3File</a> or <a href="#">GTFFile</a> object.
format	Format of the input file. Accepted values are: "auto" (the default) for auto-detection of the format, "gff3", or "gtf". Use "gff3" or "gtf" only if auto-detection failed.
dataSource	A single string describing the origin of the data file. Please be as specific as possible.
organism	What is the Genus and species of this organism. Please use proper scientific nomenclature for example: "Homo sapiens" or "Canis familiaris" and not "human" or "my fuzzy buddy". If properly written, this information may be used by the software to help you out later.
taxonomyId	By default this value is NA and the organism provided will be used to look up the correct value for this. But you can use this argument to override that and supply your own taxonomy id here (which will be separately validated). Since providing a valid taxonomy id will not require us to look up one based on your organism: this is one way that you can loosen the restrictions about what is and isn't a valid value for the organism.
circ_seqs	A character vector to list out which chromosomes should be marked as circular.
chrominfo	Data frame containing information about the chromosomes. Will be passed to the internal call to <a href="#">makeTxDb</a> . See <a href="#">?makeTxDb</a> for more information. Alternatively, can be a <a href="#">Seqinfo</a> object.
miRBaseBuild	Specify the string for the appropriate build Information from mirbase.db to use for microRNAs. This can be learned by calling <a href="#">supportedMiRBaseBuildValues</a> . By default, this value will be set to NA, which will inactivate the microRNAs accessor.
metadata	A 2-column data frame containing meta information to be included in the <a href="#">TxDb</a> object. See <a href="#">?makeTxDb</a> for more information about the format of metadata.
dbxrefTag	If not missing, the values in the Dbxref attribute with the specified tag (like "GeneID") are used for the feature names.

**Details**

makeTxDbFromGFF is a convenience function that feeds data from the parsed file to the [makeTxDbFromGRanges](#) function.

**Value**

A [TxDb](#) object.

**Author(s)**

M. Carlson and H. Pagès

**See Also**

- [makeTxDbFromGRanges](#), which makeTxDbFromGFF is based on, for making a [TxDb](#) object from a [GRanges](#) object.
- The `import` function in the **rtracklayer** package (also used by makeTxDbFromGFF internally).
- [makeTxDbFromUCSC](#), [makeTxDbFromBiomart](#), and [makeTxDbFromEnsembl](#), for making a [TxDb](#) object from online resources.
- The [supportedMiRBaseBuildValues](#) function for listing all the possible values for the miRBaseBuild argument.
- The [TxDb](#) class.
- [makeTxDb](#) for the low-level function used by the makeTxDbFrom\* functions to make the [TxDb](#) object returned to the user.

**Examples**

```
## TESTING GFF3
gfffFile <- system.file("extdata", "GFF3_files", "a.gff3", package="GenomicFeatures")
txdb <- makeTxDbFromGFF(file=gfffFile,
  dataSource="partial gtf file for Tomatoes for testing",
  organism="Solanum lycopersicum")

## TESTING GTF, this time specifying the chrominfo
gtfFile <- system.file("extdata", "GTF_files", "Aedes_aegypti.partial.gtf",
  package="GenomicFeatures")
chrominfo <- data.frame(chrom = c('supercont1.1', 'supercont1.2'),
  length=c(5220442, 5300000),
  is_circular=c(FALSE, FALSE))
metadata <- data.frame(name="Resource URL",
  value=paste0("ftp://ftp.ensemblgenomes.org/pub/metazoa/",
  "release-13/gtf/aedes_aegypti/"))
txdb2 <- makeTxDbFromGFF(file=gtfFile,
  chrominfo=chrominfo,
  dataSource="ensemblgenomes",
  organism="Aedes aegypti",
  metadata=metadata)
```

---

makeTxDbFromGRanges    *Make a TxDb object from a GRanges object*

---

## Description

The `makeTxDbFromGRanges` function allows the user to extract gene, transcript, exon, and CDS information from a [GRanges](#) object structured as GFF3 or GTF, and to return that information in a [TxDb](#) object.

## Usage

```
makeTxDbFromGRanges(gr, drop.stop.codons=FALSE, metadata=NULL, taxonomyId=NA)
```

## Arguments

<code>gr</code>	A <a href="#">GRanges</a> object structured as GFF3 or GTF, typically obtained with <code>BiocIO::import()</code> .
<code>drop.stop.codons</code>	TRUE or FALSE. If TRUE, then features of type <code>stop_codon</code> are ignored. Otherwise (the default) the stop codons are considered to be part of the CDS and merged to them.
<code>metadata</code>	A 2-column data frame containing meta information to be included in the <a href="#">TxDb</a> object. This data frame is just passed to <code>makeTxDb</code> , which <code>makeTxDbFromGRanges</code> calls at the end to make the <a href="#">TxDb</a> object from the information extracted from <code>gr</code> . See <code>?makeTxDb</code> for more information about the format of metadata.
<code>taxonomyId</code>	By default this value is NA which will result in an NA field since there is no reliable way to infer this from a <a href="#">GRanges</a> object. But you can use this argument to supply your own valid <code>taxId</code> here and if you do, then the <code>Organism</code> can be filled in as well

## Value

A [TxDb](#) object.

## Author(s)

Hervé Pagès

## See Also

- `makeTxDbFromUCSC`, `makeTxDbFromBiomart`, and `makeTxDbFromEnsembl`, for making a [TxDb](#) object from online resources.
- `makeTxDbFromGFF` for making a [TxDb](#) object from a GFF or GTF file.
- The `import` generic function in the **BiocIO** package.
- The `asGFF` method for [TxDb](#) objects (`asGFF,TxDb-method`) for the reverse of `makeTxDbFromGRanges`, that is, for turning a [TxDb](#) object into a [GRanges](#) object structured as GFF.



- The `TxDb` class.
- `makeTxDb` for the low-level function used by the `makeTxDbFrom*` functions to make the `TxDb` object returned to the user.

## Examples

```
library(BiocIO) # for the import() function

## -----
## WITH A GRanges OBJECT STRUCTURED AS GFF3
## -----
GFF3_files <- system.file("extdata", "GFF3_files",
                          package="GenomicFeatures")

path <- file.path(GFF3_files, "a.gff3")
gr <- import(path)
txdb <- makeTxDbFromGRanges(gr)
txdb

## Reverse operation:
gr2 <- asGFF(txdb)

## Sanity check (asGFF() does not propagate the CDS phase at the moment):
target <- as.list(txdb)
target$splicings$cds_phase <- NULL
stopifnot(identical(target, as.list(makeTxDbFromGRanges(gr2))))

## -----
## WITH A GRanges OBJECT STRUCTURED AS GTF
## -----
GTF_files <- system.file("extdata", "GTF_files", package="GenomicFeatures")

## test1.gtf was grabbed from http://mblab.wustl.edu/GTF22.html (5 exon
## gene with 3 translated exons):
path <- file.path(GTF_files, "test1.gtf")
gr <- import(path)
txdb <- makeTxDbFromGRanges(gr)
txdb

path <- file.path(GTF_files, "Aedes_aegypti.partial.gtf")
gr <- import(path)
txdb <- makeTxDbFromGRanges(gr)
txdb
```

## Description

The `makeTxDbFromUCSC` function allows the user to make a `TxDb` object from transcript annotations available at the UCSC Genome Browser.

Note that it uses the **RMariaDB** package internally so make sure that this package is installed.

## Usage

```
makeTxDbFromUCSC(genome="hg19", tablename="knownGene",
  transcript_ids=NULL,
  circ_seqs=NULL,
  url="https://genome.ucsc.edu/cgi-bin/",
  goldenPath.url=getOption("UCSC.goldenPath.url"),
  taxonomyId=NA,
  mirBaseBuild=NA)
```

```
supportedUCSCTables(genome="hg19", url="https://genome.ucsc.edu/cgi-bin/")
```

```
browseUCSCtrack(genome="hg19", tablename="knownGene",
  url="https://genome.ucsc.edu/cgi-bin/")
```

## Arguments

- |                |  |
|----------------|--|
| genome         | The name of a UCSC genome assembly e.g. "hg19" or "panTro6". You can use <code>rtracklayer::ucscGenomes()</code> [ , "db"] to obtain the current list of valid UCSC genome assemblies.   |
| tablename      | The name of the UCSC table containing the transcript genomic locations to retrieve. Use the <code>supportedUCSCTables</code> utility function to get the list of tables known to work with <code>makeTxDbFromUCSC</code> .   |
| transcript_ids | Optionally, only retrieve transcript locations for the specified set of transcript ids. If this is used, then the meta information displayed for the resulting <code>TxDb</code> object will say 'Full dataset: no'. Otherwise it will say 'Full dataset: yes'.  |
| circ_seqs      | <p>Like <code>GRanges</code> objects, <code>SummarizedExperiment</code> objects, and many other objects in Bioconductor, the <code>TxDb</code> object returned by <code>makeTxDbFromUCSC</code> contains a <code>seqinfo</code> component that can be accessed with <code>seqinfo()</code>. This component contains various sequence-level information like the sequence names, lengths, and circularity flag for the genome assembly of the <code>TxDb</code> object.</p> <p>As far as we know the information of which sequences are circular is not available in the UCSC Genome Browser. However, for the most commonly used UCSC genome assemblies <code>makeTxDbFromUCSC</code> will get this information from a knowledge database stored in the <b>GenomeInfoDb</b> package (see <code>?registered_UCSC_genomes</code>).</p> <p>For less commonly used UCSC genome assemblies, <code>makeTxDbFromUCSC</code> will make a guess based on the chromosome names (e.g. <code>chrM</code> or <code>2micron</code> will be assumed to be circular). Even though this works most of the time, it is not guaranteed to work <i>all the time</i>. So in this case a warning is issued. If you think the guess is incorrect then you can supply your own list of circular sequences (as a character vector) via the <code>circ_seqs</code> argument.</p> |

url, goldenPath.url	Use to specify the location of an alternate UCSC Genome Browser.
taxonomyId	By default this value is NA and the organism inferred will be used to look up the correct value for this. But you can use this argument to supply your own valid taxId here.
miRBaseBuild	Specify the string for the appropriate build information from <b>mirbase.db</b> to use for microRNAs. This can be learned by calling supportedMiRBaseBuildValues. By default, this value will be set to NA, which will inactivate the microRNAs accessor.

### Details

makeTxDbFromUCSC is a convenience function that feeds data from the UCSC source to the lower level [makeTxDb](#) function. See [?makeTxDbFromEnsembl](#) for a similar function that feeds data from an Ensembl database.

### Value

For makeTxDbFromUCSC: A [TxDb](#) object.

For supportedUCSCTables: A data frame with 3 columns (tablename, track, and subtrack) and 1 row per table known to work with makeTxDbFromUCSC. **IMPORTANT NOTE:** In the returned data frame, the set of tables associated with a track with subtracks might contain tables that don't exist for the specified genome.

### Author(s)

M. Carlson and H. Pagès

### See Also

- [makeTxDbFromEnsembl](#) and [makeTxDbFromBiomart](#) for making a [TxDb](#) object from other online resources.
- [makeTxDbFromGRanges](#) and [makeTxDbFromGFF](#) for making a [TxDb](#) object from a [GRanges](#) object, or from a GFF or GTF file.
- [ucscGenomes](#) in the **rtracklayer** package.
- The [supportedMiRBaseBuildValues](#) function for listing all the possible values for the miRBaseBuild argument.
- The [TxDb](#) class.
- [makeTxDb](#) for the low-level function used by the makeTxDbFrom\* functions to make the [TxDb](#) object returned to the user.

### Examples

```
## -----
## A. BASIC USAGE
## -----

## Use ucscGenomes() from the rtracklayer package to display the list of
```

```

## genomes available at UCSC:
library(rtracklayer)
ucscGenomes()[ , "db"]

## Display the list of tables known to work with makeTxDbFromUCSC():
supportedUCSCTables("hg38")
supportedUCSCTables("hg19")

## Open the UCSC track page for a given organism/table:
browseUCSCtrack("hg38", tablename="knownGene")
browseUCSCtrack("hg19", tablename="knownGene")

browseUCSCtrack("hg38", tablename="ncbiRefSeqSelect")
browseUCSCtrack("hg19", tablename="ncbiRefSeqSelect")

browseUCSCtrack("hg19", tablename="pseudoYale60")

browseUCSCtrack("sacCer3", tablename="ensGene")

## Retrieve a full transcript dataset for Yeast from UCSC:
txdb1 <- makeTxDbFromUCSC("sacCer3", tablename="ensGene")
txdb1

## Retrieve an incomplete transcript dataset for Mouse from UCSC (only
## transcripts linked to Entrez Gene ID 22290):
transcript_ids <- c(
  "uc009uzf.1",
  "uc009uzg.1",
  "uc009uzh.1",
  "uc009uzi.1",
  "uc009uzj.1"
)

txdb2 <- makeTxDbFromUCSC("mm10", tablename="knownGene",
  transcript_ids=transcript_ids)
txdb2

## -----
## B. IMPORTANT NOTE ABOUT supportedUCSCTables()
## -----

## In the data frame returned by supportedUCSCTables(), the set of
## tables associated with a track with subtracks might contain tables
## that don't exist for the specified genome:
supportedUCSCTables("mm10")
browseUCSCtrack("mm10", tablename="ncbiRefSeqSelect") # no such table

```

## Description

A `TxDb` package is an annotation package containing a `TxDb` object.

The `makeTxDbPackageFromUCSC` function allows the user to make a `TxDb` package from transcript annotations available at the UCSC Genome Browser.

The `makeTxDbPackageFromBiomart` function allows the user to do the same thing as `makeTxDbPackageFromUCSC` except that the annotations originate from `biomaRt`.

Finally, the `makeTxDbPackage` function allows the user to make a `TxDb` package directly from a `TxDb` object.

## Usage

```
makeTxDbPackageFromUCSC(  
  version=,  
  maintainer,  
  author,  
  destDir=".",  
  license="Artistic-2.0",  
  genome="hg19",  
  tablename="knownGene",  
  transcript_ids=NULL,  
  circ_seqs=NULL,  
  url="https://genome.ucsc.edu/cgi-bin/",  
  goldenPath.url=getOption("UCSC.goldenPath.url"),  
  taxonomyId=NA,  
  miRBaseBuild=NA)  
  
makeFDbPackageFromUCSC(  
  version,  
  maintainer,  
  author,  
  destDir=".",  
  license="Artistic-2.0",  
  genome="hg19",  
  track="tRNAs",  
  tablename="tRNAs",  
  columns = UCSCFeatureDbTableSchema(genome, track, tablename),  
  url="https://genome.ucsc.edu/cgi-bin/",  
  goldenPath.url=getOption("UCSC.goldenPath.url"),  
  chromCol=NULL,  
  chromStartCol=NULL,  
  chromEndCol=NULL,  
  taxonomyId=NA)  
  
makeTxDbPackageFromBiomart(  
  version,  
  maintainer,  
  author,
```

```

destDir=".",
license="Artistic-2.0",
biomart="ENSEMBL_MART_ENSEMBL",
dataset="hsapiens_gene_ensembl",
transcript_ids=NULL,
circ_seqs=NULL,
filter=NULL,
id_prefix="ensembl_",
host="https://www.ensembl.org",
port,
taxonomyId=NA,
miRBaseBuild=NA)

makeTxDbPackage(txdb,
                version,
                maintainer,
                author,
                destDir=".",
                license="Artistic-2.0",
                pkgname=NULL,
                provider=NULL,
                providerVersion=NULL)

supportedMiRBaseBuildValues()

makePackageName(txdb)

```

## Arguments

version	What is the version number for this package?
maintainer	Who is the package maintainer? (must include email to be valid). Should be a <a href="#">person</a> object, or something coercible to one, like a string. May be omitted if the author argument is a person containing someone with the maintainer role.
author	Who is the creator of this package? Should be a <a href="#">person</a> object, or something coercible to one, like a character vector of names. The maintainer argument will be merged into this list.
destDir	A path where the package source should be assembled.
license	What is the license (and it's version)
biomart	which BioMart database to use. Get the list of all available BioMart databases with the <a href="#">listMarts</a> function from the <code>biomaRt</code> package. See the details section below for a list of BioMart databases with compatible transcript annotations.
dataset	which dataset from BioMart. For example: "hsapiens_gene_ensembl", "mmusculus_gene_ensembl", "dmelanogaster_gene_ensembl", "celegans_gene_ensembl", "scerevisiae_gene_ensembl", etc in the ensembl database. See the examples section below for how to discover which datasets are available in a given BioMart database.
genome	genome abbreviation used by UCSC and obtained by <code>ucscGenomes()</code> [ , "db"]. For example: "hg18".

track	name of the UCSC track. Use supportedUCSCFeatureDbTracks to get the list of available tracks for a particular genome
tablename	name of the UCSC table containing the transcript annotations to retrieve. Use the supportedUCSCtables utility function to get the list of tables known to work with makeTxDbFromUCSC.
transcript_ids	optionally, only retrieve transcript annotation data for the specified set of transcript ids. If this is used, then the meta information displayed for the resulting TxDb object will say 'Full dataset: no'. Otherwise it will say 'Full dataset: yes'.
circ_seqs	a character vector to list out which chromosomes should be marked as circular.
filter	Additional filters to use in the BioMart query. Must be a named list. An example is filter=as.list(c(source="entrez"))
host	The host URL of the BioMart. Defaults to https://www.ensembl.org.
port	The port to use in the HTTP communication with the host. This argument has been deprecated. It is handled by useEnsembl depending on the host input.
id_prefix	Specifies the prefix used in BioMart attributes. For example, some BioMarts may have an attribute specified as "ensembl_transcript_id" whereas others have the same attribute specified as "transcript_id". Defaults to "ensembl_".
columns	a named character vector to list out the names and types of the other columns that the downloaded track should have. Use UCSCFeatureDbTableSchema to retrieve this information for a particular table.
url, goldenPath.url	use to specify the location of an alternate UCSC Genome Browser.
chromCol	If the schema comes back and the 'chrom' column has been labeled something other than 'chrom', use this argument to indicate what that column has been labeled as so we can properly designate it. This could happen (for example) with the knownGene track tables, which has no 'chromStart' or 'chromEnd' columns, but which DOES have columns that could reasonably substitute for these columns under particular circumstances. Therefore we allow these three columns to have arguments so that their definition can be re-specified
chromStartCol	Same thing as chromCol, but for renames of 'chromStart'
chromEndCol	Same thing as chromCol, but for renames of 'chromEnd'
txdb	A TxDb object that represents a handle to a transcript database. This object type is what is returned by makeTxDbFromUCSC, makeTxDbFromUCSC or makeTxDb
taxonomyId	By default this value is NA and the organism provided (or inferred) will be used to look up the correct value for this. But you can use this argument to override that and supply your own valid taxId here
miRBaseBuild	specify the string for the appropriate build Information from mirbase.db to use for microRNAs. This can be learned by calling supportedMiRBaseBuildValues. By default, this value will be set to NA, which will inactivate the microRNAs accessor.
pkgname	By default this value is NULL and does not need to be filled in (a package name will be generated for you). But if you override this value, then the package and it's object will be instead named after this value. Be aware that the standard rules for package names will apply, (so don't include spaces, underscores or dashes)

provider            If not given, a default is taken from the 'Data source' field of the metadata table.  
 providerVersion    If not given, a default is taken from one of 'UCSC table', 'BioMart version' or 'Data source' fields of the metadata table.

## Details

makeTxDbPackageFromUCSC is a convenience function that calls both the [makeTxDbFromUCSC](#) and the [makeTxDbPackage](#) functions. The [makeTxDbPackageFromBiomart](#) follows a similar pattern and calls the [makeTxDbFromBiomart](#) and [makeTxDbPackage](#) functions. [supportedMirBaseBuildValues](#) is a convenience function that will list all the possible values for the `miRBaseBuild` argument. [makePackageName](#) creates a package name from a TxDb object. This function is also used by [OrganismDbi](#).

## Value

A [TxDb](#) object.

## Author(s)

M. Carlson

## See Also

[makeTxDbFromUCSC](#), [makeTxDbFromBiomart](#), [makeTxDb](#), [ucscGenomes](#)

## Examples

```
## First consider relevant helper/discovery functions:
## Get the list of tables known to work with makeTxDbPackageFromUCSC():
supportedUCSCTables(genome="hg19")

## Can also list all the possible values for the miRBaseBuild argument:
supportedMirBaseBuildValues()

## Next are examples of actually building a package:
## Not run:
## Makes a transcript package for Yeast from the ensGene table at UCSC:
makeTxDbPackageFromUCSC(version="0.01",
                        maintainer="Some One <so@someplace.org>",
                        author="Some One <so@someplace.com>",
                        genome="sacCer2",
                        tablename="ensGene")

## Makes a transcript package from Human by using biomart and limited to a
## small subset of the transcripts.
transcript_ids <- c(
  "ENST00000400839",
  "ENST00000400840",
  "ENST00000478783",
  "ENST00000435657",
```



```

"ENST00000268655",
"ENST00000313243",
"ENST00000341724")

makeTxDbPackageFromBiomart(version="0.01",
                           maintainer="Some One <so@someplace.org>",
                           author="Some One <so@someplace.com>",
                           transcript_ids=transcript_ids)

## End(Not run)

```

---

mapIdsToRanges	<i>Map IDs to Genomic Ranges</i>
----------------	----------------------------------

---

## Description

Map IDs to Genomic Ranges

## Usage

```

mapIdsToRanges(x, ...)

## S4 method for signature 'TxDb'
mapIdsToRanges(x, keys, type = c("cds", "exon", "tx",
                                "gene"), columns = NULL)

```

## Arguments

x	Database to use for mapping
keys	Values to lookup, passed to <a href="#">transcripts</a> et. al.
type	Types of feature to return
columns	Additional metadata columns to include in the output
...	Additional arguments passed to methods

## Value

[GRangesList](#) corresponding to the keys

## Methods (by class)

- TxDb: TxDb method

**Examples**

```
f1 <- system.file(package = "GenomicFeatures", "extdata", "sample_ranges.rds")
txdb <- makeTxDbFromGRanges(readRDS(f1))

keys <- list(tx_name = c("ENST00000371582", "ENST00000371588",
  "ENST00000494752", "ENST00000614008", "ENST00000496771"))
mapIdsToRanges(txdb, keys = keys, type = "tx")
```

---

mapRangesToIds                      *Map Genomic Ranges to IDs*

---

**Description**

Map Genomic Ranges to IDs

**Usage**

```
mapRangesToIds(x, ...)

## S4 method for signature 'TxDb'
mapRangesToIds(x, ranges, type = c("cds", "exon", "tx",
  "gene"), columns = NULL, ...)
```

**Arguments**

x	Database to use for mapping
ranges	range object used to subset
type	of feature to return
columns	additional metadata columns to include in the output.
...	Additional arguments passed to <a href="#">findOverlaps</a>

**Value**

[DataFrame](#) of mcols from the database.

**Methods (by class)**

- TxDb: TxDb method

**Examples**

```
f1 <- system.file(package = "GenomicFeatures", "extdata", "sample_ranges.rds")
txdb <- makeTxDbFromGRanges(readRDS(f1))

keys <- list(tx_name = c("ENST00000371582", "ENST00000371588",
  "ENST00000494752", "ENST00000614008", "ENST00000496771"))
res <- mapIdsToRanges(txdb, keys = keys, type = "tx")
mapRangesToIds(txdb, res, "tx")
```

---

mapToTranscripts      *Map range coordinates between transcripts and genome space*

---

### Description

Map range coordinates between features in the transcriptome and genome (reference) space.

See [?mapToAlignments](#) in the **GenomicAlignments** package for mapping coordinates between reads (local) and genome (reference) space using a CIGAR alignment.

### Usage

```
## mapping to transcripts
## S4 method for signature 'GenomicRanges,GenomicRanges'
mapToTranscripts(x, transcripts,
  ignore.strand = FALSE)
## S4 method for signature 'GenomicRanges,GRangesList'
mapToTranscripts(x, transcripts,
  ignore.strand = FALSE, intronJunctions=FALSE)
## S4 method for signature 'ANY,TxDb'
mapToTranscripts(x, transcripts, ignore.strand = FALSE,
  extractor.fun = GenomicFeatures::transcripts, ...)
## S4 method for signature 'GenomicRanges,GRangesList'
pmapToTranscripts(x, transcripts,
  ignore.strand = FALSE)

## mapping from transcripts
## S4 method for signature 'GenomicRanges,GRangesList'
mapFromTranscripts(x, transcripts,
  ignore.strand = FALSE)
## S4 method for signature 'GenomicRanges,GRangesList'
pmapFromTranscripts(x, transcripts,
  ignore.strand = FALSE)
## S4 method for signature 'IntegerRanges,GRangesList'
pmapFromTranscripts(x, transcripts)
```

### Arguments

x	<a href="#">GenomicRanges</a> object of positions to be mapped. The seqnames of x are used in <a href="#">mapFromTranscripts</a> , i.e., when mapping from transcripts to the genome. In the case of <a href="#">pmapFromTranscripts</a> , x can be an <a href="#">IntegerRanges</a> object.
transcripts	A named <a href="#">GenomicRanges</a> or <a href="#">GRangesList</a> object used to map between x and the result. The ranges can be any feature in the transcriptome extracted from a TxDb (e.g., introns, exons, CDS parts). See <a href="#">?transcripts</a> and <a href="#">?transcriptsBy</a> for a list of extractor functions.  The transcripts object must have names. When mapping from transcripts to the genome, they are used to determine mapping pairs; in the reverse direction they become the seqlevels of the output object.

- `ignore.strand` When `ignore.strand` is `TRUE`, strand is ignored in overlaps operations (i.e., all strands are considered "+") and the strand in the output is '\*'.  
 When `ignore.strand` is `FALSE` strand in the output is taken from the `transcripts` argument. When `transcripts` is a `GRangesList`, all inner list elements of a common list element must have the same strand or an error is thrown.  
 Mapped position is computed by counting from the transcription start site (TSS) and is not affected by the value of `ignore.strand`.
- `intronJunctions`  
 Logical to indicate if intronic ranges in `x` should be reported.  
 This argument is only supported in `mapToTranscripts` when `transcripts` is a `GRangesList`. When `transcripts` is a `GRangesList`, individual ranges can be thought of as exons and the spaces between the ranges as introns.  
 When `intronJunctions=TRUE`, ranges that fall completely "within" an intron are reported as a zero-width range (start and end are taken from the ranges they fall between). A metadata column called "intronic" is returned with the `GRanges` and marked as `TRUE` for these ranges. By default, `intronJunctions=FALSE` and these ranges are not mapped.  
 Ranges that have either the start or end in an intron are considered "non hits" and are never mapped. Ranges that span introns are always mapped. Neither of these range types are controlled by the `intronJunctions` argument.
- `extractor.fun` Function to extract genomic features from a `TxDb` object.  
 This argument is only applicable to `mapToTranscripts` when `transcripts` is a `TxDb` object. The extractor should be the name of a function (not a character()) described on the `?transcripts`, `?transcriptsBy`, or `?microRNAs` man page.  
 Valid extractor functions:
- `transcripts ## default`
  - `exons`
  - `cds`
  - `genes`
  - `promoters`
  - `exonicParts`
  - `intronicParts`
  - `transcriptsBy`
  - `exonsBy`
  - `cdsBy`
  - `intronsByTranscript`
  - `fiveUTRsByTranscript`
  - `threeUTRsByTranscript`
  - `microRNAs`
  - `tRNAs`
- ... Additional arguments passed to `extractor.fun` functions.

## Details

In GenomicFeatures >= 1.21.10, the default for `ignore.strand` was changed to `FALSE` for consistency with other methods in the **GenomicRanges** and **GenomicAlignments** packages. Additionally, the mapped position is computed from the TSS and does not depend on the `ignore.strand` argument. See the section on `ignore.strand` for details.

- `mapToTranscripts`, `pmapToTranscripts` The genomic range in `x` is mapped to the local position in the transcripts ranges. A successful mapping occurs when `x` is completely within the transcripts range, equivalent to:

```
findOverlaps(..., type="within")
```

Transcriptome-based coordinates start counting at 1 at the beginning of the transcripts range and return positions where `x` was aligned. The `seqlevels` of the return object are taken from the transcripts object and should be transcript names. In this direction, mapping is attempted between all elements of `x` and all elements of transcripts.

`mapToTranscripts` uses `findOverlaps` to map ranges in `x` to ranges in transcripts. This method does not return unmapped ranges.

`pmapToTranscripts` maps the *i*-th range in `x` to the *i*-th range in transcripts. Recycling is supported for both `x` and transcripts when either is `length == 1L`; otherwise the lengths must match. Ranges in `x` that do not map (out of bounds or strand mismatch) are returned as zero-width ranges starting at 0. These ranges are given the `seqname` of "UNMAPPED".

- `mapFromTranscripts`, `pmapFromTranscripts` The transcript-based position in `x` is mapped to genomic coordinates using the ranges in transcripts. A successful mapping occurs when the following is `TRUE`:

```
width(transcripts) >= start(x) + width(x)
```

`x` is aligned to transcripts by moving in `start(x)` positions in from the beginning of the transcripts range. The `seqlevels` of the return object are chromosome names.

`mapFromTranscripts` uses the `seqname` of `x` and the names of transcripts to determine mapping pairs (vs attempting to match all possible pairs). Name matching is motivated by use cases such as differentially expressed regions where the expressed regions in `x` would only be related to a subset of regions in transcripts. This method does not return unmapped ranges.

`pmapFromTranscripts` maps the *i*-th range in `x` to the *i*-th range in transcripts and therefore does not use name matching. Recycling is supported in `pmapFromTranscripts` when either `x` or transcripts is `length == 1L`; otherwise the lengths must match. Ranges in `x` that do not map (out of bounds or strand mismatch) are returned as zero-width ranges starting at 0. These ranges are given the `seqname` of "UNMAPPED".

## Value

`pmapToTranscripts` returns a `GRanges` the same length as `x`.

`pmapFromTranscripts` returns a `GRanges` when transcripts is a `GRanges` and a `GRangesList` when transcripts is a `GRangesList`. In both cases the return object is the same length as `x`. The rationale for returning the `GRangesList` is to preserve exon structure; ranges in a list element that are not overlapped by `x` are returned as a zero-width range. The `GRangesList` return object will have no `seqlevels` called "UNMAPPED"; those will only occur when a `GRanges` is returned.

mapToTranscripts and mapFromTranscripts return GRanges objects that vary in length similar to a Hits object. The result contains mapped records only; strand mismatch and out of bound ranges are not returned. xHits and transcriptsHits metadata columns (similar to the queryHits and subjectHits of a Hits object) indicate elements of x and transcripts used in the mapping.

When intronJunctions is TRUE, mapToTranscripts returns an extra metadata column named intronic to identify the intron ranges.

When mapping to transcript coordinates, seqlevels of the output are the names on the transcripts object and most often these will be transcript names. When mapping to the genome, seqlevels of the output are the seqlevels of transcripts which are usually chromosome names.

### Author(s)

V. Obenchain, M. Lawrence and H. Pagès

### See Also

- [?mapToAlignments](#) in the **GenomicAlignments** package for methods mapping between reads and genome space using a CIGAR alignment.

### Examples

```
## -----
## A. Basic Use: Conversion between CDS and Exon coordinates and the
## genome
## -----

## Gene "Dgkb" has ENTREZID "217480":
library(org.Mm.eg.db)
Dgkb_geneid <- get("Dgkb", org.Mm.egSYMBOL2EG)

## The gene is on the positive strand, chromosome 12:
library(TxDb.Mmusculus.UCSC.mm10.knownGene)
txdb <- TxDb.Mmusculus.UCSC.mm10.knownGene
tx_by_gene <- transcriptsBy(txdb, by="gene")
Dgkb_transcripts <- tx_by_gene[[Dgkb_geneid]]
Dgkb_transcripts # all 7 Dgkb transcripts are on chr12, positive strand

## To map coordinates from local CDS or exon space to genome
## space use mapFromTranscripts().

## When mapping CDS coordinates to genome space the 'transcripts'
## argument is the collection of CDS parts by transcript.
coord <- GRanges("chr12", IRanges(4, width=1))
## Get the names of the transcripts in the gene:
Dgkb_tx_names <- mcols(Dgkb_transcripts)$tx_name
Dgkb_tx_names
## Use these names to isolate the region of interest:
cds_by_tx <- cdsBy(txdb, "tx", use.names=TRUE)
Dgkb_cds_by_tx <- cds_by_tx[intersect(Dgkb_tx_names, names(cds_by_tx))]
## Dgkb CDS parts grouped by transcript (no-CDS transcripts omitted):
Dgkb_cds_by_tx
```

```

lengths(Dgkb_cds_by_tx) # nb of CDS parts per transcript
## A requirement for mapping from transcript space to genome space
## is that seqnames in 'x' match the names in 'transcripts'.
names(Dgkb_cds_by_tx) <- rep(seqnames(coord), length(Dgkb_cds_by_tx))
## There are 6 results, one for each transcript.
mapFromTranscripts(coord, Dgkb_cds_by_tx)

## To map exon coordinates to genome space the 'transcripts'
## argument is the collection of exon regions by transcript.
coord <- GRanges("chr12", IRanges(100, width=1))
ex_by_tx <- exonsBy(txdb, "tx", use.names=TRUE)
Dgkb_ex_by_tx <- ex_by_tx[Dgkb_tx_names]
names(Dgkb_ex_by_tx) <- rep(seqnames(coord), length(Dgkb_ex_by_tx))
## Again the output has 6 results, one for each transcript.
mapFromTranscripts(coord, Dgkb_ex_by_tx)

## To go the reverse direction and map from genome space to
## local CDS or exon space, use mapToTranscripts().

## Genomic position 37981944 maps to CDS position 4:
coord <- GRanges("chr12", IRanges(37981944, width=1))
mapToTranscripts(coord, Dgkb_cds_by_tx)

## Genomic position 37880273 maps to exon position 100:
coord <- GRanges("chr12", IRanges(37880273, width=1))
mapToTranscripts(coord, Dgkb_ex_by_tx)

## The following examples use more than 2GB of memory, which is more
## than what 32-bit Windows can handle:
is_32bit_windows <- .Platform$OS.type == "windows" &&
                    .Platform$r_arch == "i386"
if (!is_32bit_windows) {
## -----
## B. Map sequence locations in exons to the genome
## -----

## NAGNAG alternative splicing plays an essential role in biological
## processes and represents a highly adaptable system for
## posttranslational regulation of gene function. The majority of
## NAGNAG studies largely focus on messenger RNA. A study by Sun,
## Lin, and Yan (http://www.hindawi.com/journals/bmri/2014/736798/)
## demonstrated that NAGNAG splicing is also operative in large
## intergenic noncoding RNA (lincRNA). One finding of interest was
## that linc-POLR3G-10 exhibited two NAGNAG acceptors located in two
## distinct transcripts: TCONS_00010012 and TCONS_00010010.

## Extract the exon coordinates of TCONS_00010012 and TCONS_00010010:
lincrna <- c("TCONS_00010012", "TCONS_00010010")
library(TxDb.Hsapiens.UCSC.hg19.lincRNAsTranscripts)
txdb <- TxDb.Hsapiens.UCSC.hg19.lincRNAsTranscripts
exons <- exonsBy(txdb, by="tx", use.names=TRUE)[lincrna]
exons

```

```

## The two NAGNAG acceptors were identified in the upstream region of
## the fourth and fifth exons located in TCONS_00010012.
## Extract the sequences for transcript TCONS_00010012:
library(BSgenome.Hsapiens.UCSC.hg19)
genome <- BSgenome.Hsapiens.UCSC.hg19
exons_seq <- getSeq(genome, exons[[1]])

## TCONS_00010012 has 4 exons:
exons_seq

## The most common triplet among the lincRNA sequences was CAG. Identify
## the location of this pattern in all exons.
cag_loc <- vmatchPattern("CAG", exons_seq)

## Convert the first occurrence of CAG in each exon back to genome
## coordinates.
first_loc <- do.call(c, sapply(cag_loc, "[", 1, simplify=TRUE))
pmapFromTranscripts(first_loc, exons[[1]])

## -----
## C. Map dbSNP variants to CDS or cDNA coordinates
## -----

## The GIPR gene encodes a G-protein coupled receptor for gastric
## inhibitory polypeptide (GIP). Originally GIP was identified to
## inhibited gastric acid secretion and gastrin release but was later
## demonstrated to stimulate insulin release in the presence of elevated
## glucose.

## In this example 5 SNPs located in the GIPR gene are mapped to cDNA
## coordinates. A list of SNPs in GIPR can be downloaded from dbSNP or
## NCBI.
rsids <- c("rs4803846", "rs139322374", "rs7250736", "rs7250754",
           "rs9749185")

## Extract genomic coordinates with a SNPlocs package.
library(SNPlocs.Hsapiens.dbSNP144.GRCh38)
snps <- snpsById(SNPlocs.Hsapiens.dbSNP144.GRCh38, rsids)

## Gene regions of GIPR can be extracted from a TxDb package of
## compatible build. The TxDb package uses Entrez gene identifiers
## and GIPR is a gene symbol. Let's first lookup its Entrez gene ID.
library(org.Hs.eg.db)
GIPR_geneid <- get("GIPR", org.Hs.egSYMBOL2EG)

## The transcriptsBy() extractor returns a range for each transcript that
## includes the UTR and exon regions (i.e., cDNA).
library(TxDb.Hsapiens.UCSC.hg38.knownGene)
txdb <- TxDb.Hsapiens.UCSC.hg38.knownGene
tx_by_gene <- transcriptsBy(txdb, "gene")
GIPR_transcripts <- tx_by_gene[GIPR_geneid]
GIPR_transcripts # all 8 GIPR transcripts are on chr19, positive strand

```



```

## Before mapping, the chromosome names (seqlevels) in the two
## objects must be harmonized. The style is NCBI for 'snps' and
## UCSC for 'GIPR_transcripts'.
seqlevelsStyle(snps)
seqlevelsStyle(GIPR_transcripts)

## Modify the style (and genome) in 'snps' to match 'GIPR_transcripts'.
seqlevelsStyle(snps) <- seqlevelsStyle(GIPR_transcripts)

## The 'GIPR_transcripts' object is a GRangesList of length 1. This single
## list element contains the cDNA range for 8 different transcripts. To
## map to each transcript individually 'GIPR_transcripts' must be unlisted
## before mapping.

## Map all 5 SNPS to all 8 transcripts:
mapToTranscripts(snps, unlist(GIPR_transcripts))

## Map the first SNP to transcript "ENST00000590918.5" and the second to
## "ENST00000263281.7".
pmapToTranscripts(snps[1:2], unlist(GIPR_transcripts)[1:2])

## The cdsBy() extractor returns CDS parts by gene or by transcript.
## Extract the CDS parts for transcript "ENST00000263281.7".
cds <- cdsBy(txdb, "tx", use.names=TRUE)["ENST00000263281.7"]
cds

## The 'cds' object is a GRangesList of length 1 containing the ranges of
## all CDS parts for single transcript "ENST00000263281.7".

## To map to the concatenated group of ranges leave 'cds' as a GRangesList.
mapToTranscripts(snps, cds)

## Only the second SNP could be mapped. Unlisting the 'cds' object maps
## the SNPs to the individual cds ranges (vs the concatenated range).
mapToTranscripts(snps[2], unlist(cds))

## The location is the same because the SNP hit the first CDS part. If
## the transcript were on the "-" strand the difference in concatenated
## vs non-concatenated position would be more obvious.

## Change strand:
strand(cds) <- strand(snps) <- "-"
mapToTranscripts(snps[2], unlist(cds))
}

```

## Description

Generic functions to extract microRNA or tRNA genomic ranges from an object. This page documents the methods for [TxDb](#) objects only.

## Usage

```
microRNAs(x)
## S4 method for signature 'TxDb'
microRNAs(x)

tRNAs(x)
## S4 method for signature 'TxDb'
tRNAs(x)
```

## Arguments

x                    A [TxDb](#) object.

## Value

A [GRanges](#) object.

## Author(s)

M. Carlson

## See Also

- [transcripts](#), [transcriptsBy](#), and [transcriptsByOverlaps](#) for the core genomic features extractors.
- The [TxDb](#) class.

## Examples

```
## Not run: library(TxDb.Hsapiens.UCSC.hg19.knownGene)
library(mirbase.db)
microRNAs(TxDb.Hsapiens.UCSC.hg19.knownGene)

## End(Not run)
```

---

nearest-methods      *Finding the nearest genomic range neighbor in a TxDb*

---

## Description

The distance methods for TxDb objects and subclasses.

## Usage

```
## S4 method for signature 'GenomicRanges,TxDb'
distance(x, y, ignore.strand=FALSE,
        ..., id, type=c("gene", "tx", "exon", "cds"))
```

## Arguments

x	The query <a href="#">GenomicRanges</a> instance.
y	For distance, a <a href="#">TxDb</a> instance. The id is used to extract ranges from the <a href="#">TxDb</a> which are then used to compute the distance from x.
id	A character vector the same length as x. The id must be identifiers in the <a href="#">TxDb</a> object. type indicates what type of identifier id is.
type	A character(1) describing the id. Must be one of 'gene', 'tx', 'exon' or 'cds'.
ignore.strand	A logical indicating if the strand of the ranges should be ignored. When TRUE, strand is set to '+'.
...	Additional arguments for methods.

## Details

- distance: Returns the distance for each range in x to the range extracted from the [TxDb](#) object y. Values in id are matched to one of 'gene\_id', 'tx\_id', 'exon\_id' or 'cds\_id' identifiers in the [TxDb](#) and the corresponding ranges are extracted. The type argument specifies which identifier is represented in id. The extracted ranges are used in the distance calculation with the ranges in x.

The method returns NA values when the genomic region defined by id cannot be collapsed into a single range (e.g., when a gene spans multiple chromosomes) or if the id is not found in y.

The behavior of distance with respect to zero-width ranges has changed in Bioconductor 2.12. See the man page `?distance` in `IRanges` for details.

## Value

For distance, an integer vector of distances between the ranges in x and y.

## Author(s)

Valerie Obenchain <[vobencha@fhcrc.org](mailto:vobencha@fhcrc.org)>

**See Also**

- [nearest-methods](#) man page in IRanges.
- [nearest-methods](#) man page in GenomicRanges.

**Examples**

```
## -----
## distance()
## -----

library(TxDb.Dmelanogaster.UCSC.dm3.ensGene)
txdb <- TxDb.Dmelanogaster.UCSC.dm3.ensGene
gr <- GRanges(c("chr2L", "chr2R"),
              IRanges(c(100000, 200000), width=100))
distance(gr, txdb, id=c("FBgn0259717", "FBgn0261501"), type="gene")
distance(gr, txdb, id=c("10000", "23000"), type="cds")

## The id's must be in the appropriate order with respect to 'x'.
distance(gr, txdb, id=c("4", "4097"), type="tx")

## 'id' "4" is on chr2L and "4097" is on chr2R.
transcripts(txdb, filter=list(tx_id=c("4", "4097")))

## If we reverse the 'id' the chromosomes are incompatible with gr.
distance(gr, txdb, id=c("4097", "4"), type="tx")

## distance() compares each 'x' to the corresponding 'y'.
## If an 'id' is not found in the TxDb 'y' will not
## be the same length as 'x' and an error is thrown.
## Not run:
distance(gr, txdb, id=c("FBgn0000008", "INVALID"), type="gene") ## will fail

## End(Not run)
```

---

proteinToGenome

*Map protein-relative coordinates to genomic coordinates*


---

**Description**

proteinToGenome is a generic function for mapping ranges of protein-relative positions to the genome.

NOTE: This man page is for the proteinToGenome S4 generic function and methods defined in the **GenomicFeatures** package, which are (loosely) modeled on the [proteinToGenome](#) function from the **ensemldb** package. See `?ensemldb::proteinToGenome` for the latter.

**Usage**

```
## S4 generic function:
proteinToGenome(x, db, ...) # dispatch is on 2nd argument 'db'

## S4 method for signature 'ANY'
proteinToGenome(x, db)

## S4 method for signature 'GRangesList'
proteinToGenome(x, db)
```

**Arguments**

- x** A named [IRanges](#) object (or derivative) containing ranges of *protein-relative positions* (protein-relative positions are positions relative to a protein sequence). The names on **x** must be transcript names present in **db**. More precisely, for the default `proteinToGenome()` method, `names(x)` must be a subset of:
- ```
mcols(transcripts(db, columns="tx_name"))$tx_name
```
- And for the method for [GRangesList](#) objects, `names(x)` must be a subset of:
- ```
names(db)
```
- db** For the default `proteinToGenome()` method: A [TxDb](#) object or any object that supports `transcripts()` and `cdsBy()` (e.g. an [EnsDb](#) object from the **ensembldb** package). For the method for [GRangesList](#) objects: A named [GRangesList](#) object (or derivative) where each list element is a [GRanges](#) object representing a CDS (the ranges in the [GRanges](#) object must represent the CDS parts ordered by ascending exon rank).
- ...** Further arguments to be passed to specific methods.

**Details**

The `proteinToGenome()` method for [GRangesList](#) objects is the workhorse behind the default method. Note that the latter is a thin wrapper around the former, which simply does the following:

1. Use `cdsBy()` to extract the CDS parts from **db**. The CDS parts are returned in a [GRangesList](#) object that has the names of the transcript on it (one transcript name per list element).
2. Call `proteinToGenome()` on **x** and the [GRangesList](#) object returned by `cdsBy()`.

**Value**

A named [GRangesList](#) object *parallel* to **x** (the transcript names on **x** are propagated). The *i*-th list element in the returned object is the result of mapping the range of protein-relative positions `x[i]` to the genome.

Note that a given range in `x` can only be mapped to the genome if the name on it is the name of a *coding* transcript. If it's not (i.e. if it's the name of a *non-coding* transcript), then an empty `GRanges` object is placed in the returned object to indicate the impossible mapping, and a warning is issued.

Otherwise, if a given range in `x` can be mapped to the genome, then the result of the mapping is represented by a non-empty `GRanges` object. Note that this object represents the original CDS associated to `x`, trimmed on its 5' end or 3' end, or on both. Furthermore, this object will have the same metadata columns as the `GRanges` object representing the original CDS, plus the 2 following ones:

- `protein_start`: The protein-relative start of the mapping.
- `protein_end`: The protein-relative end of the mapping.

### Note

Unlike `ensemldb::proteinToGenome()` which can work either with Ensembl protein IDs or Ensembl transcript IDs on `x`, the default `proteinToGenome()` method described above only accepts *transcript names* on `x`.

This means that, if the user is in possession of protein IDs, they must first replace them with the corresponding transcript IDs (referred to as *transcript names* in the context of `TxDb` objects). How to do this exactly depends on the origin of those IDs (UCSC, Ensembl, GTF/GFF3 file, FlyBase, etc...)

### Author(s)

H. Pagès, using `ensemldb::proteinToGenome()` for inspiration and design.

### See Also

- The `proteinToGenome` function in the **ensemldb** package, which the `proteinToGenome()` generic and methods documented in this man page are (loosely) modeled on.
- `TxDb` objects.
- `EnsDb` objects (`TxDb`-like objects) in the **ensemldb** package.
- `transcripts` for extracting transcripts from a `TxDb`-like object.
- `cdsBy` for extracting CDS parts from a `TxDb`-like object.
- `IRanges` objects in the **IRanges** package.
- `GRanges` and `GRangesList` objects in the **GenomicRanges** package.

### Examples

```
## -----
## USING TOY CDS
## -----

## CDS1 has 2 CDS parts:
CDS1 <- GRanges(c("chrX:11-60:+", "chrX:101-125:+"))

## CDS2 has 3 CDS parts:
CDS2 <- GRanges(c("chrY:201-230:-", "chrY:101-125:-", "chrY:11-60:-"))
```

```

## Put them in a GRangesList object:
cds_by_tx <- GRangesList(TX1=CDS1, TX2=CDS2)
cds_by_tx

x1 <- IRanges(start=8, end=20, names="TX1")
proteinToGenome(x1, cds_by_tx)

x2 <- IRanges(start=c(1, 18), end=c(25, 20), names=c("TX1", "TX1"))
x2
proteinToGenome(x2, cds_by_tx)

x3 <- IRanges(start=8, end=15, names="TX2")
proteinToGenome(x3, cds_by_tx)

x4 <- c(x3, x2)
x4
proteinToGenome(x4, cds_by_tx)

## -----
## USING A TxDb OBJECT
## -----
library(TxDb.Dmelanogaster.UCSC.dm3.ensGene)
txdb <- TxDb.Dmelanogaster.UCSC.dm3.ensGene

## The first transcript (FBtr0309810) is non-coding:
x <- IRanges(c(FBtr0309810="11-55", FBtr0306539="90-300"))
res <- proteinToGenome(x, txdb)
res

```

---

select-methods

*Using the "select" interface on TxDb objects*


---

## Description

select, columns and keys can be used together to extract data from a [TxDb](#) object.

## Details

In the code snippets below, x is a [TxDb](#) object.

keytypes(x): allows the user to discover which keytypes can be passed in to select or keys and the keytype argument.

keys(x, keytype, pattern, column, fuzzy): Return keys for the database contained in the [TxDb](#) object .

The keytype argument specifies the kind of keys that will be returned. By default keys will return the "GENEID" keys for the database.

If keys is used with pattern, it will pattern match on the keytype.

But if the column argument is also provided along with the pattern argument, then pattern will be matched against the values in column instead.

And if keys is called with column and no pattern argument, then it will return all keys that have corresponding values in the column argument.

Thus, the behavior of keys all depends on how many arguments are specified.

Use of the fuzzy argument will toggle fuzzy matching to TRUE or FALSE. If pattern is not used, fuzzy is ignored.

`columns(x)`: Show which kinds of data can be returned for the [TxDb](#) object.

`select(x, keys, columns, keytype)`: When all the appropriate arguments are specified select will retrieve the matching data as a data.frame based on parameters for selected keys and columns and keytype arguments.

### Author(s)

Marc Carlson

### See Also

- [AnnotationDb-class](#) for more description of methods `select`, `keytypes`, `keys` and `columns`.
- [transcripts](#), [transcriptsBy](#), and [transcriptsByOverlaps](#), for other ways to extract genomic features from a [TxDb](#) object.
- The [TxDb](#) class.

### Examples

```
txdb_file <- system.file("extdata", "Biomart_Ensembl_sample.sqlite",
                        package="GenomicFeatures")
txdb <- loadDb(txdb_file)
txdb

## find key types
keytypes(txdb)

## list IDs that can be used to filter
head(keys(txdb, "GENEID"))
head(keys(txdb, "TXID"))
head(keys(txdb, "TXNAME"))

## list columns that can be returned by select
columns(txdb)

## call select
res <- select(txdb, head(keys(txdb, "GENEID")),
             columns=c("GENEID", "TXNAME"),
             keytype="GENEID")
head(res)
```



---

transcriptLengths	<i>Extract the transcript lengths (and other metrics) from a TxDb object</i>
-------------------	--

---

### Description

The `transcriptLengths` function extracts the transcript lengths from a `TxDb` object. It also returns the CDS and UTR lengths for each transcript if the user requested them.

### Usage

```
transcriptLengths(txdb, with.cds_len=FALSE,  
                  with.utr5_len=FALSE, with.utr3_len=FALSE, ...)
```

### Arguments

<code>txdb</code>	A <code>TxDb</code> object.
<code>with.cds_len</code> , <code>with.utr5_len</code> , <code>with.utr3_len</code>	TRUE or FALSE. Whether or not to also extract and return the CDS, 5' UTR, and 3' UTR lengths for each transcript.
<code>...</code>	Additional arguments used by transcripts and other accessor functions.

### Details

All the lengths are counted in number of nucleotides.

The length of a processed transcript is just the sum of the lengths of its exons. This should not be confounded with the length of the stretch of DNA transcribed into RNA (a.k.a. transcription unit), which can be obtained with `width(transcripts(txdb))`.

### Value

A data frame with 1 row per transcript. The rows are guaranteed to be in the same order as the elements of the `GRanges` object returned by `transcripts(txdb)`. The data frame has between 5 and 8 columns, depending on what the user requested via the `with.cds_len`, `with.utr5_len`, and `with.utr3_len` arguments.

The first 3 columns are the same as the metadata columns of the object returned by

```
transcripts(txdb, columns=c("tx_id", "tx_name", "gene_id"))
```

that is:

- `tx_id`: The internal transcript ID. This ID is unique within the scope of the `TxDb` object. It is not an official or public ID (like an Ensembl or FlyBase ID) or an Accession number, so it cannot be used to lookup the transcript in public data bases or in other `TxDb` objects. Furthermore, this ID could change when re-running the code that was used to make the `TxDb` object.

- `tx_name`: An official/public transcript name or ID that can be used to lookup the transcript in public data bases or in other [TxDb](#) objects. This column is not guaranteed to contain unique values and it can contain NAs.
- `gene_id`: The official/public ID of the gene that the transcript belongs to. Can be NA if the gene is unknown or if the transcript is not considered to belong to a gene.

The other columns are quantitative:

- `nexon`: The number of exons in the transcript.
- `tx_len`: The length of the processed transcript.
- `cds_len`: [optional] The length of the CDS region of the processed transcript.
- `utr5_len`: [optional] The length of the 5' UTR region of the processed transcript.
- `utr3_len`: [optional] The length of the 3' UTR region of the processed transcript.

### Author(s)

Hervé Pagès

### See Also

- [transcripts](#), [transcriptsBy](#), and [transcriptsByOverlaps](#), for extracting genomic feature locations from a [TxDb](#)-like object.
- [exonicParts](#) and [intronicParts](#) for extracting non-overlapping exonic or intronic parts from a [TxDb](#)-like object.
- [extractTranscriptSeqs](#) for extracting transcript (or CDS) sequences from chromosome sequences.
- [coverageByTranscript](#) for computing coverage by transcript (or CDS) of a set of ranges.
- [makeTxDbFromUCSC](#), [makeTxDbFromBiomart](#), and [makeTxDbFromEnsembl](#), for making a [TxDb](#) object from online resources.
- [makeTxDbFromGRanges](#) and [makeTxDbFromGFF](#) for making a [TxDb](#) object from a [GRanges](#) object, or from a GFF or GTF file.
- The [TxDb](#) class.

### Examples

```
library(TxDb.Dmelanogaster.UCSC.dm3.ensGene)
txdb <- TxDb.Dmelanogaster.UCSC.dm3.ensGene
dm3_txlens <- transcriptLengths(txdb)
head(dm3_txlens)

dm3_txlens <- transcriptLengths(txdb, with.cds_len=TRUE,
                               with.utr5_len=TRUE,
                               with.utr3_len=TRUE)

head(dm3_txlens)

## When cds_len is 0 (non-coding transcript), utr5_len and utr3_len
## must also be 0:
```

```

non_coding <- dm3_txlens[dm3_txlens$cds_len == 0, ]
stopifnot(all(non_coding[6:8] == 0))

## When cds_len is not 0 (coding transcript), cds_len + utr5_len +
## utr3_len must be equal to tx_len:
coding <- dm3_txlens[dm3_txlens$cds_len != 0, ]
stopifnot(all(rowSums(coding[6:8]) == coding[[5]]))

## A sanity check:
stopifnot(identical(dm3_txlens$tx_id, mcols(transcripts(txdb))$tx_id))

```

---

transcriptLocs2refLocs

*Converting transcript-based locations into reference-based locations*

---

## Description

transcriptLocs2refLocs converts transcript-based locations into reference-based (aka chromosome-based or genomic) locations.

transcriptWidths computes the lengths of the transcripts (called the "widths" in this context) based on the boundaries of their exons.

## Usage

```

transcriptLocs2refLocs(tlocs,
  exonStarts=list(), exonEnds=list(), strand=character(0),
  decreasing.rank.on.minus.strand=FALSE, error.if.out.of.bounds=TRUE)

transcriptWidths(exonStarts=list(), exonEnds=list())

```

## Arguments

tlocs	A list of integer vectors of the same length as exonStarts and exonEnds. Each element in tlocs must contain transcript-based locations.
exonStarts, exonEnds	The starts and ends of the exons, respectively. Each argument can be a list of integer vectors, an <a href="#">IntegerList</a> object, or a character vector where each element is a comma-separated list of integers. In addition, the lists represented by exonStarts and exonEnds must have the same shape i.e. have the same lengths and have elements of the same lengths. The length of exonStarts and exonEnds is the number of transcripts.
strand	A character vector of the same length as exonStarts and exonEnds specifying the strand ("+" or "-") from which the transcript is coming.
decreasing.rank.on.minus.strand	TRUE or FALSE. Describes the order of exons in transcripts located on the minus strand: are they ordered by increasing (default) or decreasing rank?

error.if.out.of.bounds

TRUE or FALSE. Controls how out of bound tlocs are handled: an error is thrown (default) or NA is returned.

### Value

For transcriptLocs2refLocs: A list of integer vectors of the same shape as tlocs.

For transcriptWidths: An integer vector with one element per transcript.

### Author(s)

Hervé Pagès

### See Also

- [extractTranscriptSeqs](#) for extracting transcript (or CDS) sequences from chromosomes.
- [coverageByTranscript](#) for computing coverage by transcript (or CDS) of a set of ranges.

### Examples

```
## -----
## WITH A SMALL SET OF HUMAN TRANSCRIPTS
## -----
txdb_file <- system.file("extdata", "hg19_knownGene_sample.sqlite",
                        package="GenomicFeatures")
txdb <- loadDb(txdb_file)
ex_by_tx <- exonsBy(txdb, by="tx", use.names=TRUE)
genome <- BSgenome::getBSgenome("hg19") # load the hg19 genome
tx_seqs <- extractTranscriptSeqs(genome, ex_by_tx)

## Get the reference-based locations of the first 4 (5' end)
## and last 4 (3' end) nucleotides in each transcript:
tlocs <- lapply(width(tx_seqs), function(w) c(1:4, (w-3):w))
tx_strand <- sapply(strand(ex_by_tx), runValue)

## Note that, because of how we made them, 'tlocs', 'start(ex_by_tx)',
## 'end(ex_by_tx)' and 'tx_strand' are "parallel" objects i.e. they
## have the same length, and, for any valid positional index, elements
## at this position are corresponding to each other. This is how
## transcriptLocs2refLocs() expects them to be!
rlocs <- transcriptLocs2refLocs(tlocs,
                              start(ex_by_tx), end(ex_by_tx),
                              tx_strand, decreasing.rank.on.minus.strand=TRUE)

## -----
## WITH TWO WORM TRANSCRIPTS: ZC101.3.1 AND F37B1.1.1
## -----
library(TxDb.Celegans.UCSC.ce11.ensGene)
txdb <- TxDb.Celegans.UCSC.ce11.ensGene
my_tx_names <- c("ZC101.3.1", "F37B1.1.1")
## Both transcripts are on chromosome II, the first one on its positive
## strand and the second one on its negative strand:
```

```

my_tx <- transcripts(txdb, filter=list(tx_name=my_tx_names))
my_tx

## Using transcripts stored in a GRangesList object:
ex_by_tx <- exonsBy(txdb, use.names=TRUE)[my_tx_names]
genome <- getBSgenome("ce11") # load the ce11 genome
tx_seqs <- extractTranscriptSeqs(genome, ex_by_tx)
tx_seqs

## Since the 2 transcripts are on the same chromosome, an alternative
## is to store them in an IRangesList object and use that object with
## extractTranscriptSeqs():
ex_by_tx2 <- ranges(ex_by_tx)
tx_seqs2 <- extractTranscriptSeqs(genome$chrII, ex_by_tx2,
                                strand=strand(my_tx))
stopifnot(identical(as.character(tx_seqs), as.character(tx_seqs2)))

## Store exon starts and ends in two IntegerList objects for use with
## transcriptWidths() and transcriptLocs2refLocs():
exon_starts <- start(ex_by_tx)
exon_ends <- end(ex_by_tx)

## Same as 'width(tx_seqs)':
transcriptWidths(exonStarts=exon_starts, exonEnds=exon_ends)

transcriptLocs2refLocs(list(c(1:2, 202:205, 1687:1688),
                           c(1:2, 193:196, 721:722)),
                       exonStarts=exon_starts,
                       exonEnds=exon_ends,
                       strand=c("+", "-"))

## A sanity check:
ref_locs <- transcriptLocs2refLocs(list(1:1688, 1:722),
                                   exonStarts=exon_starts,
                                   exonEnds=exon_ends,
                                   strand=c("+", "-"))
stopifnot(genome$chrII[ref_locs[[1]]] == tx_seqs[[1]])
stopifnot(complement(genome$chrII)[ref_locs[[2]]] == tx_seqs[[2]])

```

---

transcripts

*Extract genomic features from a TxDb-like object*


---

## Description

Generic functions to extract genomic features from a TxDb-like object. This page documents the methods for [TxDb](#) objects only.

## Usage

```
transcripts(x, ...)
```

```

## S4 method for signature 'TxDb'
transcripts(x, columns=c("tx_id", "tx_name"), filter=NULL, use.names=FALSE)

exons(x, ...)
## S4 method for signature 'TxDb'
exons(x, columns="exon_id", filter=NULL, use.names=FALSE)

cds(x, ...)
## S4 method for signature 'TxDb'
cds(x, columns="cds_id", filter=NULL, use.names=FALSE)

genes(x, ...)
## S4 method for signature 'TxDb'
genes(x, columns="gene_id", filter=NULL, single.strand.genes.only=TRUE)

## S4 method for signature 'TxDb'
promoters(x, upstream=2000, downstream=200, use.names=TRUE, ...)

```

## Arguments

x	A <a href="#">TxDb</a> object.
...	For the <code>transcripts()</code> , <code>exons()</code> , <code>cds()</code> , and <code>genes()</code> generic functions: arguments to be passed to methods. For the <code>promoters()</code> method for <a href="#">TxDb</a> objects: arguments to be passed to the internal call to <code>transcripts()</code> .
columns	Columns to include in the output. Must be <code>NULL</code> or a character vector as given by the <code>columns</code> method. With the following restrictions: <ul style="list-style-type: none"> <li>• "TXCHROM" and "TXSTRAND" are not allowed for <code>transcripts()</code>.</li> <li>• "EXONCHROM" and "EXONSTRAND" are not allowed for <code>exons()</code>.</li> <li>• "CDSCHROM" and "CDSSTRAND" are not allowed for <code>cds()</code>.</li> </ul> If the vector is named, those names are used for the corresponding column in the element metadata of the returned object.
filter	Either <code>NULL</code> or a named list of vectors to be used to restrict the output. Valid names for this list are: "gene_id", "tx_id", "tx_name", "tx_chrom", "tx_strand", "exon_id", "exon_name", "exon_chrom", "exon_strand", "cds_id", "cds_name", "cds_chrom", "cds_strand" and "exon_rank".
use.names	<code>TRUE</code> or <code>FALSE</code> . If <code>TRUE</code> , the feature names are set as the names of the returned object, with NAs being replaced with empty strings.
single.strand.genes.only	<code>TRUE</code> or <code>FALSE</code> . If <code>TRUE</code> (the default), then genes are returned in a <a href="#">GRanges</a> object and those genes that cannot be represented by a single genomic range (because they have exons located on both strands of the same reference sequence or on more than one reference sequence) are dropped with a message. If <code>FALSE</code> , then all the genes are returned in a <a href="#">GRangesList</a> object with the columns specified thru the <code>columns</code> argument set as <i>top level</i> metadata columns. (Please keep in mind that the <i>top level</i> metadata columns of a <a href="#">GRangesList</a> object are not displayed by the <code>show()</code> method.)

upstream	For <code>promoters()</code> : An <code>integer(1)</code> value indicating the number of bases upstream from the transcription start site. For additional details see <code>?promoters,GRanges-method`</code> .
downstream	For <code>promoters()</code> : An <code>integer(1)</code> value indicating the number of bases downstream from the transcription start site. For additional details see <code>?promoters,GRanges-method`</code> .

### Details

These are the main functions for extracting features from a `TxDb`-like object. Note that `cds()` extracts the bulk *CDS parts* stored in `x`, that is, the CDS regions associated with exons. It is often more useful to extract them grouped by transcript with `cdsBy()`.

To restrict the output based on interval information, use the `transcriptsByOverlaps()`, `exonsByOverlaps()`, or `cdsByOverlaps()` function.

The `promoters()` function computes user-defined promoter regions for the transcripts in a `TxDb`-like object. The return object is a `GRanges` of promoter regions around the transcription start site the span of which is defined by `upstream` and `downstream`. For additional details on how the promoter range is computed and the handling of + and - strands see `?promoters,GRanges-method``.

### Value

A `GRanges` object. The only exception being when `genes()` is used with `single.strand.genes.only=FALSE`, in which case a `GRangesList` object is returned.

### Author(s)

M. Carlson, P. Aboyoun and H. Pagès

### See Also

- `transcriptsBy` and `transcriptsByOverlaps` for more ways to extract genomic features from a `TxDb`-like object.
- `transcriptLengths` for extracting the transcript lengths (and other metrics) from a `TxDb` object.
- `exonicParts` and `intronicParts` for extracting non-overlapping exonic or intronic parts from a `TxDb`-like object.
- `extendExonsIntoIntrons` for extending exons into their adjacent introns.
- `extractTranscriptSeqs` for extracting transcript (or CDS) sequences from reference sequences.
- `coverageByTranscript` for computing coverage by transcript (or CDS) of a set of ranges.
- `select-methods` for how to use the simple "select" interface to extract information from a `TxDb` object.
- `microRNAs` and `tRNAs` for extracting microRNA or tRNA genomic ranges from a `TxDb` object.
- `id2name` for mapping `TxDb` internal ids to external names for a given feature type.
- The `TxDb` class.

**Examples**

```

txdb_file <- system.file("extdata", "hg19_knownGene_sample.sqlite",
                        package="GenomicFeatures")
txdb <- loadDb(txdb_file)

## -----
## transcripts()
## -----

tx1 <- transcripts(txdb)
tx1

transcripts(txdb, use.names=TRUE)
transcripts(txdb, columns=NULL, use.names=TRUE)

filter <- list(tx_chrom = c("chr3", "chr5"), tx_strand = "+")
tx2 <- transcripts(txdb, filter=filter)
tx2

## Sanity checks:
stopifnot(
  identical(mcols(tx1)$tx_id, seq_along(tx1)),
  identical(tx2, tx1[seqnames(tx1) == "chr3" & strand(tx1) == "+"])
)

## -----
## exons()
## -----

exons(txdb, columns=c("EXONID", "TXNAME"),
      filter=list(exon_id=1))
exons(txdb, columns=c("EXONID", "TXNAME"),
      filter=list(tx_name="uc009vip.1"))

## -----
## genes()
## -----

genes(txdb) # a GRanges object
cols <- c("tx_id", "tx_chrom", "tx_strand",
         "exon_id", "exon_chrom", "exon_strand")
## By default, genes are returned in a GRanges object and those that
## cannot be represented by a single genomic range (because they have
## exons located on both strands of the same reference sequence or on
## more than one reference sequence) are dropped with a message:
single_strand_genes <- genes(txdb, columns=cols)

## Because we've returned single strand genes only, the "tx_chrom"
## and "exon_chrom" metadata columns are guaranteed to match
## 'seqnames(single_strand_genes)':
stopifnot(identical(as.character(seqnames(single_strand_genes)),
                    as.character(mcols(single_strand_genes)$tx_chrom)))

```



```

stopifnot(identical(as.character(seqnames(single_strand_genes)),
                    as.character(mcols(single_strand_genes)$exon_chrom)))

## and also the "tx_strand" and "exon_strand" metadata columns are
## guaranteed to match 'strand(single_strand_genes)':
stopifnot(identical(as.character(strand(single_strand_genes)),
                    as.character(mcols(single_strand_genes)$tx_strand)))
stopifnot(identical(as.character(strand(single_strand_genes)),
                    as.character(mcols(single_strand_genes)$exon_strand)))

all_genes <- genes(txdb, columns=cols, single.strand.genes.only=FALSE)
all_genes # a GRangesList object
multiple_strand_genes <- all_genes[elementNROWS(all_genes) >= 2]
multiple_strand_genes
mcols(multiple_strand_genes)

## -----
## promoters()
## -----

## This:
promoters(txdb, upstream=100, downstream=50)
## is equivalent to:
promoters(transcripts(txdb, use.names=TRUE), upstream=100, downstream=50)

## Extra arguments are passed to transcripts(). So this:
columns <- c("tx_name", "gene_id")
promoters(txdb, upstream=100, downstream=50, columns=columns)
## is equivalent to:
promoters(transcripts(txdb, columns=columns, use.names=TRUE),
          upstream=100, downstream=50)

```

---

transcriptsBy	<i>Extract and group genomic features of a given type from a TxDb-like object</i>
---------------	---

---

## Description

Generic functions to extract genomic features of a given type grouped based on another type of genomic feature. This page documents the methods for [TxDb](#) objects only.

## Usage

```

transcriptsBy(x, by=c("gene", "exon", "cds"), ...)
## S4 method for signature 'TxDb'
transcriptsBy(x, by=c("gene", "exon", "cds"), use.names=FALSE)

exonsBy(x, by=c("tx", "gene"), ...)
## S4 method for signature 'TxDb'

```

```

exonsBy(x, by=c("tx", "gene"), use.names=FALSE)

cdsBy(x, by=c("tx", "gene"), ...)
## S4 method for signature 'TxDb'
cdsBy(x, by=c("tx", "gene"), use.names=FALSE)

intronsByTranscript(x, ...)
## S4 method for signature 'TxDb'
intronsByTranscript(x, use.names=FALSE)

fiveUTRsByTranscript(x, ...)
## S4 method for signature 'TxDb'
fiveUTRsByTranscript(x, use.names=FALSE)

threeUTRsByTranscript(x, ...)
## S4 method for signature 'TxDb'
threeUTRsByTranscript(x, use.names=FALSE)

```

## Arguments

x	A <a href="#">TxDb</a> object.
...	Arguments to be passed to or from methods.
by	One of "gene", "exon", "cds" or "tx". Determines the grouping.
use.names	Controls how to set the names of the returned <a href="#">GRangesList</a> object. These functions return all the features of a given type (e.g. all the exons) grouped by another feature type (e.g. grouped by transcript) in a <a href="#">GRangesList</a> object. By default (i.e. if use.names is FALSE), the names of this <a href="#">GRangesList</a> object (aka the group names) are the internal ids of the features used for grouping (aka the grouping features), which are guaranteed to be unique. If use.names is TRUE, then the names of the grouping features are used instead of their internal ids. For example, when grouping by transcript (by="tx"), the default group names are the transcript internal ids ("tx_id"). But, if use.names=TRUE, the group names are the transcript names ("tx_name"). Note that, unlike the feature ids, the feature names are not guaranteed to be unique or even defined (they could be all NAs). A warning is issued when this happens. See <a href="#">?id2name</a> for more information about feature internal ids and feature external names and how to map the formers to the latters.  Finally, use.names=TRUE cannot be used when grouping by gene by="gene". This is because, unlike for the other features, the gene ids are external ids (e.g. Entrez Gene or Ensembl ids) so the db doesn't have a "gene_name" column for storing alternate gene names.

## Details

These functions return a [GRangesList](#) object where the ranges within each of the elements are ordered according to the following rule:

When using `exonsBy` or `cdsBy` with `by="tx"`, the returned exons or CDS parts are ordered by ascending rank for each transcript, that is, by their position in the transcript. In all other cases, the

ranges will be ordered by chromosome, strand, start, and end values.

### Value

A [GRangesList](#) object.

### Author(s)

M. Carlson, P. Aboyoun and H. Pagès

### See Also

- [transcripts](#) and [transcriptsByOverlaps](#) for more ways to extract genomic features from a [TxDb](#)-like object.
- [transcriptLengths](#) for extracting the transcript lengths (and other metrics) from a [TxDb](#) object.
- [exonicParts](#) and [intronicParts](#) for extracting non-overlapping exonic or intronic parts from a [TxDb](#)-like object.
- [extendExonsIntoIntrons](#) for extending exons into their adjacent introns.
- [extractTranscriptSeqs](#) for extracting transcript (or CDS) sequences from chromosome sequences.
- [coverageByTranscript](#) for computing coverage by transcript (or CDS) of a set of ranges.
- [select-methods](#) for how to use the simple "select" interface to extract information from a [TxDb](#) object.
- [id2name](#) for mapping [TxDb](#) internal ids to external names for a given feature type.
- The [TxDb](#) class.

### Examples

```
txdb_file <- system.file("extdata", "hg19_knownGene_sample.sqlite",
                        package="GenomicFeatures")
txdb <- loadDb(txdb_file)

## Extract the transcripts grouped by gene:
transcriptsBy(txdb, "gene")

## Extract the exons grouped by gene:
exonsBy(txdb, "gene")

## Extract the CDS parts grouped by transcript:
cds_by_tx0 <- cdsBy(txdb, "tx")
## With more informative group names:
cds_by_tx1 <- cdsBy(txdb, "tx", use.names=TRUE)
## Note that 'cds_by_tx1' can also be obtained with:
names(cds_by_tx0) <- id2name(txdb, feature.type="tx")[names(cds_by_tx0)]
stopifnot(identical(cds_by_tx0, cds_by_tx1))

## Extract the introns grouped by transcript:
intronsByTranscript(txdb)
```

```
## Extract the 5' UTRs grouped by transcript:
fiveUTRsByTranscript(txdb)
fiveUTRsByTranscript(txdb, use.names=TRUE) # more informative group names
```

---

transcriptsByOverlaps *Extract genomic features from a TxDb-like object based on their genomic location*

---

## Description

Generic functions to extract genomic features for specified genomic locations. This page documents the methods for [TxDb](#) objects only.

## Usage

```
transcriptsByOverlaps(x, ranges,
                      maxgap = -1L, minoverlap = 0L,
                      type = c("any", "start", "end"), ...)
```

```
## S4 method for signature 'TxDb'
```

```
transcriptsByOverlaps(x, ranges,
                      maxgap = -1L, minoverlap = 0L,
                      type = c("any", "start", "end"),
                      columns = c("tx_id", "tx_name"))
```

```
exonsByOverlaps(x, ranges,
                maxgap = -1L, minoverlap = 0L,
                type = c("any", "start", "end"), ...)
```

```
## S4 method for signature 'TxDb'
```

```
exonsByOverlaps(x, ranges,
                maxgap = -1L, minoverlap = 0L,
                type = c("any", "start", "end"),
                columns = "exon_id")
```

```
cdsByOverlaps(x, ranges,
              maxgap = -1L, minoverlap = 0L,
              type = c("any", "start", "end"), ...)
```

```
## S4 method for signature 'TxDb'
```

```
cdsByOverlaps(x, ranges,
              maxgap = -1L, minoverlap = 0L,
              type = c("any", "start", "end"),
              columns = "cds_id")
```

## Arguments

x                    A [TxDb](#) object.

ranges              A [GRanges](#) object to restrict the output.

maxgap, minoverlap, type  
 Used in the internal call to `findOverlaps()` to detect overlaps. See `?findOverlaps` in the **IRanges** package for a description of these arguments.

... Arguments to be passed to or from methods.

columns Columns to include in the output. See `?transcripts` for the possible values.

### Details

These functions subset the results of `transcripts`, `exons`, and `cds` function calls with using the results of `findOverlaps` calls based on the specified ranges.

### Value

a GRanges object

### Author(s)

P. Aboyoun

### See Also

- `transcripts` and `transcriptsBy` for more ways to extract genomic features from a `TxDb`-like object.
- `transcriptLengths` for extracting the transcript lengths (and other metrics) from a `TxDb` object.
- `exonicParts` and `intronicParts` for extracting non-overlapping exonic or intronic parts from a `TxDb`-like object.
- `extractTranscriptSeqs` for extracting transcript (or CDS) sequences from chromosome sequences.
- `coverageByTranscript` for computing coverage by transcript (or CDS) of a set of ranges.
- `select-methods` for how to use the simple "select" interface to extract information from a `TxDb` object.
- `id2name` for mapping `TxDb` internal ids to external names for a given feature type.
- The `TxDb` class.

### Examples

```
txdb <- loadDb(system.file("extdata", "hg19_knownGene_sample.sqlite",
  package="GenomicFeatures"))
gr <- GRanges(Rle("chr1", 2),
  IRanges(c(500,10500), c(10000,30000)),
  strand = Rle("-", 2))
transcriptsByOverlaps(txdb, gr)
```

TxDb-class

*TxDb objects***Description**

The TxDb class is a container for storing transcript annotations.

**Methods**

In the code snippets below, *x* is a TxDb object.

`metadata(x)`: Return *x*'s metadata in a data frame.

`seqlevels0(x)`: Get the *sequence levels* originally in *x*. This ignores any change the user might have made to the *sequence levels* with the `seqlevels` setter.

`seqlevels(x)`, `seqlevels(x) <- value`: Get or set the *sequence levels* in *x*.

`seqinfo(x)`, `seqinfo(x) <- value`: Get or set the information about the underlying sequences. Note that, for now, the setter only supports replacement of the sequence names, i.e., except for their sequence names (accessed with `seqnames(value)` and `seqnames(seqinfo(x))`, respectively), [Seqinfo](#) objects `value` (supplied) and `seqinfo(x)` (current) must be identical.

`isActiveSeq(x)`: Return the currently active sequences for this txdb object as a named logical vector. Only active sequences will be tapped when using the supplied accessor methods. Inactive sequences will be ignored. By default, all available sequences will be active.

`isActiveSeq(x) <- value`: Allows the user to change which sequences will be actively accessed by the accessor methods by altering the contents of this named logical vector.

`seqlevelsStyle(x)`, `seqlevelsStyle(x) <- value`: Get or set the seqname style for *x*. See the [seqlevelsStyle](#) generic getter and setter in the **GenomeInfoDb** package for more information.

`as.list(x)`: Dump the entire db into a list of data frames, say `txdb_dump`, that can then be used to recreate the original db with `do.call(makeTxDb, txdb_dump)` with no loss of information (except possibly for some of the metadata). Note that the transcripts are dumped in the same order in all the data frames.

**Author(s)**

Hervé Pagès, Marc Carlson

**See Also**

- [makeTxDbFromUCSC](#), [makeTxDbFromBiomart](#), and [makeTxDbFromEnsembl](#), for making a TxDb object from online resources.
- [makeTxDbFromGRanges](#) and [makeTxDbFromGFF](#) for making a TxDb object from a GRanges object, or from a GFF or GTF file.
- [saveDb](#) and [loadDb](#) in the **AnnotationDbi** package for saving and loading a TxDb object as an SQLite file.
- [transcripts](#), [transcriptsBy](#), and [transcriptsByOverlaps](#), for extracting genomic feature locations from a TxDb-like object.

- [transcriptLengths](#) for extracting the transcript lengths (and other metrics) from a [TxDb](#) object.
- [select-methods](#) for how to use the simple "select" interface to extract information from a TxDb object.
- The [Seqinfo](#) class in the **GenomeInfoDb** package.

## Examples

```
txdb_file <- system.file("extdata", "Biomart_Ensembl_sample.sqlite",
                        package="GenomicFeatures")
txdb <- loadDb(txdb_file)
txdb

## Use of seqinfo():
seqlevelsStyle(txdb)
seqinfo(txdb)
seqlevels(txdb)
seqlengths(txdb) # shortcut for 'seqlengths(seqinfo(txdb))'
isCircular(txdb) # shortcut for 'isCircular(seqinfo(txdb))'
names(which(isCircular(txdb)))

## You can set user-supplied seqlevels on 'txdb' to restrict any further
## operations to a subset of chromosomes:
seqlevels(txdb) <- c("Y", "6")
## Then you can restore the seqlevels stored in the db:
seqlevels(txdb) <- seqlevels0(txdb)

## Use of as.list():
txdb_dump <- as.list(txdb)
txdb_dump
txdb1 <- do.call(makeTxDb, txdb_dump)
stopifnot(identical(as.list(txdb1), txdb_dump))
```

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