

# Package ‘S4Vectors’

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**Title** S4 implementation of vectors and lists

**Description** The S4Vectors package defines the Vector and List virtual classes and a set of generic functions that extend the semantic of ordinary vectors and lists in R. Package developers can easily implement vector-like or list-like objects as concrete subclasses of Vector or List. In addition, a few low-level concrete subclasses of general interest (e.g. DataFrame, Rle, and Hits) are implemented in the S4Vectors package itself (many more are implemented in the IRanges package and in other Bioconductor infrastructure packages).

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Annotated-class	<i>Annotated class</i>
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## Description

The virtual class `Annotated` is used to standardize the storage of metadata with a subclass.

## Details

The `Annotated` class supports the storage of global metadata in a subclass. This is done through the metadata slot that stores a list object.

## Accessors

In the following code snippets, `x` is an `Annotated` object.

```
metadata(x), metadata(x) <- value: Get or set the list holding arbitrary R objects as annotations. May be, and often is, empty.
```

## Author(s)

P. Aboyoun

## See Also

The [Vector](#) class, which extends `Annotated` directly.

## Examples

```
showClass("Annotated") # shows (some of) the known subclasses

## If the IRanges package was not already loaded, this will show
## more subclasses:
library(IRanges)
showClass("Annotated")
```

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DataFrame-class	<i>DataFrame objects</i>
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### Description

The DataFrame class extends the [DataTable](#) virtual class and supports the storage of any type of object (with `length` and `[]` methods) as columns.

### Details

On the whole, the DataFrame behaves very similarly to `data.frame`, in terms of construction, subsetting, splitting, combining, etc. The most notable exception is that the row names are optional. This means calling `rownames(x)` will return `NULL` if there are no row names. Of course, it could return `seq_len(nrow(x))`, but returning `NULL` informs, for example, combination functions that no row names are desired (they are often a luxury when dealing with large data).

As DataFrame derives from [Vector](#), it is possible to set an annotation string. Also, another DataFrame can hold metadata on the columns.

For a class to be supported as a column, it must have `length` and `[]` methods, where `[]` supports subsetting only by `i` and respects `drop=FALSE`. Optionally, a method may be defined for the `showAsCell` generic, which should return a vector of the same length as the subset of the column passed to it. This vector is then placed into a `data.frame` and converted to text with `format`. Thus, each element of the vector should be some simple, usually character, representation of the corresponding element in the column.

### Constructor

`DataFrame(..., row.names = NULL, check.names = TRUE)`: Constructs a DataFrame in similar fashion to [data.frame](#). Each argument in `...` is coerced to a DataFrame and combined column-wise. No special effort is expended to automatically determine the row names from the arguments. The row names should be given in `row.names`; otherwise, there are no row names. This is by design, as row names are normally undesirable when data is large. If `check.names` is `TRUE`, the column names will be checked for syntactic validity and made unique, if necessary.

To store an object of a class that does not support coercion to DataFrame, wrap it in `I()`. The class must still have methods for `length` and `[]`.

### Accessors

In the following code snippets, `x` is a DataFrame.

`dim(x)`: Get the length two integer vector indicating in the first and second element the number of rows and columns, respectively.

`dimnames(x), dimnames(x) <- value`: Get and set the two element list containing the row names (character vector of length `nrow(x)` or `NULL`) and the column names (character vector of length `ncol(x)`).

## Coercion

`as(from, "DataFrame")`: By default, constructs a new `DataFrame` with `from` as its only column. If `from` is a `matrix` or `data.frame`, all of its columns become columns in the new `DataFrame`. If `from` is a list, each element becomes a column, recycling as necessary. Note that for the `DataFrame` to behave correctly, each column object must support element-wise subsetting via the `[]` method and return the number of elements with `length`. It is recommended to use the `DataFrame` constructor, rather than this interface.

`as.list(x)`: Coerces `x`, a `DataFrame`, to a list.

`as.data.frame(x, row.names=NULL, optional=FALSE)`: Coerces `x`, a `DataFrame`, to a `data.frame`. Each column is coerced to a `data.frame` and then column bound together. If `row.names` is `NULL`, they are retrieved from `x`, if it has any. Otherwise, they are inferred by the `data.frame` constructor.

NOTE: conversion of `x` to a `data.frame` is not supported if `x` contains any `list`, `SimpleList`, or `CompressedList` columns.

`as(from, "data.frame")`: Coerces a `DataFrame` to a `data.frame` by calling `as.data.frame(from)`.

`as.matrix(x)`: Coerces the `DataFrame` to a `matrix`, if possible.

## Subsetting

In the following code snippets, `x` is a `DataFrame`.

`x[i, j, drop]`: Behaves very similarly to the `data.frame` method, except `i` can be a logical `Rle` object and subsetting by `matrix` indices is not supported. Indices containing `NA`'s are also not supported.

`x[i, j] <- value`: Behaves very similarly to the `data.frame` method.

`x[[i]]`: Behaves very similarly to the `data.frame` method, except arguments `j` and `exact` are not supported. Column name matching is always exact. Subsetting by matrices is not supported.

`x[[i]] <- value`: Behaves very similarly to the `data.frame` method, except argument `j` is not supported.

## Author(s)

Michael Lawrence

## See Also

- [DataTable](#) and [SimpleList](#) which `DataFrame` extends directly.

## Examples

```
score <- c(1L, 3L, NA)
counts <- c(10L, 2L, NA)
row.names <- c("one", "two", "three")

df <- DataFrame(score) # single column
df[["score"]]
```

```
df <- DataFrame(score, row.names = row.names) #with row names
rownames(df)

df <- DataFrame(vals = score) # explicit naming
df[["vals"]]

# arrays
ary <- array(1:4, c(2,1,2))
sw <- DataFrame(I(ary))

# a data.frame
sw <- DataFrame(swiss)
as.data.frame(sw) # swiss, without row names
# now with row names
sw <- DataFrame(swiss, row.names = rownames(swiss))
as.data.frame(sw) # swiss

# subsetting

sw[] # identity subset
sw[,] # same

sw[NULL] # no columns
sw[,NULL] # no columns
sw[NULL,] # no rows

## select columns
sw[1:3]
sw[,1:3] # same as above
sw["Fertility"]
sw[,c(TRUE, FALSE, FALSE, FALSE, FALSE, FALSE)]

## select rows and columns
sw[4:5, 1:3]

sw[1] # one-column DataFrame
## the same
sw[, 1, drop = FALSE]
sw[, 1] # a (unnamed) vector
sw[[1]] # the same
sw[["Fertility"]]

sw[["Fert"]] # should return NULL

sw[1,] # a one-row DataFrame
sw[1,, drop=TRUE] # a list

## duplicate row, unique row names are created
sw[c(1, 1:2),]

## indexing by row names
sw["Courtelary",]
subsw <- sw[1:5,1:4]
```

```

subsw["C",] # partially matches

## row and column names
cn <- paste("X", seq_len(ncol(swiss)), sep = ".")
colnames(sw) <- cn
colnames(sw)
rn <- seq(nrow(sw))
rownames(sw) <- rn
rownames(sw)

## column replacement

df[["counts"]] <- counts
df[["counts"]]
df[[3]] <- score
df[["X"]]
df[[3]] <- NULL # deletion

```

---

 DataTable-class

*DataTable objects*


---

### Description

DataTable is an API only (i.e. virtual class with no slots) for accessing objects with a rectangular shape like [DataFrame](#) or [RangedData](#) objects. It mimics the API for standard [data.frame](#) objects.

### Accessors

In the following code snippets, `x` is a `DataTable`.

`nrow(x)`, `ncol(x)`: Get the number of rows and columns, respectively.

`NROW(x)`, `NCOL(x)`: Same as `nrow(x)` and `ncol(x)`, respectively.

`dim(x)`: Length two integer vector defined as `c(nrow(x), ncol(x))`.

`rownames(x)`, `colnames(x)`: Get the names of the rows and columns, respectively.

`dimnames(x)`: Length two list of character vectors defined as `list(rownames(x), colnames(x))`.

### Subsetting

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

`x[i, j, drop=TRUE]`: Return a new `DataTable` object made of the selected rows and columns. For single column selection, the `drop` argument specifies whether or not to coerce the returned sequence to a standard vector.

`head(x, n=6L)`: If `n` is non-negative, returns the first `n` rows of the `DataTable` object. If `n` is negative, returns all but the last `abs(n)` rows of the `DataTable` object.

`tail(x, n=6L)`: If `n` is non-negative, returns the last `n` rows of the `DataTable` object. If `n` is negative, returns all but the first `abs(n)` rows of the `DataTable` object.

`subset(x, subset, select, drop=FALSE)`: Return a new `DataTable` object using:

- subset** logical expression indicating rows to keep, where missing values are taken as `FALSE`.
- select** expression indicating columns to keep.
- drop** passed on to `[]` indexing operator.

`na.omit(object)`: Returns a subset with incomplete cases removed.

`na.exclude(object)`: Returns a subset with incomplete cases removed (but to be included with NAs in statistical results).

`is.na(x)`: Returns a logical matrix indicating which cells are missing.

`complete.cases(x)`: Returns a logical vector identifying which cases have no missing values.

### Combining

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

`cbind(...)`: Creates a new `DataTable` by combining the columns of the `DataTable` objects in  
....

`rbind(...)`: Creates a new `DataTable` by combining the rows of the `DataTable` objects in ....

`merge(x, y, ...)`: Merges two `DataTable` objects `x` and `y`, with arguments in ... being the same as those allowed by the base `merge`. It is allowed for either `x` or `y` to be a `data.frame`.

### Looping

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

`by(data, INDICES, FUN, ..., simplify = TRUE)`: Apply `FUN` to each group of data, a `DataTable`, formed by the factor (or list of factors) `INDICES`. Exactly the same contract as `as.data.frame`.

### Utilities

`duplicated(x)`: Returns a logical vector indicating the rows that are identical to a previous row.

`unique(x)`: Returns a new `DataTable` after removing the duplicated rows from `x`.

`show(x)`: By default the `show` method displays 5 head and 5 tail lines. The number of lines can be altered by setting the global options `showHeadLines` and `showTailLines`. If the object length is less than the sum of the options, the full object is displayed. These options affect `GRanges`, `GAlignments`, `Ranges`, `DataTable` and `XString` objects.

### Coercion

`as.env(x, enclos = parent.frame())`: Creates an environment from `x` with a symbol for each `colnames(x)`. The values are not actually copied into the environment. Rather, they are dynamically bound using `makeActiveBinding`. This prevents unnecessary copying of the data from the external vectors into R vectors. The values are cached, so that the data is not copied every time the symbol is accessed.

## Statistical modeling with DataTable

A number of wrappers are implemented for performing statistical procedures, such as model fitting, with DataTable objects.

### Tabulation:

```
xtabs(formula = ~., data, subset, na.action,          exclude = c(NA, NaN), drop.unused.levels = FALSE):
  Like the original xtabs, except data is a DataTable.
```

### See Also

- [DataFrame](#) for an implementation that mimics data.frame.
- [data.frame](#)

### Examples

```
showClass("DataTable") # shows (some of) the known subclasses

library(IRanges)
df <- DataFrame(as.data.frame(UCBAdmissions))
xtabs(Freq ~ Gender + Admit, df)
```

---

Hits-class

*Hits objects*

---

### Description

The Hits class stores a set of hits between 2 vector-like objects, one called the "query" and the other one the "subject".

For example, the [findOverlaps](#) function, defined and documented in the **IRanges** package, returns the hits between the query and subject arguments in a Hits object.

### Details

The `as.matrix` method coerces a Hits object to a two column matrix with one row for each hit, where the value in the first column is the index of an element in the query and the value in the second column is the index of an element in the subject.

The `as.table` method counts the number of hits for each query element and outputs the counts as a table.

To transpose a Hits `x`, so that the subject and query are interchanged, call `t(x)`. This allows, for example, counting the number of hits for each subject element using `as.table`.



**Coercion**

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

`as.matrix(x)`: Coerces `x` to a two column integer matrix, with each row representing a hit between a query index (first column) and subject index (second column).

`as.table(x)`: counts the number of hits for each query element in `x` and outputs the counts as a table.

`t(x)`: Interchange the query and subject in `x`, returns a transposed `Hits`.

**Subsetting**

`x[i]`: Subset the `Hits` object.

**Accessors**

`length(x)`: get the number of hits

`queryHits(x)`: Equivalent to `as.data.frame(x)[[1]]`.

`subjectHits(x)`: Equivalent to `as.data.frame(x)[[2]]`.

`queryLength(x)`, `nrow(x)`: get the number of elements in the query

`subjectLength(x)`, `ncol(x)`: get the number of elements in the subject

`countQueryHits(x)`: Counts the number of hits for each query, returning an integer vector.

`countSubjectHits(x)`: Counts the number of hits for each subject, returning an integer vector.

**Other operations**

`remapHits(x, query.map=NULL, new.queryLength=NA, subject.map=NULL, new.subjectLength=NA)`

Remaps the hits in `x` thru a "query map" and/or a "subject map" map. The query hits are remapped thru the "query map", which is specified via the `query.map` and `new.queryLength` arguments. The subject hits are remapped thru the "subject map", which is specified via the `subject.map` and `new.subjectLength` arguments.

The "query map" is conceptually a function (in the mathematical sense) and is also known as the "mapping function". It must be defined on the  $1..M$  interval and take values in the  $1..N$  interval, where  $N$  is `queryLength(x)` and  $M$  is the value specified by the user via the `new.queryLength` argument. Note that this mapping function doesn't need to be injective or surjective. Also it is not represented by an R function but by an integer vector of length  $M$  with no NAs. More precisely `query.map` can be `NULL` (identity map), or a vector of `queryLength(x)` non-NA integers that are  $\geq 1$  and  $\leq$  `new.queryLength`, or a factor of length `queryLength(x)` with no NAs (a factor is treated as an integer vector, and, if missing, `new.queryLength` is taken to be its number of levels). Note that a factor will typically be used to represent a mapping function that is not injective.

The same apply to the "subject map".

`remapHits` returns a `Hits` object where all the query and subject hits (accessed with `queryHits` and `subjectHits`, respectively) have been remapped thru the 2 specified maps. This remapping is actually only the 1st step of the transformation, and is followed by 2 additional steps: (2) the removal of duplicated hits, and (3) the reordering of the hits (first by query hits, then by subject hits). Note that if the 2 maps are injective then the remapping won't introduce

duplicated hits, so, in that case, step (2) is a no-op (but is still performed). Also if the "query map" is strictly ascending and the "subject map" ascending then the remapping will preserve the order of the hits, so, in that case, step (3) is also a no-op (but is still performed).

### Author(s)

Michael Lawrence

### See Also

- [findOverlaps](#) in the **IRanges** package, which generates an instance of this class.
- [Hits-examples](#) in the **IRanges** package, for some examples of Hits object basic manipulation.
- [setops-methods](#) in the **IRanges** package, for set operations on Hits objects.

### Examples

```
## See ?Hits-examples in the IRanges package for examples of basic
## manipulation of Hits objects.
```

---

isSorted

*Test if a vector-like object is sorted*

---

### Description

isSorted and isStrictlySorted test if a vector-like object is sorted or strictly sorted, respectively. isConstant tests if a vector-like or array-like object is constant. Currently only isConstant methods for vectors or arrays of type integer or double are implemented.

### Usage

```
isSorted(x)
isStrictlySorted(x)
isConstant(x)
```

### Arguments

x                    A vector-like object. Can also be an array-like object for isConstant.

### Details

Vector-like objects of length 0 or 1 are always considered to be sorted, strictly sorted, and constant. Strictly sorted and constant objects are particular cases of sorted objects. isStrictlySorted(x) is equivalent to isSorted(x) && !anyDuplicated(x)

### Value

A single logical i.e. TRUE, FALSE or NA.

**Author(s)**

H. Pages

**See Also**

- [is.unsorted](#).
- [duplicated](#) and [unique](#).
- [all.equal](#).
- [NA](#) and [is.finite](#).

**Examples**

```
## -----
## A. isSorted() and isStrictlySorted()
## -----

x <- 1:10

isSorted(x)          # TRUE
isSorted(-x)         # FALSE
isSorted(rev(x))     # FALSE
isSorted(-rev(x))    # TRUE

isStrictlySorted(x) # TRUE

x2 <- rep(x, each=2)
isSorted(x2)         # TRUE
isStrictlySorted(x2) # FALSE

## -----
## B. "isConstant" METHOD FOR integer VECTORS
## -----

## On a vector with no NAs:
stopifnot(isConstant(rep(-29L, 10000)))

## On a vector with NAs:
stopifnot(!isConstant(c(0L, NA, -29L)))
stopifnot(is.na(isConstant(c(-29L, -29L, NA))))

## On a vector of length <= 1:
stopifnot(isConstant(NA_integer_))

## -----
## C. "isConstant" METHOD FOR numeric VECTORS
## -----
## This method does its best to handle rounding errors and special
## values NA, NaN, Inf and -Inf in a way that "makes sense".
## Below we only illustrate handling of rounding errors.
```

```
## Here values in x are "conceptually" the same:
x <- c(11/3,
      2/3 + 4/3 + 5/3,
      50 + 11/3 - 50,
      7.00001 - 1000003/300000)
## However, due to machine rounding errors, they are not *strictly*
## equal:
duplicated(x)
unique(x)
## only *nearly* equal:
all.equal(x, rep(11/3, 4)) # TRUE

## isConstant(x) uses all.equal() internally to decide whether
## the values in x are all the same or not:
stopifnot(isConstant(x))

## This is not perfect though:
isConstant((x - 11/3) * 1e8) # FALSE on Intel Pentium paltforms
                             # (but this is highly machine dependent!)
```

---

List-class

*List objects*


---

## Description

List objects are [Vector](#) objects with a "[[" method, `elementType` and `elementLengths` method. The List class serves a similar role as `list` in base R.

It adds one slot, the `elementType` slot, to the two slots shared by all [Vector](#) objects.

The `elementType` slot is the preferred location for List subclasses to store the type of data represented in the sequence. It is designed to take a character of length 1 representing the class of the sequence elements. While the List class performs no validity checking based on `elementType`, if a subclass expects elements to be of a given type, that subclass is expected to perform the necessary validity checking. For example, the subclass [IntegerList](#) (defined in the **IRanges** package) has `elementType = "integer"` and its validity method checks if this condition is TRUE.

To be functional, a class that inherits from List must define at least a "[[" method (in addition to the minimum set of [Vector](#) methods).

## Construction

List objects are typically constructed using one of the 3 following methods:

- Use of a constructor function. Many constructor functions are provided for List objects e.g. `List`, [IntegerList](#), [RleList](#), [RangesList](#), [GRangesList](#), etc... Which one to use depends on the particular type of List object to construct. The name of a constructor function is always the name of a valid class. If it's the name of a *concrete* class (e.g. the [GRangesList](#) constructor defined in the **GenomicRanges** package), then the constructor function returns an instance of that class. If it's the name of a *virtual* class (e.g. the `List` constructor defined in this package, or the [IntegerList](#) or [RleList](#) or [RangesList](#) constructors defined in the

**IRanges** package), then the returned object belongs to a concrete subclass of that virtual class. Which subclass exactly depends on each constructor function (see man page of a particular constructor function for the details).

- Coercion to List or to a List subclass. Many coercion methods are provided to turn any object into a List object. One general and convenient way to convert any vector-like object into a List is to call `as(x, "List")`. This will typically yield an object from a subclass of [CompressedList](#).
- Use of [extractList](#). This function, defined in the **IRanges** package, extracts user-specified groups of elements from a vector-like object and returns them in a List (or sometimes list) object.

### Accessors

In the following code snippets, `x` is a List object.

`length(x)`: Get the number of list elements in `x`.

`names(x)`, `names(x) <- value`: Get or set the names of the elements in the List.

`mcols(x, use.names=FALSE)`, `mcols(x) <- value`: Get or set the metadata columns. See [Vector](#) man page for more information.

`elementType(x)`: Get the scalar string naming the class from which all elements must derive.

`elementLengths(x)`: Get the length (or nb of row for a matrix-like object) of each of the elements. Equivalent to `sapply(x, NROW)`.

`isEmpty(x)`: Returns a logical indicating either if the sequence has no elements or if all its elements are empty.

### Coercion

To List.

`as(x, "List")`: Converts a vector-like object into a List, usually a [CompressedList](#) derivative. One notable exception is when `x` is an ordinary list, in which case `as(x, "List")` returns a [SimpleList](#) derivative.

To explicitly request a [SimpleList](#) derivative, call `as(x, "SimpleList")`.

See [?CompressedList](#) (you might need to load the **IRanges** package first) and [?SimpleList](#) for more information about the [CompressedList](#) and [SimpleList](#) representations.

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

`as.list(x, ...)`, `as(from, "list")`: Turns `x` into an ordinary list.

`unlist(x, recursive=TRUE, use.names=TRUE)`: Concatenates the elements of `x` into a single vector-like object (of class `elementType(x)`).

`as.data.frame(x, row.names=NULL, optional=FALSE, value.name="value", use.outer.mcols=TRUE)`: Coerces a List to a data.frame. The result has the same length as unlisted `x` with two additional columns, `group` and `group_name`. `group` is an integer that indicates which list element the record came from. `group_name` holds the list name associated with each record; `value` is character by default and factor when `group_name.as.factor` is TRUE.

When `use.outer.mcols` is `TRUE` the metadata columns on the outer list elements of `x` are replicated out and included in the `data.frame`. List objects that unlist to a single vector (column) are given the column name 'value' by default. A custom name can be provided in `value.name`.

Splitting values in the resulting `data.frame` by the original groups in `x` should be done using the group column as the `f` argument to `splitAsList`. To relist data, use `x` as the skeleton argument to `relist`.

`as.env(x, enclos = parent.frame())`: Creates an environment from `x` with a symbol for each `names(x)`. The values are not actually copied into the environment. Rather, they are dynamically bound using `makeActiveBinding`. This prevents unnecessary copying of the data from the external vectors into R vectors. The values are cached, so that the data is not copied every time the symbol is accessed.

### Subsetting

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

`x[i]`: Return a new List object made of the list elements selected by subscript `i`. Subscript `i` can be of any type supported by subsetting of a Vector object (see [Vector](#) man page for the details), plus the following types: [IntegerList](#), [LogicalList](#), [CharacterList](#), [integer-RleList](#), [logical-RleList](#), [character-RleList](#), and [RangesList](#). Those additional types perform subsetting within the list elements rather than across them.

`x[i] <- value`: Replacement version of `x[i]`.

`x[[i]]`: Return the selected list element `i`, where `i` is a numeric or character vector of length 1.

`x[[i]] <- value`: Replacement version of `x[[i]]`.

`x$name, x$name <- value`: Similar to `x[[name]]` and `x[[name]] <- value`, but `name` is taken literally as an element name.

### Author(s)

P. Aboyoun and H. Pages

### See Also

- [List-utils](#) for common operations on List objects.
- [Vector](#) objects for the parent class.
- The [SimpleList](#) class for a direct extension of the List class.
- The [CompressedList](#) class defined in the **IRanges** package for another direct extension of the List class.
- The [IntegerList](#), [RleList](#), and [IRanges](#) classes and constructors defined in the **IRanges** package for more examples of concrete List subclasses.
- The [extractList](#) function defined in the **IRanges** package for grouping elements of a vector-like object into a list-like object.

### Examples

```
showClass("List") # shows (some of) the known subclasses
```

**Description**

Various functions and methods for looping on [List](#) objects, functional programming on [List](#) objects, and evaluation of an expression in a [List](#) object.

**Usage**

```
## Looping on List objects:
## -----

## S4 method for signature List
lapply(X, FUN, ...)

## S4 method for signature List
sapply(X, FUN, ..., simplify=TRUE, USE.NAMES=TRUE)

endoapply(X, FUN, ...)

mendoapply(FUN, ..., MoreArgs=NULL)

revElements(x, i)

## Functional programming methods for List objects:
## -----

## S4 method for signature List
Reduce(f, x, init, right=FALSE, accumulate=FALSE)
## S4 method for signature List
Filter(f, x)
## S4 method for signature List
Find(f, x, right=FALSE, nomatch=NULL)
## S4 method for signature List
Map(f, ...)
## S4 method for signature List
Position(f, x, right=FALSE, nomatch=NA_integer_)

## Evaluation of an expression in a List object:
## -----

## S4 method for signature List
within(data, expr, ...)
```

**Arguments**

X, x            A list, data.frame or [List](#) object.

FUN	The function to be applied to each element of X (for <code>endoapply</code> ) or for the elements in <code>...</code> (for <code>mendoapply</code> ).
<code>...</code>	For <code>lapply</code> , <code>sapply</code> , and <code>endoapply</code> , optional arguments to FUN. For <code>mendoapply</code> , a set of list, data.frame or <a href="#">List</a> objects to compute over. For <code>Map</code> , one or more <a href="#">List</a> objects. (FIXME: Mixing <a href="#">List</a> objects with ordinary lists doesn't seem to work properly at the moment.)
<code>simplify</code> , <code>USE.NAMES</code>	See <code>?base::sapply</code> for a description of these arguments.
<code>MoreArgs</code>	A list of other arguments to FUN.
<code>i</code>	Index specifying the elements to replace. Can be anything supported by <code>[&lt;-</code> .
<code>f</code> , <code>init</code> , <code>right</code> , <code>accumulate</code> , <code>nomatch</code>	See <code>?base::Reduce</code> for a description of these arguments.
<code>data</code>	A <a href="#">List</a> object.
<code>expr</code>	Expression to evaluate.

## Details

**Looping on List objects:** Like the standard `lapply` function defined in the `base` package, the `lapply` method for [List](#) objects returns a list of the same length as X, with each element being the result of applying FUN to the corresponding element of X.

Like the standard `sapply` function defined in the `base` package, the `sapply` method for [List](#) objects is a user-friendly version of `lapply` by default returning a vector or matrix if appropriate.

`endoapply` and `mendoapply` perform the endomorphic equivalents of `lapply` and `mapply` by returning objects of the same class as the inputs rather than a list.

`revElements` is a convenient way to do `x[i] <- endoapply(x[i], rev)`.

**Functional programming methods for List objects:** The R base package defines some higher-order functions that are commonly found in Functional Programming Languages. See `?base::Reduce` for the details, and, in particular, for a description of their arguments. The `S4Vectors` package provides methods for [List](#) objects, so, in addition to be an ordinary vector or list, the `x` argument can also be a [List](#) object.

**Evaluation of an expression in a List object:** `within` evaluates `expr` within `as.env(data)` via `eval(data)`. Similar to `with`, except assignments made during evaluation are taken as assignments into `data`, i.e., new symbols have their value appended to `data`, and assigning new values to existing symbols results in replacement.

## Value

`endoapply` returns an object of the same class as X, each element of which is the result of applying FUN to the corresponding element of X.

`mendoapply` returns an object of the same class as the first object specified in `...`, each element of which is the result of applying FUN to the corresponding elements of `...`.

See `?base::Reduce` for the value returned by the functional programming methods.

See `?base::within` for the value returned by `within`.



**Author(s)**

P. Aboyoun

**See Also**

- The [List](#) class.
- base: `:lapply` and base: `:mapply` for the default `lapply` and `mapply` methods.
- base: `:Reduce` for the default functional programming methods.
- base: `:within` for the default `within` method.

**Examples**

```
a <- data.frame(x = 1:10, y = rnorm(10))
b <- data.frame(x = 1:10, y = rnorm(10))

endoapply(a, function(x) (x - mean(x))/sd(x))
mendoapply(function(e1, e2) (e1 - mean(e1)) * (e2 - mean(e2)), a, b)

library(IRanges)
x <- IntegerList(a=1:3, b=16:11, c=22:21, d=31:36)
x

Reduce("+", x)

Filter(is.unsorted, x)

pos1 <- Position(is.unsorted, x)
stopifnot(identical(Find(is.unsorted, x), x[[pos1]]))

pos2 <- Position(is.unsorted, x, right=TRUE)
stopifnot(identical(Find(is.unsorted, x, right=TRUE), x[[pos2]]))

y <- x * 1000L
Map("c", x, y)
```

---

**Rle-class***Rle objects*

---

**Description**

The `Rle` class is a general container for storing an atomic vector that is stored in a run-length encoding format. It is based on the `rle` function from the base package.

## Constructors

`Rle(values)`: This constructor creates an Rle instances out of an atomic vector `values`.

`Rle(values, lengths)`: This constructor creates an Rle instances out of an atomic vector or factor object `values` and an integer or numeric vector `lengths` with all positive elements that represent how many times each value is repeated. The length of these two vectors must be the same.

`as(from, "Rle")`: This constructor creates an Rle instances out of an atomic vector `from`.

## Accessors

In the code snippets below, `x` is an Rle object:

`runLength(x)`: Returns the run lengths for `x`.

`runValue(x)`: Returns the run values for `x`.

`nrun(x)`: Returns the number of runs in `x`.

`start(x)`: Returns the starts of the runs for `x`.

`end(x)`: Returns the ends of the runs for `x`.

`width(x)`: Same as `runLength(x)`.

## Replacers

In the code snippets below, `x` is an Rle object:

`runLength(x) <- value`: Replaces `x` with a new Rle object using run values `runValue(x)` and run lengths `value`.

`runValue(x) <- value`: Replaces `x` with a new Rle object using run values `value` and run lengths `runLength(x)`.

## Coercion

In the code snippets below, `x` and `from` are Rle objects:

`as.vector(x, mode="any"), as(from, "vector")`: Creates an atomic vector based on the values contained in `x`. The vector will be coerced to the requested mode, unless mode is "any", in which case the most appropriate type is chosen.

`as.vectorORfactor(x)`: Creates an atomic vector or factor, based on the type of values contained in `x`. This is the most general way to decompress the Rle to a native R data structure.

`as.logical(x), as(from, "logical")`: Creates a logical vector based on the values contained in `x`.

`as.integer(x), as(from, "integer")`: Creates an integer vector based on the values contained in `x`.

`as.numeric(x), as(from, "numeric")`: Creates a numeric vector based on the values contained in `x`.

`as.complex(x), as(from, "complex")`: Creates a complex vector based on the values contained in `x`.

`as.character(x)`, `as(from, "character")`: Creates a character vector based on the values contained in `x`.

`as.raw(x)`, `as(from, "raw")`: Creates a raw vector based on the values contained in `x`.

`as.factor(x)`, `as(from, "factor")`: Creates a factor object based on the values contained in `x`.

`as.data.frame(x)`, `as(from, "data.frame")`: Creates a `data.frame` with a single column holding the result of `as.vector(x)`.

## General Methods

In the code snippets below, `x` is an Rle object:

`x[i, drop=getOption("dropRle", default=FALSE)]`: Subsets `x` by index `i`, where `i` can be positive integers, negative integers, a logical vector of the same length as `x`, an Rle object of the same length as `x` containing logical values, or an [IRanges](#) object. When `drop=FALSE` returns an Rle object. When `drop=TRUE`, returns an atomic vector.

`x[i] <- value`: Replaces elements in `x` specified by `i` with corresponding elements in `value`. Supports the same types for `i` as `x[i]`.

`x %in% table`: Returns a logical Rle representing set membership in `table`.

`append(x, values, after = length(x))`: Insert one Rle into another Rle.  
`values` the Rle to insert.  
`after` the subscript in `x` after which the values are to be inserted.

`c(x, ...)`: Combines a set of Rle objects.

`findRun(x, vec)`: Returns an integer vector indicating the run indices in Rle `vec` that are referenced by the indices in the integer vector `x`.

`head(x, n = 6L)`: If `n` is non-negative, returns the first `n` elements of `x`. If `n` is negative, returns all but the last `abs(n)` elements of `x`.

`is.na(x)`: Returns a logical Rle indicating with values are NA.

`is.unsorted(x, na.rm = FALSE, strictly = FALSE)`: Returns a logical value specifying if `x` is unsorted.  
`na.rm` remove missing values from check.  
`strictly` check for `_strictly_` increasing values.

`length(x)`: Returns the underlying vector length of `x`.

`match(x, table, nomatch = NA_integer_, incomparables = NULL)`: Matches the values in `x` to `table`:  
`table` the values to be matched against.  
`nomatch` the value to be returned in the case when no match is found.  
`incomparables` a vector of values that cannot be matched. Any value in `x` matching a value in this vector is assigned the `nomatch` value.

`rep(x, times, length.out, each), rep.int(x, times)`: Repeats the values in `x` through one of the following conventions:  
`times` Vector giving the number of times to repeat each element if of length `length(x)`, or to repeat the whole vector if of length 1.  
`length.out` Non-negative integer. The desired length of the output vector.

each Non-negative integer. Each element of `x` is repeated each times.

`rev(x)`: Reverses the order of the values in `x`.

`shiftApply(SHIFT, X, Y, FUN, ..., OFFSET = 0L, simplify = TRUE, verbose = FALSE)`:  
Let `i` be the indices in `SHIFT`, `X_i = window(X, 1 + OFFSET, length(X) - SHIFT[i])`,  
and `Y_i = window(Y, 1 + SHIFT[i], length(Y) - OFFSET)`. Calculates the set of  
`FUN(X_i, Y_i, ...)` values and return the results in a convenient form:

`SHIFT` A non-negative integer vector of shift values.

`X, Y` The Rle objects to shift.

`FUN` The function, found via `match.fun`, to be applied to each set of shifted vectors.

`...` Further arguments for `FUN`.

**OFFSET** A non-negative integer offset to maintain throughout the shift operations.

`simplify` A logical value specifying whether or not the result should be simplified to a vector  
or matrix if possible.

`verbose` A logical value specifying whether or not to print the `i` indices to track the iterations.

`show(object)`: Prints out the Rle object in a user-friendly way.

`order(..., na.last = TRUE, decreasing = FALSE)`: Returns a permutation which rearranges  
its first argument into ascending or descending order, breaking ties by further arguments. See  
[order](#).

`sort(x, decreasing = FALSE, na.last = NA)`: Sorts the values in `x`.

`decreasing` If `TRUE`, sort values in decreasing order. If `FALSE`, sort values in increasing order.

`na.last` If `TRUE`, missing values are placed last. If `FALSE`, they are placed first. If `NA`, they  
are removed.

`subset(x, subset)`: Returns a new Rle object made of the subset using logical vector `subset`.

`table(...)`: Returns a table containing the counts of the unique values. Supported arguments  
include `useNA` with values of 'no' and 'ifany'. Multiple Rle's must be combined with `c()`  
before calling `table`.

`tail(x, n = 6L)`: If `n` is non-negative, returns the last `n` elements of `x`. If `n` is negative, returns  
all but the first `abs(n)` elements of `x`.

`unique(x, incomparables = FALSE, ...)`: Returns the unique run values. The `incomparables`  
argument takes a vector of values that cannot be compared with `FALSE` being a special value  
that means that all values can be compared.

## Set Operations

In the code snippets below, `x` and `y` are Rle object or some other vector-like object:

`setdiff(x, y)`: Returns the unique elements in `x` that are not in `y`.

`union(x, y)`: Returns the unique elements in either `x` or `y`.

`intersect(x, y)`: Returns the unique elements in both `x` and `y`.

## Author(s)

P. Aboyoun

**See Also**

[Rle-utils](#) and [Rle-runstat](#) for more operations on Rle objects.

[rle](#)

[Vector-class](#)

**Examples**

```
x <- Rle(10:1, 1:10)
x

runLength(x)
runValue(x)
nrun(x)

diff(x)
unique(x)
sort(x)
x[c(1,3,5,7,9)]
x > 4

x2 <- Rle(LETTERS[c(21:26, 25:26)], 8:1)
table(x2)

y <- Rle(c(TRUE, TRUE, FALSE, FALSE, TRUE, FALSE, TRUE, TRUE, TRUE))
y
as.vector(y)
rep(y, 10)
c(y, x > 5)
```

---

Rle-runstat

*Fixed-width running window summaries*


---

**Description**

The `runsum`, `runmean`, `runmed`, `runwtsum`, `runq` functions calculate the sum, mean, median, weighted sum, and order statistic for fixed width running windows.

**Usage**

```
runsum(x, k, endrule = c("drop", "constant"), ...)

runmean(x, k, endrule = c("drop", "constant"), ...)

## S4 method for signature Rle
smoothEnds(y, k = 3)

## S4 method for signature Rle
runmed(x, k, endrule = c("median", "keep", "drop", "constant"),
```

```

algorithm = NULL, print.level = 0)

runwtsum(x, k, wt, endrule = c("drop", "constant"), ...)

runq(x, k, i, endrule = c("drop", "constant"), ...)

```

### Arguments

x	The data object.
k	An integer indicating the fixed width of the running window. Must be odd when <code>endrule != "drop"</code> .
endrule	A character string indicating how the values at the beginning and the end (of the data) should be treated. "median" see <a href="#">runmed</a> ; "keep" see <a href="#">runmed</a> ; "drop" do not extend the running statistics to be the same length as the underlying vectors; "constant" copies running statistic to the first values and analogously for the last ones making the smoothed ends <i>constant</i> .
wt	A numeric vector of length k that provides the weights to use.
i	An integer in [0, k] indicating which order statistic to calculate.
...	Additional arguments passed to methods. Specifically, <code>na.rm</code> . When <code>na.rm = TRUE</code> , the NA and NaN values are removed. When <code>na.rm = FALSE</code> , NA is returned if either NA or NaN are in the specified window.

### Details

The `runsum`, `runmean`, `runmed`, `runwtsum`, and `runq` functions provide efficient methods for calculating the specified numeric summary by performing the looping in compiled code.

### Value

An object of the same class as `x`.

### Author(s)

P. Aboyoun and V. Obenchain

### See Also

[runmed](#), [Rle-class](#), [RleList-class](#)

### Examples

```

x <- Rle(1:10, 1:10)
runsum(x, k = 3)
runsum(x, k = 3, endrule = "constant")
runmean(x, k = 3)

```

```

runwtsum(x, k = 3, wt = c(0.25, 0.5, 0.25))
runq(x, k = 5, i = 3, endrule = "constant")

## Missing and non-finite values
x <- Rle(c(1, 2, NA, 0, 3, Inf, 4, NaN))
runsum(x, k = 2)
runsum(x, k = 2, na.rm = TRUE)
runmean(x, k = 2, na.rm = TRUE)
runwtsum(x, k = 2, wt = c(0.25, 0.5), na.rm = TRUE)
runq(x, k = 2, i = 2, na.rm = TRUE) ## max value in window

## The .naive_runsum() function demonstrates the semantics of
## runsum(). This test ensures the behavior is consistent with
## base::sum().

.naive_runsum <- function(x, k, na.rm=FALSE)
  sapply(0:(length(x)-k),
        function(offset) sum(x[1:k + offset], na.rm=na.rm))

x0 <- c(1, Inf, 3, 4, 5, NA)
x <- Rle(x0)
target1 <- .naive_runsum(x0, 3, na.rm = TRUE)
target2 <- runsum(x, 3, na.rm = TRUE)
stopifnot(target1 == target2)
current <- as.vector(runsum(x, 3, na.rm = TRUE))
stopifnot(target1 == current)

## runmean() and runwtsum() :
x <- Rle(c(2, 1, NA, 0, 1, -Inf))
runmean(x, k = 3)
runmean(x, k = 3, na.rm = TRUE)
runwtsum(x, k = 3, wt = c(0.25, 0.50, 0.25))
runwtsum(x, k = 3, wt = c(0.25, 0.50, 0.25), na.rm = TRUE)

## runq() :
runq(x, k = 3, i = 1, na.rm = TRUE) ## smallest value in window
runq(x, k = 3, i = 3, na.rm = TRUE) ## largest value in window

## When na.rm = TRUE, it is possible the number of non-NA
## values in the window will be less than the i specified.
## Here we request the 4th smallest value in the window,
## which translates to the value at the 4/5 (0.8) percentile.
x <- Rle(c(1, 2, 3, 4, 5))
runq(x, k=length(x), i=4, na.rm=TRUE)

## The same request on a Rle with two missing values
## finds the value at the 0.8 percentile of the vector
## at the new length of 3 after the NAs have been removed.
## This translates to round((0.8) * 3).
x <- Rle(c(1, 2, 3, NA, NA))
runq(x, k=length(x), i=4, na.rm=TRUE)

```

**Description**

Common operations on [Rle](#) objects.

**Group Generics**

Rle objects have support for S4 group generic functionality:

Arith "+", "-", "\*", "^", "%%", "%/%", "/"

Compare "==", ">", "<", "!=", "<=", ">="

Logic "&", "|"

Ops "Arith", "Compare", "Logic"

Math "abs", "sign", "sqrt", "ceiling", "floor", "trunc", "cummax", "cummin", "cumprod",  
"cumsum", "log", "log10", "log2", "log1p", "acos", "acosh", "asin", "asinh", "atan",  
"atanh", "exp", "expm1", "cos", "cosh", "sin", "sinh", "tan", "tanh", "gamma", "lgamma",  
"digamma", "trigamma"

Math2 "round", "signif"

Summary "max", "min", "range", "prod", "sum", "any", "all"

Complex "Arg", "Conj", "Im", "Mod", "Re"

See [S4groupGeneric](#) for more details.

**General Methods**

In the code snippets below, `x` is an Rle object:

`aggregate(x, by, FUN, start = NULL, end = NULL, width = NULL, frequency = NULL, delta = NULL)`

Generates summaries on the specified windows and returns the result in a convenient form:

`by` An object with `start`, `end`, and `width` methods.

`FUN` The function, found via `match.fun`, to be applied to each window of `x`.

`start`, `end`, `width` the start, end, or width of the window. If `by` is missing, then must supply two of the three.

`frequency`, `delta` Optional arguments that specify the sampling frequency and increment within the window.

... Further arguments for `FUN`.

`simplify` A logical value specifying whether or not the result should be simplified to a vector or matrix if possible.

`summary(object, ..., digits = max(3, getOption("digits") - 3))`: Summarizes the Rle object using an atomic vector convention. The `digits` argument is used for number formatting with `signif()`.



### Logical Data Methods

In the code snippets below, `x` is an Rle object:

`!x`: Returns logical negation (NOT) of `x`.

`which(x)`: Returns an integer vector representing the TRUE indices of `x`.

`ifelse(x, yes, no)`: For each element of `x`, returns the corresponding element in `yes` if TRUE, otherwise the element in `no`. `yes` and `no` may be Rle objects or anything else coercible to a vector.

### Numerical Data Methods

In the code snippets below, `x` is an Rle object:

`diff(x, lag = 1, differences = 1)`: Returns suitably lagged and iterated differences of `x`.

`lag` An integer indicating which lag to use.

`differences` An integer indicating the order of the difference.

`pmax(..., na.rm = FALSE), pmax.int(..., na.rm = FALSE)`: Parallel maxima of the Rle input values. Removes NAs when `na.rm = TRUE`.

`pmin(..., na.rm = FALSE), pmin.int(..., na.rm = FALSE)`: Parallel minima of the Rle input values. Removes NAs when `na.rm = TRUE`.

`which.max(x)`: Returns the index of the first element matching the maximum value of `x`.

`mean(x, na.rm = FALSE)`: Calculates the mean of `x`. Removes NAs when `na.rm = TRUE`.

`var(x, y = NULL, na.rm = FALSE)`: Calculates the variance of `x` or covariance of `x` and `y` if both are supplied. Removes NAs when `na.rm = TRUE`.

`cov(x, y, use = "everything"), cor(x, y, use = "everything")`: Calculates the covariance and correlation respectively of Rle objects `x` and `y`. The `use` argument is an optional character string giving a method for computing covariances in the presence of missing values. This must be (an abbreviation of) one of the strings "everything", "all.obs", "complete.obs", "na.or.complete", or "pairwise.complete.obs".

`sd(x, na.rm = FALSE)`: Calculates the standard deviation of `x`. Removes NAs when `na.rm = TRUE`.

`median(x, na.rm = FALSE)`: Calculates the median of `x`. Removes NAs when `na.rm = TRUE`.

`quantile(x, probs = seq(0, 1, 0.25), na.rm = FALSE, names = TRUE, type = 7, ...)`: Calculates the specified quantiles of `x`.

`probs` A numeric vector of probabilities with values in [0,1].

`na.rm` If TRUE, removes NAs from `x` before the quantiles are computed.

`names` If TRUE, the result has names describing the quantiles.

`type` An integer between 1 and 9 selecting one of the nine quantile algorithms detailed in [quantile](#).

`...` Further arguments passed to or from other methods.

`mad(x, center = median(x), constant = 1.4826, na.rm = FALSE, low = FALSE, high = FALSE)`: Calculates the median absolute deviation of `x`.

`center` The center to calculate the deviation from.

`constant` The scale factor.

`na.rm` If TRUE, removes NAs from `x` before the `mad` is computed.

`low` If TRUE, compute the 'lo-median'.

`high` If TRUE, compute the 'hi-median'.

`IQR(x, na.rm = FALSE)`: Calculates the interquartile range of `x`.

`na.rm` If TRUE, removes NAs from `x` before the `IQR` is computed.

`smoothEnds(y, k = 3)`: Smooth end points of an `Rle` `y` using subsequently smaller medians and Tukey's end point rule at the very end.

`k` An integer indicating the width of largest median window; must be odd.

### Character Data Methods

In the code snippets below, `x` is an `Rle` object:

`nchar(x, type = "chars", allowNA = FALSE)`: Returns an integer `Rle` representing the number of characters in the corresponding values of `x`.

`type` One of `c("bytes", "chars", "width")`.

`allowNA` Should NA be returned for invalid multibyte strings rather than throwing an error?

`substr(x, start, stop)`, `substring(text, first, last = 1000000L)`: Returns a character or factor `Rle` containing the specified substrings beginning at `start/first` and ending at `stop/last`.

`chartr(old, new, x)`: Returns a character or factor `Rle` containing a translated version of `x`.

`old` A character string specifying the characters to be translated.

`new` A character string specifying the translations.

`tolower(x)`: Returns a character or factor `Rle` containing a lower case version of `x`.

`toupper(x)`: Returns a character or factor `Rle` containing an upper case version of `x`.

`sub(pattern, replacement, x, ignore.case = FALSE, perl = FALSE, fixed = FALSE, useBytes = FALSE)`: Returns a character or factor `Rle` containing replacements based on matches determined by regular expression matching. See [sub](#) for a description of the arguments.

`gsub(pattern, replacement, x, ignore.case = FALSE, perl = FALSE, fixed = FALSE, useBytes = FALSE)`: Returns a character or factor `Rle` containing replacements based on matches determined by regular expression matching. See [gsub](#) for a description of the arguments.

`paste(..., sep = " ", collapse = NULL)`: Returns a character or factor `Rle` containing a concatenation of the values in `...`

### Factor Data Methods

In the code snippets below, `x` is an `Rle` object:

`levels(x)`, `levels(x) <- value`: Gets and sets the factor levels, respectively.

`nlevels(x)`: Returns the number of factor levels.

### Author(s)

P. Abouyou

**See Also**[Rle](#) objects[S4groupGeneric](#)**Examples**

```
x <- Rle(10:1, 1:10)
x

sqrt(x)
x^2 + 2 * x + 1
range(x)
sum(x)
mean(x)
aggregate(x, x > 4, mean)
aggregate(x, FUN = mean, start = 1:(length(x) - 50), end = 51:length(x))

z <- c("the", "quick", "red", "fox", "jumps", "over", "the", "lazy", "brown", "dog")
z <- Rle(z, seq_len(length(z)))
chartr("a", "@", z)
toupper(z)
```

---

[SimpleList-class](#)[SimpleList objects](#)

---

**Description**

The (non-virtual) SimpleList class extends the [List](#) virtual class.

**Details**

The SimpleList class is the simplest, most generic concrete implementation of the [List](#) abstraction. It provides an implementation that subclasses can easily extend.

In a SimpleList object the list elements are stored internally in an ordinary list.

**Constructor**

See the [List](#) man page for a quick overview of how to construct [List](#) objects in general.

The following constructor is provided for SimpleList objects:

`SimpleList(...)`: Takes possibly named objects as elements for the new SimpleList object.

**Accessors**

Same as for [List](#) objects. See the [List](#) man page for more information.

**Coercion**

All the coercions documented in the [List](#) man page apply to [SimpleList](#) objects.

**Subsetting**

Same as for [List](#) objects. See the [List](#) man page for more information.

**Looping and functional programming**

Same as for [List](#) objects. See [?List-utils](#) for more information.

**Displaying**

When a [SimpleList](#) object is displayed, the "Simple" prefix is removed from the real class name of the object. See [classNameForDisplay](#) for more information about this.

**See Also**

- [List](#) objects for the parent class.
- The [CompressedList](#) class defined in the **IRanges** package for a more efficient alternative to [SimpleList](#).
- The [SimpleIntegerList](#) class defined in the **IRanges** package for a [SimpleList](#) subclass example.
- The [DataFrame](#) class for another [SimpleList](#) subclass example.

**Examples**

```
## Displaying a SimpleList object:
x1 <- SimpleList(a=letters, i=Rle(22:20, 4:2))
class(x1)

## The "Simple" prefix is removed from the real class name of the
## object:
x1

library(IRanges)
x2 <- IntegerList(11:12, integer(0), 3:-2, compress=FALSE)
class(x2)

## The "Simple" prefix is removed from the real class name of the
## object:
x2

## This is controlled by internal helper classNameForDisplay():
classNameForDisplay(x2)
```

---

str-utils

*Some utility functions to operate on strings*


---

## Description

Some low-level string utilities that operate on ordinary character vectors. For more advanced string manipulations, see the **Biostrings** package.

## Usage

```
unstrsplit(x, sep="") # sep default is "" (empty string)
```

```
strsplitAsListOfIntegerVectors(x, sep=",") # sep default is ","
```

## Arguments

x	For <code>unstrsplit</code> : A list-like object where each list element is a character vector, or a character vector (identity). For <code>strsplitAsListOfIntegerVectors</code> : A character vector where each element is a string containing comma-separated decimal integer values.
sep	A single string containing the separator character. For <code>strsplitAsListOfIntegerVectors</code> , the separator must be a single-byte character.

## Details

**unstrsplit:** `unstrsplit(x, sep)` is equivalent to (but much faster than) `sapply(x, paste0, collapse=sep)`. It's performing the reverse transformation of `strsplit( , fixed=TRUE)`, that is, if `x` is a character vector with no NAs and `sep` a single string, then `unstrsplit(strsplit(x, split=sep, fixed=TRUE), sep)` is identical to `x`. A notable exception to this though is when `strsplit` finds a match at the end of a string, in which case the last element of the output (which should normally be an empty string) is not returned (see `?strsplit` for the details).

**strsplitAsListOfIntegerVectors:** `strsplitAsListOfIntegerVectors` is similar to the `strsplitAsListOfIntegerVect` function shown in the Examples section below, except that the former generally raises an error where the latter would have inserted an NA in the returned object. More precisely:

- The latter accepts NAs in the input, the former doesn't (raises an error).
- The latter introduces NAs by coercion (with a warning), the former doesn't (raises an error).
- The latter supports "inaccurate integer conversion in coercion" when the value to coerce is `> INT_MAX` (then it's coerced to `INT_MAX`), the former doesn't (raises an error).
- The latter coerces non-integer values (e.g. 10.3) to an int by truncating them, the former doesn't (raises an error).

When it fails, `strsplitAsListOfIntegerVectors` will print an informative error message. Finally, `strsplitAsListOfIntegerVectors` is faster and uses much less memory than `strsplitAsListOfIntegerVectors`

**Value**

`unstrsplit` returns a character vector with one string per list element in `x`.

`strsplitAsListOfIntegerVectors` returns a list where each list element is an integer vector. There is one list element per string in `x`.

**Author(s)**

H. Pages

**See Also**

- The `strsplit` function in the **base** package.

**Examples**

```
## -----
## unstrsplit()
## -----
x <- list(A=c("abc", "XY"), B=NULL, C=letters[1:4])
unstrsplit(x)
unstrsplit(x, sep=",")
unstrsplit(x, sep=" => ")

data(islands)
x <- names(islands)
y <- strsplit(x, split=" ", fixed=TRUE)
x2 <- unstrsplit(y, sep=" ")
stopifnot(identical(x, x2))

## But...
names(x) <- x
y <- strsplit(x, split="in", fixed=TRUE)
x2 <- unstrsplit(y, sep="in")
y[x != x2]
## In other words: strsplit() behavior sucks :-/

## -----
## strsplitAsListOfIntegerVectors()
## -----
x <- c("1116,0,-19",
      " +55291 , 2476,",
      "19184,4269,5659,6470,6721,7469,14601",
      "7778889, 426900, -4833,5659,6470,6721,7096",
      "19184 , -99999")

y <- strsplitAsListOfIntegerVectors(x)
y

## In normal situations (i.e. when the input is well-formed),
## strsplitAsListOfIntegerVectors() does actually the same as the
## function below but is more efficient (both in speed and memory
```

```
## footprint):
strsplitAsListOfIntegerVectors2 <- function(x, sep=",")
{
  tmp <- strsplit(x, sep, fixed=TRUE)
  lapply(tmp, as.integer)
}
y2 <- strsplitAsListOfIntegerVectors2(x)
stopifnot(identical(y, y2))
```

---

Vector-class

*Vector objects*


---

## Description

The Vector virtual class serves as the heart of the S4Vectors package and has over 90 subclasses. It serves a similar role as [vector](#) in base R.

The Vector class supports the storage of *global* and *element-wise* metadata:

1. The *global* metadata annotates the object as a whole: this metadata is accessed via the metadata accessor and is represented as an ordinary list;
2. The *element-wise* metadata annotates individual elements of the object: this metadata is accessed via the `mcols` accessor (`mcols` stands for *metadata columns*) and is represented as a [DataTable](#) object (i.e. as an instance of a concrete subclass of [DataTable](#), e.g. a [DataFrame](#) object), with a row for each element and a column for each metadata variable. Note that the element-wise metadata can also be NULL.

To be functional, a class that inherits from Vector must define at least a length and a "[ " method.

## Accessors

In the following code snippets, `x` is a Vector object.

`length(x)`: Get the number of elements in `x`.

`NROW(x)`: Defined as `length(x)` for any Vector object that is *not* a [DataTable](#) object. If `x` is a [DataTable](#) object, then it's defined as `nrow(x)`.

`names(x)`, `names(x) <- value`: Get or set the names of the elements in the Vector.

`rename(x, value, ...)`: Replace the names of `x` according to a mapping defined by a named character vector, formed by concatenating `value` with any arguments in `...`. The names of the character vector indicate the source names, and the corresponding values the destination names. This also works on a plain old vector.

`nlevels(x)`: Returns the number of factor levels.

`mcols(x, use.names=FALSE)`, `mcols(x) <- value`: Get or set the metadata columns. If `use.names=TRUE` and the metadata columns are not NULL, then the names of `x` are propagated as the row names of the returned [DataTable](#) object. When setting the metadata columns, the supplied value must be NULL or a [DataTable](#) object holding element-wise metadata.

`elementMetadata(x, use.names=FALSE)`, `elementMetadata(x) <- value`, `values(x, use.names=FALSE)`, `values(x) <- value`: Alternatives to `mcols` functions. Their use is discouraged.

### Coercion

`as(from, "data.frame")`, `as.data.frame(from)`: Coerces `from`, a Vector, to a `data.frame` by first coercing the Vector to a vector via `as.vector`. Note that many Vector derivatives do not support `as.vector`, so this coercion is possible only for certain types.

`as.env(x)`: Constructs an environment object containing the elements of `mcols(x)`.

### Subsetting

In the code snippets below, `x` is a Vector object or regular R vector object. The R vector object methods for `window` are defined in this package and the remaining methods are defined in base R.

`x[i, drop=TRUE]`: If defined, returns a new Vector object made of selected elements `i`, which can be missing; an NA-free logical, numeric, or character vector; or a logical Rle object. The `drop` argument specifies whether or not to coerce the returned sequence to an ordinary vector.

`x[i] <- value`: Replacement version of `x[i]`.

### Combining

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

`c(x, ...)`: Combine `x` and the Vector objects in `...` together. Any object in `...` must belong to the same class as `x`, or to one of its subclasses, or must be `NULL`. The result is an object of the same class as `x`.

`append(x, values, after = length(x))`: Insert the Vector `values` onto `x` at the position given by `after`. `values` must have an `elementType` that extends that of `x`.

### Displaying

FOR ADVANCED USERS OR DEVELOPERS Displaying of a Vector object is controlled by 2 internal helpers, `classNameForDisplay` and `showAsCell`.

For most objects `classNameForDisplay(x)` just returns `class(x)`. However, for some objects it can return the name of a parent class that is more suitable for display because it's simpler and as informative as the real class name. See [SimpleList](#) objects (defined in this package) and [CompressedList](#) objects (defined in the **IRanges** package) for examples of objects for which `classNameForDisplay` returns the name of a parent class.

`showAsCell(x)` produces a character vector *parallel* to `x` (i.e. with one string per vector element in `x`) that contains compact string representations of each elements in `x`.

Note that `classNameForDisplay` and `showAsCell` are generic functions so developers can implement methods to control how their own Vector extension gets displayed.

### See Also

- [Rle](#), [IRanges](#) and [XRaw](#) for example implementations.
- [Vector-comparison](#) for comparing, ordering, and tabulating vector-like objects.
- [List](#) for a direct Vector extension that serves a similar role as [list](#) in base R.
- [extractList](#) for grouping elements of a vector-like object into a list-like object.
- [DataTable](#) which is the type of objects returned by the `mcols` accessor.
- The [Annotated](#) class, which Vector extends.



**Examples**

```
showClass("Vector") # shows (some of) the known subclasses
```

---

Vector-comparison      *Compare, order, tabulate vector-like objects*

---

**Description**

Generic functions and methods for comparing, ordering, and tabulating vector-like objects.

**Usage**

```
## Element-wise (aka "parallel") comparison of 2 Vector objects
## -----

compare(x, y)

## S4 method for signature Vector,Vector
e1 == e2
## S4 method for signature Vector,ANY
e1 == e2
## S4 method for signature ANY,Vector
e1 == e2

## S4 method for signature Vector,Vector
e1 <= e2
## S4 method for signature Vector,ANY
e1 <= e2
## S4 method for signature ANY,Vector
e1 <= e2

## S4 method for signature Vector,Vector
e1 != e2
## S4 method for signature Vector,ANY
e1 != e2
## S4 method for signature ANY,Vector
e1 != e2

## S4 method for signature Vector,Vector
e1 >= e2
## S4 method for signature Vector,ANY
e1 >= e2
## S4 method for signature ANY,Vector
e1 >= e2

## S4 method for signature Vector,Vector
```

```
e1 < e2
## S4 method for signature Vector,ANY
e1 < e2
## S4 method for signature ANY,Vector
e1 < e2

## S4 method for signature Vector,Vector
e1 > e2
## S4 method for signature Vector,ANY
e1 > e2
## S4 method for signature ANY,Vector
e1 > e2

## selfmatch()
## -----

selfmatch(x, ...)

## duplicated() & unique()
## -----

## S4 method for signature Vector
duplicated(x, incomparables=FALSE, ...)

## S4 method for signature Vector
unique(x, incomparables=FALSE, ...)

## %in%
## ----

## S4 method for signature Vector,Vector
x %in% table
## S4 method for signature Vector,ANY
x %in% table
## S4 method for signature ANY,Vector
x %in% table

## findMatches() & countMatches()
## -----

findMatches(x, table, select=c("all", "first", "last"), ...)
countMatches(x, table, ...)

## sort()
## -----

## S4 method for signature Vector
sort(x, decreasing=FALSE, ...)
```

```
## table()
## -----

## S4 method for signature Vector
table(...)
```

### Arguments

`x`, `y`, `e1`, `e2`, `table`  
 Vector-like objects.

`incomparables` The duplicated method for `Vector` objects does NOT support this argument. The unique method for `Vector` objects, which is implemented on top of duplicated, propagates this argument to its call to duplicated. See `?base::duplicated` and `?base::unique` for more information about this argument.

`select` Only `select="all"` is supported at the moment. Note that you can use `match` if you want to do `select="first"`. Otherwise you're welcome to request this on the Bioconductor mailing list.

`decreasing` See `?base::sort`.

`...` A `Vector` object for `table` (the `table` method for `Vector` objects can only take one input object).  
 Otherwise, extra arguments supported by specific methods. In particular:

- The default `selfmatch` method, which is implemented on top of `match`, propagates the extra arguments to its call to `match`.
- The duplicated method for `Vector` objects, which is implemented on top of `selfmatch`, accepts extra argument `fromLast` and propagates the other extra arguments to its call to `selfmatch`. See `?base::duplicated` for more information about this argument.
- The unique method for `Vector` objects, which is implemented on top of `duplicated`, propagates the extra arguments to its call to `duplicated`.
- The default `findMatches` and `countMatches` methods, which are implemented on top of `match` and `selfmatch`, propagate the extra arguments to their calls to `match` and `selfmatch`.
- The `sort` method for `Vector` objects, which is implemented on top of `order`, only accepts extra argument `na.last` and propagates it to its call to `order`.

### Details

Doing `compare(x, y)` on 2 vector-like objects `x` and `y` of length 1 must return an integer less than, equal to, or greater than zero if the single element in `x` is considered to be respectively less than, equal to, or greater than the single element in `y`. If `x` or `y` have a length  $\neq 1$ , then they are typically expected to have the same length so `compare(x, y)` can operate element-wise, that is, in that case it returns an integer vector of the same length as `x` and `y` where the  $i$ -th element is the result of comparing `x[i]` and `y[i]`. If `x` and `y` don't have the same length and are not zero-length vectors, then the shortest is first recycled to the length of the longest. If one of them is a zero-length vector then `compare(x, y)` returns a zero-length integer vector.

`selfmatch(x, ...)` is equivalent to `match(x, x, ...)`. This is actually how the default method is implemented. However note that `selfmatch(x, ...)` will typically be more efficient than `match(x, x, ...)` on vector-like objects for which a specific `selfmatch` method is implemented. `findMatches` is an enhanced version of `match` which, by default (i.e. if `select="all"`), returns all the matches in a [Hits](#) object.

`countMatches` returns an integer vector of the length of `x` containing the number of matches in `table` for each element in `x`.

## Value

For `compare`: see [Details](#) section above.

For `selfmatch`: an integer vector of the same length as `x`.

For `duplicated`, `unique`, and `%in%`: see `?BiocGenerics::duplicated`, `?BiocGenerics::unique`, and `?%in%`.

For `findMatches`: a [Hits](#) object by default (i.e. if `select="all"`).

For `countMatches`: an integer vector of the length of `x` containing the number of matches in `table` for each element in `x`.

For `sort`: see `?BiocGenerics::sort`.

For `table`: a 1D array of integer values promoted to the "table" class. See `?BiocGeneric::table` for more information.

## Note

The following notes are for developers who want to implement comparing, ordering, and tabulating methods for their own [Vector](#) subclass:

1. The 6 traditional binary comparison operators are: `==`, `!=`, `<=`, `>=`, `<`, and `>`. The **S4Vectors** package provides the following methods for these operators:

```
setMethod("==", c("Vector", "Vector"),
  function(e1, e2) { compare(e1, e2) == 0L }
)
setMethod("<=", c("Vector", "Vector"),
  function(e1, e2) { compare(e1, e2) <= 0L }
)
setMethod("!=" , c("Vector", "Vector"),
  function(e1, e2) { !(e1 == e2) }
)
setMethod(">=", c("Vector", "Vector"),
  function(e1, e2) { e2 <= e1 }
)
setMethod("<", c("Vector", "Vector"),
  function(e1, e2) { !(e2 <= e1) }
)
setMethod(">", c("Vector", "Vector"),
  function(e1, e2) { !(e1 <= e2) }
)
```

With these definitions, the 6 binary operators work out-of-the-box on **Vector** objects for which `compare` works the expected way. If `compare` is not implemented, then it's enough to implement `==` and `<=` methods to have the 4 remaining operators (`!=`, `>=`, `<`, and `>`) work out-of-the-box.

2. The **S4Vectors** package provides no `compare` method for **Vector** objects. Specific `compare` methods need to be implemented for specific **Vector** subclasses (e.g. for **Ranges** objects). These specific methods must obey the rules described in the Details section above.
3. The `duplicated`, `unique`, and `%in%` methods for **Vector** objects are implemented on top of `selfmatch`, `duplicated`, and `match`, respectively, so they work out-of-the-box on **Vector** objects for which `selfmatch`, `duplicated`, and `match` work the expected way.
4. Also the default `findMatches` and `countMatches` methods are implemented on top of `match` and `selfmatch` so they work out-of-the-box on **Vector** objects for which those things work the expected way.
5. However, since `selfmatch` itself is also implemented on top of `match`, then having `match` work the expected way is actually enough to get `selfmatch`, `duplicated`, `unique`, `%in%`, `findMatches`, and `countMatches` work out-of-the-box on **Vector** objects.
6. The `sort` method for **Vector** objects is implemented on top of `order`, so it works out-of-the-box on **Vector** objects for which `order` works the expected way.
7. The `table` method for **Vector** objects is implemented on top of `selfmatch`, `order`, and `as.character`, so it works out-of-the-box on a **Vector** object for which those things work the expected way.
8. The **S4Vectors** package provides no `match` or `order` methods for **Vector** objects. Specific methods need to be implemented for specific **Vector** subclasses (e.g. for **Ranges** objects).

### Author(s)

H. Pages

### See Also

- The **Vector** class.
- **Ranges-comparison** in the **IRanges** package for comparing and ordering ranges.
- `==` and `%in%` in the **base** package, and `BiocGenerics::match`, `BiocGenerics::duplicated`, `BiocGenerics::unique`, `BiocGenerics::order`, `BiocGenerics::sort`, `BiocGenerics::rank` in the **BiocGenerics** package for general information about the comparison/ordering operators and functions.
- The **Hits** class.
- `BiocGeneric::table` in the **BiocGenerics** package.

### Examples

```
## -----
## A. SIMPLE EXAMPLES
## -----

y <- c(16L, -3L, -2L, 15L, 15L, 0L, 8L, 15L, -2L)
```

```

selfmatch(y)

x <- c(unique(y), 999L)
findMatches(x, y)
countMatches(x, y)

## See ?Ranges-comparison for more examples (on Ranges objects). You
## might need to load the IRanges package first.

## -----
## B. FOR DEVELOPPERS: HOW TO IMPLEMENT THE BINARY COMPARISON OPERATORS
##   FOR YOUR Vector SUBCLASS
## -----

## The answer is: dont implement them. Just implement compare() and the
## binary comparison operators will work out-of-the-box. Here is an
## example:

## (1) Implement a simple Vector subclass.

setClass("Raw", contains="Vector", representation(data="raw"))

setMethod("length", "Raw", function(x) length(x@data))

setMethod("[", "Raw",
  function(x, i, j, ..., drop) { x@data <- x@data[i]; x }
)

x <- new("Raw", data=charToRaw("AB.x0a-BAA+C"))
stopifnot(identical(length(x), 12L))
stopifnot(identical(x[7:3], new("Raw", data=charToRaw("-a0x."))))

## (2) Implement a "compare" method for Raw objects.

setMethod("compare", c("Raw", "Raw"),
  function(x, y) {as.integer(x@data) - as.integer(y@data)}
)

stopifnot(identical(which(x == x[1]), c(1L, 9L, 10L)))
stopifnot(identical(x[x < x[5]], new("Raw", data=charToRaw(".-+"))))

```

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