

Package ‘alakazam’

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Type Package

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Title Immunoglobulin Clonal Lineage and Diversity Analysis

Description Provides methods for high-throughput adaptive immune receptor repertoire sequencing (AIRR-Seq; Rep-Seq) analysis. In particular, immunoglobulin (Ig) sequence lineage reconstruction, lineage topology analysis, diversity profiling, amino acid property analysis and gene usage.

Citations:

Gupta and Vander Heiden, et al (2017) <[doi:10.1093/bioinformatics/btv359](https://doi.org/10.1093/bioinformatics/btv359)>,

Stern, Yaari and Vander Heiden, et al (2014) <[doi:10.1126/scitranslmed.3008879](https://doi.org/10.1126/scitranslmed.3008879)>.

License AGPL-3

URL <https://alakazam.readthedocs.io/>

BugReports <https://bitbucket.org/kleinsteinstein/alakazam/issues>

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ABBREV_AA	<i>Amino acid abbreviation translations</i>
-----------	---

Description

Mappings of amino acid abbreviations.

Usage

ABBREV_AA

Format

Named character vector defining single-letter character codes to three-letter abbreviation mappings.

Examples

```
aa <- c("Ala", "Ile", "Trp")
translateStrings(aa, ABBREV_AA)
```

AbundanceCurve-class	<i>S4 class defining a clonal abundance curve</i>
----------------------	---

Description

AbundanceCurve defines clonal abundance values.

Usage

```
## S4 method for signature 'AbundanceCurve'
print(x)

## S4 method for signature 'AbundanceCurve,missing'
plot(x, y, ...)
```

Arguments

x	AbundanceCurve object
y	ignored.
...	arguments to pass to plotDiversityCurve .

Slots

abundance data.frame with relative clonal abundance data and confidence intervals, containing the following columns:

- group: group identifier.
- clone_id or CLONE: clone identifier.
- p: relative abundance of the clone.
- lower: lower confidence interval bound.
- upper: upper confidence interval bound.
- rank: the rank of the clone abundance.

bootstrap data.frame of bootstrapped clonal distributions.

clone_by string specifying the name of the clone column.

group_by string specifying the name of the grouping column.

groups vector specifying the names of unique groups in group column.

n numeric vector indicating the number of sequences sampled in each group.

nboot numeric specifying the number of bootstrap iterations to use.

ci confidence interval defining the upper and lower bounds (a value between 0 and 1).

 alakazam

The alakazam package

Description

alakazam is a member of the Immcantation framework of tools and serves five main purposes:

- Providing core functionality for other R packages in Immcantation. This includes common tasks such as file I/O, basic DNA sequence manipulation, and interacting with V(D)J segment and gene annotations.
- Providing an R interface for interacting with the output of the pRESTO and Change-O tool suites.
- Performing clonal abundance and diversity analysis on lymphocyte repertoires.
- Performing lineage reconstruction on clonal populations of immunoglobulin (Ig) sequences.
- Performing physicochemical property analyses of lymphocyte receptor sequences.

For additional details regarding the use of the alakazam package see the vignettes:

`browseVignettes("alakazam")`

File I/O

- `readChangeoDb`: Input Change-O style files.
- `writeChangeoDb`: Output Change-O style files.

Sequence cleaning

- `maskSeqEnds`: Mask ragged ends.
- `maskSeqGaps`: Mask gap characters.
- `collapseDuplicates`: Remove duplicate sequences.

Lineage reconstruction

- `makeChangeoClone`: Clean sequences for lineage reconstruction.
- `buildPhyIipLineage`: Perform lineage reconstruction of Ig sequences.

Lineage topology analysis

- `tableEdges`: Tabulate annotation relationships over edges.
- `testEdges`: Significance testing of annotation edges.
- `testMRCA`: Significance testing of MRCA annotations.
- `summarizeSubtrees`: Various summary statistics for subtrees.
- `plotSubtrees`: Plot distributions of summary statistics for a population of trees.

Diversity analysis

- `countClones`: Calculate clonal abundance.
- `estimateAbundance`: Bootstrap clonal abundance curves.
- `alphaDiversity`: Generate clonal alpha diversity curves.
- `plotAbundanceCurve`: Plot clone size distribution as a rank-abundance
- `plotDiversityCurve`: Plot clonal diversity curves.
- `plotDiversityTest`: Plot testing at given diversity hill indicex.

Ig and TCR sequence annotation

- `countGenes`: Calculate Ig and TCR allele, gene and family usage.
- `extractVRegion`: Extract CDRs and FWRs sub-sequences.
- `getAllele`: Get V(D)J allele names.
- `getGene`: Get V(D)J gene names.
- `getFamily`: Get V(D)J family names.
- `junctionAlignment`: Junction alignment properties

Sequence distance calculation

- `seqDist`: Calculate Hamming distance between two sequences.
- `seqEqual`: Test two sequences for equivalence.
- `pairwiseDist`: Calculate a matrix of pairwise Hamming distances for a set of sequences.
- `pairwiseEqual`: Calculate a logical matrix of pairwise equivalence for a set of sequences.

Amino acid properties

- `translateDNA`: Translate DNA sequences to amino acid sequences.
- `aminoAcidProperties`: Calculate various physicochemical properties of amino acid sequences.
- `countPatterns`: Count patterns in sequences.

References

1. Vander Heiden JA, Yaari G, et al. pRESTO: a toolkit for processing high-throughput sequencing raw reads of lymphocyte receptor repertoires. *Bioinformatics*. 2014 30(13):1930-2.
2. Stern JNH, Yaari G, Vander Heiden JA, et al. B cells populating the multiple sclerosis brain mature in the draining cervical lymph nodes. *Sci Transl Med*. 2014 6(248):248ra107.
3. Wu Y-CB, et al. Influence of seasonal exposure to grass pollen on local and peripheral blood IgE repertoires in patients with allergic rhinitis. *J Allergy Clin Immunol*. 2014 134(3):604-12.
4. Gupta NT, Vander Heiden JA, et al. Change-O: a toolkit for analyzing large-scale B cell immunoglobulin repertoire sequencing data. *Bioinformatics*. 2015 Oct 15;31(20):3356-8.

aliphatic

Calculates the aliphatic index of amino acid sequences

Description

aliphatic calculates the aliphatic index of amino acid sequences using the method of Ikai. Non-informative positions are excluded, where non-informative is defined as any character in c("X", "-", ".", "*").

Usage

```
aliphatic(seq, normalize = TRUE)
```

Arguments

seq	vector of strings containing amino acid sequences.
normalize	if TRUE then divide the aliphatic index of each amino acid sequence by the number of informative positions. Non-informative position are defined by the presence any character in c("X", "-", ".", "*"). If FALSE then return the raw aliphatic index.

Value

A vector of the aliphatic indices for the sequence(s).

References

1. Ikai AJ. Thermostability and aliphatic index of globular proteins. *J Biochem.* 88, 1895-1898 (1980).

Examples

```
seq <- c("CARDRSTPWRRGIASSTTVRTSW", NA, "XQTQMYVRT")
aliphatic(seq)
```

alphaDiversity	<i>Calculate clonal alpha diversity</i>
----------------	---

Description

alphaDiversity takes in a data.frame or [AbundanceCurve](#) and computes diversity scores (D) over an interval of diversity orders (q).

Usage

```
alphaDiversity(data, min_q = 0, max_q = 4, step_q = 0.1, ci = 0.95, ...)
```

Arguments

data	data.frame with Change-O style columns containing clonal assignments or a AbundanceCurve generate by estimateAbundance object containing a previously calculated bootstrap distributions of clonal abundance.
min_q	minimum value of q .
max_q	maximum value of q .
step_q	value by which to increment q .
ci	confidence interval to calculate; the value must be between 0 and 1.
...	additional arguments to pass to estimateAbundance . Additional arguments are ignored if a AbundanceCurve is provided as input.

Details

Clonal diversity is calculated using the generalized diversity index (Hill numbers) proposed by Hill (Hill, 1973). See [calcDiversity](#) for further details.

To generate a smooth curve, D is calculated for each value of q from min_q to max_q incremented by step_q. When uniform=TRUE variability in total sequence counts across unique values in the group column is corrected by repeated resampling from the estimated complete clonal distribution to a common number of sequences. The complete clonal abundance distribution that is resampled

from is inferred by using the Chao1 estimator to infer the number of unseen clones, followed by applying the relative abundance correction and unseen clone frequencies described in Chao et al, 2015.

The diversity index (D) for each group is the mean value of over all resampling realizations. Confidence intervals are derived using the standard deviation of the resampling realizations, as described in Chao et al, 2015.

Significance of the difference in diversity index (D) between groups is tested by constructing a bootstrap delta distribution for each pair of unique values in the group column. The bootstrap delta distribution is built by subtracting the diversity index D_a in group a from the corresponding value D_b in group b, for all bootstrap realizations, yielding a distribution of nboot total deltas; where group a is the group with the greater mean D . The p-value for hypothesis $D_a \neq D_b$ is the value of $P(\emptyset)$ from the empirical cumulative distribution function of the bootstrap delta distribution, multiplied by 2 for the two-tailed correction.

Note, this method may inflate statistical significance when clone sizes are uniformly small, such as when most clones sizes are 1, sample size is small, and `max_n` is near the total count of the smallest data group. Use caution when interpreting the results in such cases.

Value

A [DiversityCurve](#) object summarizing the diversity scores.

References

1. Hill M. Diversity and evenness: a unifying notation and its consequences. *Ecology*. 1973 54(2):427-32.
2. Chao A. Nonparametric Estimation of the Number of Classes in a Population. *Scand J Stat*. 1984 11, 265270.
3. Chao A, et al. Rarefaction and extrapolation with Hill numbers: A framework for sampling and estimation in species diversity studies. *Ecol Monogr*. 2014 84:45-67.
4. Chao A, et al. Unveiling the species-rank abundance distribution by generalizing the Good-Turing sample coverage theory. *Ecology*. 2015 96, 11891201.

See Also

See [calcDiversity](#) for the basic calculation and [DiversityCurve](#) for the return object. See [plotDiversityCurve](#) for plotting the return object.

Examples

```
# Group by sample identifier in two steps
abund <- estimateAbundance(ExampleDb, group="sample_id", nboot=100)
div <- alphaDiversity(abund, step_q=1, max_q=10)
plotDiversityCurve(div, legend_title="Sample")

# Grouping by isotype rather than sample identifier in one step
div <- alphaDiversity(ExampleDb, group="c_call", min_n=40, step_q=1, max_q=10,
                     nboot=100)
plotDiversityCurve(div, legend_title="Isotype")
```

aminoAcidProperties *Calculates amino acid chemical properties for sequence data*

Description

aminoAcidProperties calculates amino acid sequence physicochemical properties, including length, hydrophobicity, bulkiness, polarity, aliphatic index, net charge, acidic residue content, basic residue content, and aromatic residue content.

Usage

```
aminoAcidProperties(  
  data,  
  property = c("length", "gravy", "bulk", "aliphatic", "polarity", "charge", "basic",  
    "acidic", "aromatic"),  
  seq = "junction",  
  nt = TRUE,  
  trim = FALSE,  
  label = NULL,  
  ...  
)
```

Arguments

data	data.frame containing sequence data.
property	vector strings specifying the properties to be calculated. Defaults to calculating all defined properties.
seq	character name of the column containing input sequences.
nt	boolean, TRUE if the sequences (or sequence) are DNA and will be translated.
trim	if TRUE remove the first and last codon/amino acids from each sequence before calculating properties. If FALSE do not modify input sequences.
label	name of sequence region to add as prefix to output column names.
...	additional named arguments to pass to the functions gravy , bulk , aliphatic , polar or charge .

Details

For all properties except for length, non-informative positions are excluded, where non-informative is defined as any character in `c("X", "-", ".", "*")`.

The scores for `gravy`, `bulkiness` and `polarity` are calculated as simple averages of the scores for each informative positions. The `basic`, `acid` and `aromatic` indices are calculated as the fraction of informative positions falling into the given category.

The `aliphatic` index is calculated using the Ikai, 1980 method.

The net charge is calculated using the method of Moore, 1985, excluding the N-terminus and C-terminus charges, and normalizing by the number of informative positions. The default pH for the calculation is 7.4.

The following data sources were used for the default property scores:

- hydrophathy: Kyte & Doolittle, 1982.
- bulkiness: Zimmerman et al, 1968.
- polarity: Grantham, 1974.
- pK: EMBOSS.

Value

A modified data data.frame with the following columns:

- *_aa_length: number of amino acids.
- *_aa_gravy: grand average of hydrophobicity (gravy) index.
- *_aa_bulk: average bulkiness of amino acids.
- *_aa_aliphatic: aliphatic index.
- *_aa_polarity: average polarity of amino acids.
- *_aa_charge: net charge.
- *_aa_basic: fraction of informative positions that are Arg, His or Lys.
- *_aa_acidic: fraction of informative positions that are Asp or Glu.
- *_aa_aromatic: fraction of informative positions that are His, Phe, Trp or Tyr.

Where * is the value from label or the name specified for seq if label=NULL.

References

1. Zimmerman JM, Eliezer N, Simha R. The characterization of amino acid sequences in proteins by statistical methods. *J Theor Biol* 21, 170-201 (1968).
2. Grantham R. Amino acid difference formula to help explain protein evolution. *Science* 185, 862-864 (1974).
3. Ikai AJ. Thermostability and aliphatic index of globular proteins. *J Biochem* 88, 1895-1898 (1980).
4. Kyte J, Doolittle RF. A simple method for displaying the hydropathic character of a protein. *J Mol Biol* 157, 105-32 (1982).
5. Moore DS. Amino acid and peptide net charges: A simple calculational procedure. *Biochem Educ* 13, 10-11 (1985).
6. Wu YC, et al. High-throughput immunoglobulin repertoire analysis distinguishes between human IgM memory and switched memory B-cell populations. *Blood* 116, 1070-8 (2010).
7. Wu YC, et al. The relationship between CD27 negative and positive B cell populations in human peripheral blood. *Front Immunol* 2, 1-12 (2011).
8. <http://emboss.sourceforge.net/apps/cvs/emboss/apps/iep.html>

See Also

See [countPatterns](#) for counting the occurrence of specific amino acid subsequences. See [gravy](#), [bulk](#), [aliphatic](#), [polar](#) and [charge](#) for functions that calculate the included properties individually.

Examples

```
# Subset example data
db <- ExampleDb[c(1,10,100), c("sequence_id", "junction")]

# Calculate default amino acid properties from DNA sequences
aminoAcidProperties(db, seq="junction")
# Calculate default amino acid properties from amino acid sequences
# Use a custom output column prefix
db$junction_aa <- translatedDNA(db$junction)
aminoAcidProperties(db, seq="junction_aa", label="junction", nt=FALSE)

# Use the Grantham, 1974 side chain volume scores from the seqinr package
# Set pH=7.0 for the charge calculation
# Calculate only average volume and charge
# Remove the head and tail amino acids from the junction, thus making it the CDR3
library(seqinr)
data(aaindex)
x <- aaindex[["GRAR740103"]]$I
# Rename the score vector to use single-letter codes
names(x) <- translateStrings(names(x), ABBREV_AA)
# Calculate properties
aminoAcidProperties(db, property=c("bulk", "charge"), seq="junction",
                    trim=TRUE, label="cdr3", bulkiness=x, pH=7.0)
```

baseTheme

Standard ggplot settings

Description

baseTheme defines common ggplot theme settings for plotting.

Usage

```
baseTheme(sizing = c("figure", "window"))
```

Arguments

sizing defines the style and sizing of the theme. One of c("figure", "window") where sizing="figure" is appropriately sized for pdf export at 7 to 7.5 inch width, and sizing="window" is sized for an interactive session.

Value

A ggplot2 object.

See Also

[theme](#).

buildPhylipLineage *Infer an Ig lineage using PHYLIP*

Description

buildPhylipLineage reconstructs an Ig lineage via maximum parsimony using the dnapars application, or maximum likelihood using the dnaml application of the PHYLIP package.

Usage

```
buildPhylipLineage(
  clone,
  phylip_exec,
  dist_mat = getDNAMatrix(gap = 0),
  rm_temp = FALSE,
  verbose = FALSE,
  temp_path = NULL,
  onetree = FALSE,
  branch_length = c("mutations", "distance")
)
```

Arguments

clone	ChangeoClone object containing clone data.
phylip_exec	absolute path to the PHYLIP dnapars executable.
dist_mat	character distance matrix to use for reassigning edge weights. Defaults to a Hamming distance matrix returned by getDNAMatrix with gap=0. If gap characters, c("-", "."), are assigned a value of -1 in dist_mat then contiguous gaps of any run length, which are not present in both sequences, will be counted as a distance of 1. Meaning, indels of any length will increase the sequence distance by 1. Gap values other than -1 will return a distance that does not consider indels as a special case.
rm_temp	if TRUE delete the temporary directory after running dnapars; if FALSE keep the temporary directory.
verbose	if FALSE suppress the output of dnapars; if TRUE STDOUT and STDERR of dnapars will be passed to the console.
temp_path	specific path to temp directory if desired.
onetree	if TRUE save only one tree.
branch_length	specifies how to define branch lengths; one of "mutations" or "distance". If set to "mutations" (default), then branch lengths represent the number of mutations between nodes. If set to "distance", then branch lengths represent the expected number of mutations per site, unaltered from PHYLIP output.

Details

buildPhylipLineage builds the lineage tree of a set of unique Ig sequences via maximum parsimony through an external call to the dnapars application of the PHYLIP package. dnapars is called with default algorithm options, except for the search option, which is set to "Rearrange on one best tree". The germline sequence of the clone is used for the outgroup.

Following tree construction using dnapars, the dnapars output is modified to allow input sequences to appear as internal nodes of the tree. Intermediate sequences inferred by dnapars are replaced by children within the tree having a Hamming distance of zero from their parent node. With the default `dist_mat`, the distance calculation allows IUPAC ambiguous character matches, where an ambiguous character has distance zero to any character in the set of characters it represents. Distance calculation and movement of child nodes up the tree is repeated until all parent-child pairs have a distance greater than zero between them. The germline sequence (outgroup) is moved to the root of the tree and excluded from the node replacement processes, which permits the trunk of the tree to be the only edge with a distance of zero. Edge weights of the resultant tree are assigned as the distance between each sequence.

Value

An igraph graph object defining the Ig lineage tree. Each unique input sequence in `clone` is a vertex of the tree, with additional vertices being either the germline (root) sequences or inferred intermediates. The graph object has the following attributes.

Vertex attributes:

- `name`: value in the `sequence_id` column of the data slot of the input `clone` for observed sequences. The germline (root) vertex is assigned the name "Germline" and inferred intermediates are assigned names with the format "Inferred1", "Inferred2",
- `sequence`: value in the `sequence` column of the data slot of the input `clone` for observed sequences. The germline (root) vertex is assigned the sequence in the `germline` slot of the input `clone`. The sequence of inferred intermediates are extracted from the dnapars output.
- `label`: same as the name attribute.

Additionally, each other column in the data slot of the input `clone` is added as a vertex attribute with the attribute name set to the source column name. For the germline and inferred intermediate vertices, these additional vertex attributes are all assigned a value of NA.

Edge attributes:

- `weight`: Hamming distance between the sequence attributes of the two vertices.
- `label`: same as the weight attribute.

Graph attributes:

- `clone`: clone identifier from the `clone` slot of the input `ChangeoClone`.
- `v_gene`: V-segment gene call from the `v_gene` slot of the input `ChangeoClone`.
- `j_gene`: J-segment gene call from the `j_gene` slot of the input `ChangeoClone`.
- `junc_len`: junction length (nucleotide count) from the `junc_len` slot of the input `ChangeoClone`. Alternatively, this function will return an `phylo` object, which is compatible with the `ape` package. This object will contain reconstructed ancestral sequences in `nodes` attribute.

References

1. Felsenstein J. PHYLIP - Phylogeny Inference Package (Version 3.2). Cladistics. 1989 5:164-166.
2. Stern JNH, Yaari G, Vander Heiden JA, et al. B cells populating the multiple sclerosis brain mature in the draining cervical lymph nodes. Sci Transl Med. 2014 6(248):248ra107.

See Also

Takes as input a [ChangeoClone](#). Temporary directories are created with [makeTempDir](#). Distance is calculated using [seqDist](#). See [\[igraph\]](http://www.rdocumentation.org/packages/igraph/topics/aaa-igraph-package)(<http://www.rdocumentation.org/packages/igraph/topics/aaa-igraph-package>) and [\[igraph.plotting\]](http://www.rdocumentation.org/packages/igraph/topics/plot.common)(<http://www.rdocumentation.org/packages/igraph/topics/plot.common>) for working with igraph graph objects.

Examples

```
## Not run:
# Preprocess clone
db <- subset(ExampleDb, clone_id == 3138)
clone <- makeChangeoClone(db, text_fields=c("sample_id", "c_call"),
                          num_fields="duplicate_count")

# Run PHYLIP and process output
phylip_exec <- "~/apps/phylip-3.695/bin/dnapars"
graph <- buildPhyliLineage(clone, phylip_exec, rm_temp=TRUE)

# Plot graph with a tree layout
library(igraph)
plot(graph, layout=layout_as_tree, vertex.label=V(graph)$c_call,
      vertex.size=50, edge.arrow.mode=0, vertex.color="grey80")

# To consider each indel event as a mutation, change the masking character
# and distance matrix
clone <- makeChangeoClone(db, text_fields=c("sample_id", "c_call"),
                          num_fields="duplicate_count", mask_char="-")
graph <- buildPhyliLineage(clone, phylip_exec, dist_mat=getDNAMatrix(gap=-1),
                          rm_temp=TRUE)

## End(Not run)
```

bulk

Calculates the average bulkiness of amino acid sequences

Description

bulk calculates the average bulkiness score of amino acid sequences. Non-informative positions are excluded, where non-informative is defined as any character in `c("X", "-", ".", "*")`.

Usage

```
bulk(seq, bulkiness = NULL)
```

Arguments

seq	vector of strings containing amino acid sequences.
bulkiness	named numerical vector defining bulkiness scores for each amino acid, where names are single-letter amino acid character codes. If NULL, then the Zimmerman et al, 1968 scale is used.

Value

A vector of bulkiness scores for the sequence(s).

References

1. Zimmerman JM, Eliezer N, Simha R. The characterization of amino acid sequences in proteins by statistical methods. J Theor Biol 21, 170-201 (1968).

See Also

For additional size related indices see [aaindex](#).

Examples

```
# Default bulkiness scale
seq <- c("CARDRSTPWRRGIASSTTVRTSW", "XXTQMYVRT")
bulk(seq)

# Use the Grantham, 1974 side chain volume scores from the seqinr package
library(seqinr)
data(aaindex)
x <- aaindex[["GRAR740103"]]$I
# Rename the score vector to use single-letter codes
names(x) <- translateStrings(names(x), ABBREV_AA)
# Calculate average volume
bulk(seq, bulkiness=x)
```

calcCoverage

Calculate sample coverage

Description

calcCoverage calculates the sample coverage estimate, a measure of sample completeness, for varying orders using the method of Chao et al, 2015, falling back to the Chao1 method in the first order case.

Usage

```
calcCoverage(x, r = 1)
```

Arguments

x numeric vector of abundance counts.
r coverage order to calculate.

Value

The sample coverage of the given order r.

References

1. Chao A. Nonparametric Estimation of the Number of Classes in a Population. Scand J Stat. 1984 11, 265270.
2. Chao A, et al. Unveiling the species-rank abundance distribution by generalizing the Good-Turing sample coverage theory. Ecology. 2015 96, 11891201.

See Also

Used by [alphaDiversity](#).

Examples

```
# Calculate clone sizes  
clones <- countClones(ExampleDb, groups="sample_id")  
  
# Calculate 1st order coverage for a single sample  
calcCoverage(clones$seq_count[clones$sample_id == "+7d"])
```

calcDiversity

Calculate the diversity index

Description

calcDiversity calculates the clonal diversity index for a vector of diversity orders.

Usage

```
calcDiversity(p, q)
```

Arguments

p numeric vector of clone (species) counts or proportions.
q numeric vector of diversity orders.

Details

This method, proposed by Hill (Hill, 1973), quantifies diversity as a smooth function (D) of a single parameter q . Special cases of the generalized diversity index correspond to the most popular diversity measures in ecology: species richness ($q = 0$), the exponential of the Shannon-Weiner index (q approaches 1), the inverse of the Simpson index ($q = 2$), and the reciprocal abundance of the largest clone (q approaches $+\infty$). At $q = 0$ different clones weight equally, regardless of their size. As the parameter q increase from 0 to $+\infty$ the diversity index (D) depends less on rare clones and more on common (abundant) ones, thus encompassing a range of definitions that can be visualized as a single curve.

Values of $q < 0$ are valid, but are generally not meaningful. The value of D at $q = 1$ is estimated by D at $q = 0.9999$.

Value

A vector of diversity scores D for each q .

References

1. Hill M. Diversity and evenness: a unifying notation and its consequences. Ecology. 1973 54(2):427-32.

See Also

Used by [alphaDiversity](#).

Examples

```
# May define p as clonal member counts
p <- c(1, 1, 3, 10)
q <- c(0, 1, 2)
calcDiversity(p, q)

# Or proportional abundance
p <- c(1/15, 1/15, 1/5, 2/3)
calcDiversity(p, q)
```

ChangeoClone-class *S4 class defining a clone*

Description

ChangeoClone defines a common data structure for perform lineage reconstruction from Change-O data.

Slots

`data` `data.frame` containing sequences and annotations. Contains the columns `SEQUENCE_ID` and `SEQUENCE`, as well as any additional sequence-specific annotation columns.

`clone` string defining the clone identifier.

`germline` string containing the germline sequence for the clone.

`v_gene` string defining the V segment gene call.

`j_gene` string defining the J segment gene call.

`junc_len` numeric junction length (nucleotide count).

See Also

See [makeChangeoClone](#) and [buildPhylipLineage](#) for use.

charge

Calculates the net charge of amino acid sequences.

Description

`charge` calculates the net charge of amino acid sequences using the method of Moore, 1985, with exclusion of the C-terminus and N-terminus charges.

Usage

```
charge(seq, pH = 7.4, pK = NULL, normalize = FALSE)
```

Arguments

`seq` vector strings defining of amino acid sequences.

`pH` environmental pH.

`pK` named vector defining pK values for each charged amino acid, where names are the single-letter amino acid character codes `c("R", "H", "K", "D", "E", "C", "Y")`. If `NULL`, then the EMBOSS scale is used.

`normalize` if `TRUE` then divide the net charge of each amino acid sequence by the number of informative positions. Non-informative position are defined by the presence any character in `c("X", "-", ".", "*")`. If `FALSE` then return the raw net charge.

Value

A vector of net charges for the sequence(s).

References

1. Moore DS. Amino acid and peptide net charges: A simple calculational procedure. *Biochem Educ.* 13, 10-11 (1985).
2. <http://emboss.sourceforge.net/apps/cvs/emboss/apps/iep.html>

See Also

For additional pK scales see [pK](#).

Examples

```
seq <- c("CARDRSTPWRRGIASSTTVRTSW", "XXTQMYVRT")
# Unnormalized charge
charge(seq)
# Normalized charge
charge(seq, normalize=TRUE)

# Use the Murray et al, 2006 scores from the seqinr package
library(seqinr)
data(pK)
x <- setNames(pK[["Murray"]], rownames(pK))
# Calculate charge
charge(seq, pK=x)
```

checkColumns

Check data.frame for valid columns and issue message if invalid

Description

Check data.frame for valid columns and issue message if invalid

Usage

```
checkColumns(data, columns, logic = c("all", "any"))
```

Arguments

data	data.frame to check.
columns	vector of column names to check.
logic	one of "all" or "any" controlling whether all, or at least one, of the columns must be valid, respectively.

Value

TRUE if columns are valid and a string message if not.

Examples

```
df <- data.frame(A=1:3, B=4:6, C=rep(NA, 3))
checkColumns(df, c("A", "B"), logic="all")
checkColumns(df, c("A", "B"), logic="any")
checkColumns(df, c("A", "C"), logic="all")
checkColumns(df, c("A", "C"), logic="any")
```

```
checkColumns(df, c("A", "D"), logic="all")
checkColumns(df, c("A", "D"), logic="any")
```

collapseDuplicates *Remove duplicate DNA sequences and combine annotations*

Description

collapseDuplicates identifies duplicate DNA sequences, allowing for ambiguous characters, removes the duplicate entries, and combines any associated annotations.

Usage

```
collapseDuplicates(
  data,
  id = "sequence_id",
  seq = "sequence_alignment",
  text_fields = NULL,
  num_fields = NULL,
  seq_fields = NULL,
  add_count = FALSE,
  ignore = c("N", "-", ".", "?"),
  sep = ",",
  dry = FALSE,
  verbose = FALSE
)
```

Arguments

data	data.frame containing Change-O columns. The data.frame must contain, at a minimum, a unique identifier column and a column containing a character vector of DNA sequences.
id	name of the column containing sequence identifiers.
seq	name of the column containing DNA sequences.
text_fields	character vector of textual columns to collapse. The textual annotations of duplicate sequences will be merged into a single string with each unique value alphabetized and delimited by sep.
num_fields	vector of numeric columns to collapse. The numeric annotations of duplicate sequences will be summed.
seq_fields	vector of nucleotide sequence columns to collapse. The sequence with the fewest number of non-informative characters will be retained. Where a non-informative character is one of c("N", "-", ".", "?"). Note, this is distinct from the seq parameter which is used to determine duplicates.
add_count	if TRUE add the column collapse_count that indicates the number of sequences that were collapsed to build each unique entry.

ignore	vector of characters to ignore when testing for equality.
sep	character to use for delimiting collapsed annotations in the <code>text_fields</code> columns. Defines both the input and output delimiter.
dry	if TRUE perform dry run. Only labels the sequences without collapsing them.
verbose	if TRUE report the number input, discarded and output sequences; if FALSE process sequences silently.

Details

collapseDuplicates identifies duplicate sequences in the `seq` column by testing for character identity, with consideration of IUPAC ambiguous nucleotide codes. A cluster of sequences are considered duplicates if they are all equivalent, and no member of the cluster is equivalent to a sequence in a different cluster.

Textual annotations, specified by `text_fields`, are collapsed by taking the unique set of values within in each duplicate cluster and delimiting those values by `sep`. Numeric annotations, specified by `num_fields`, are collapsed by summing all values in the duplicate cluster. Sequence annotations, specified by `seq_fields`, are collapsed by retaining the first sequence with the fewest number of N characters.

Columns that are not specified in either `text_fields`, `num_fields`, or `seq_fields` will be retained, but the value will be chosen from a random entry amongst all sequences in a cluster of duplicates.

An ambiguous sequence is one that can be assigned to two different clusters, wherein the ambiguous sequence is equivalent to two sequences which are themselves non-equivalent. Ambiguous sequences arise due to ambiguous characters at positions that vary across sequences, and are discarded along with their annotations when `dry=FALSE`. Thus, ambiguous sequences are removed as duplicates of some sequence, but do not create a potential false-positive annotation merger. Ambiguous sequences are not included in the `collapse_count` annotation that is added when `add_count=TRUE`.

If `dry=TRUE` sequences will not be removed from the input. Instead, the following columns will be appended to the input defining the collapse action that would have been performed in the `dry=FALSE` case.

- `collapse_id`: an identifier for the group of identical sequences.
- `collapse_class`: string defining how the sequence matches to the other in the set. one of "duplicated" (has duplicates), "unique" (no duplicates), "ambiguous_duplicate" (no duplicates after ambiguous sequences are removed), or "ambiguous" (matches multiple non-duplicate sequences).
- `collapse_pass`: TRUE for the sequences that would be retained.

Value

A modified data frame with duplicate sequences removed and annotation fields collapsed if `dry=FALSE`. If `dry=TRUE`, sequences will be labeled with the collapse action, but the input will be otherwise unmodified (see Details).

See Also

Equality is tested with [seqEqual](#) and [pairwiseEqual](#). For IUPAC ambiguous character codes see [IUPAC_DNA](#).

Examples

```
# Example data.frame
db <- data.frame(sequence_id=LETTERS[1:4],
                 sequence_alignment=c("CCCCTGGG", "CCCCTGGN", "NAACTGGN", "NNNCTGNN"),
                 c_call=c("IGHM", "IGHG", "IGHG", "IGHA"),
                 sample_id=c("S1", "S1", "S2", "S2"),
                 duplicate_count=1:4,
                 stringsAsFactors=FALSE)

# Annotations are not parsed if neither text_fields nor num_fields is specified
# The retained sequence annotations will be random
collapseDuplicates(db, verbose=TRUE)

# Unique text_fields annotations are combined into a single string with ","
# num_fields annotations are summed
# Ambiguous duplicates are discarded
collapseDuplicates(db, text_fields=c("c_call", "sample_id"), num_fields="duplicate_count",
                  verbose=TRUE)

# Use alternate delimiter for collapsing textual annotations
collapseDuplicates(db, text_fields=c("c_call", "sample_id"), num_fields="duplicate_count",
                  sep="/", verbose=TRUE)

# Add count of duplicates
collapseDuplicates(db, text_fields=c("c_call", "sample_id"), num_fields="duplicate_count",
                  add_count=TRUE, verbose=TRUE)

# Masking ragged ends may impact duplicate removal
db$sequence_alignment <- maskSeqEnds(db$sequence_alignment)
collapseDuplicates(db, text_fields=c("c_call", "sample_id"), num_fields="duplicate_count",
                  add_count=TRUE, verbose=TRUE)
```

combineIgphym1

Combine IgPhyML object parameters into a dataframe

Description

combineIgphym1 combines IgPhyML object parameters into a data.frame.

Usage

```
combineIgphym1(iglist, format = c("wide", "long"))
```

Arguments

iglist list of igphym1 objects returned by [readIgphym1](#). Each must have an id column in its param attribute, which can be added automatically using the id option of [readIgphym1](#).

format string specifying whether each column of the resulting data.frame should represent a parameter (wide) or if there should only be three columns; i.e. id, variable, and value (long).

Details

combineIgphyml combines repertoire-wide parameter estimates from multiple igphyml objects produced by readIgphyml into a dataframe that can be easily used for plotting and other hypothesis testing analyses.

All igphyml objects used must have an "id" column in their param attribute, which can be added automatically from the id flag of readIgphyml.

Value

A data.frame containing HLP model parameter estimates for all igphyml objects. Only parameters shared among all objects will be returned.

References

1. Hoehn KB, Lunter G, Pybus OG - A Phylogenetic Codon Substitution Model for Antibody Lineages. Genetics 2017 206(1):417-427 <https://doi.org/10.1534/genetics.116.196303>
2. Hoehn KB, Vander Heiden JA, Zhou JQ, Lunter G, Pybus OG, Kleinstejn SHK - Repertoire-wide phylogenetic models of B cell molecular evolution reveal evolutionary signatures of aging and vaccination. bioRxiv 2019 <https://doi.org/10.1101/558825>

See Also

[readIgphyml](#)

Examples

```
## Not run:
# Read in and combine two igphyml runs
s1 <- readIgphyml("IB+7d_lineages_gy.tsv_igphyml_stats_hlp.tab", id="+7d")
s2 <- readIgphyml("IB+7d_lineages_gy.tsv_igphyml_stats_hlp.tab", id="s2")
combineIgphyml(list(s1, s2))

## End(Not run)
```

countClones

Tabulates clones sizes

Description

countClones determines the number of sequences and total copy number of clonal groups.

Usage

```
countClones(  
  data,  
  groups = NULL,  
  copy = NULL,  
  clone = "clone_id",  
  remove_na = TRUE  
)
```

Arguments

data	data.frame with columns containing clonal assignments.
groups	character vector defining data columns containing grouping variables. If groups=NULL, then do not group data.
copy	name of the data column containing copy numbers for each sequence. If this value is specified, then total copy abundance is determined by the sum of copy numbers within each clonal group.
clone	name of the data column containing clone identifiers.
remove_na	removes rows with NA values in the clone column if TRUE and issues a warning. Otherwise, keeps those rows and considers NA as a clone in the final counts and relative abundances.

Value

A data.frame summarizing clone counts and frequencies with columns:

- `clone_id`: clone identifier. This is the default column name, specified with `clone='clone_id'`. If the function call uses Change-O formatted data and `clone='CLONE'`, this column will have name CLONE.
- `seq_count`: total number of sequences for the clone.
- `seq_freq`: frequency of the clone as a fraction of the total number of sequences within each group.
- `copy_count`: sum of the copy counts in the copy column. Only present if the copy argument is specified.
- `copy_freq`: frequency of the clone as a fraction of the total copy number within each group. Only present if the copy argument is specified.

Also includes additional columns specified in the groups argument.

Examples

```
# Without copy numbers  
clones <- countClones(ExampleDb, groups="sample_id")  
  
# With copy numbers and multiple groups  
clones <- countClones(ExampleDb, groups=c("sample_id", "c_call"), copy="duplicate_count")
```

countGenes	<i>Tabulates V(D)J allele, gene or family usage.</i>
------------	--

Description

Determines the count and relative abundance of V(D)J alleles, genes or families within groups.

Usage

```
countGenes(
  data,
  gene,
  groups = NULL,
  copy = NULL,
  clone = NULL,
  fill = FALSE,
  mode = c("gene", "allele", "family", "asis"),
  remove_na = TRUE
)
```

Arguments

data	data.frame with AIRR-format or Change-O style columns.
gene	column containing allele assignments. Only the first allele in the column will be considered when mode is "gene", "family" or "allele". The value will be used as it is with mode="asis".
groups	columns containing grouping variables. If NULL do not group.
copy	name of the data column containing copy numbers for each sequence. If this value is specified, then total copy abundance is determined by the sum of copy numbers within each gene. This argument is ignored if clone is specified.
clone	name of the data column containing clone identifiers for each sequence. If this value is specified, then one gene will be considered for each clone. Note, this is accomplished by using the most common gene within each clone identifier. As such, ambiguous alleles within a clone will not be accurately represented.
fill	logical of c(TRUE, FALSE) specifying when if groups (when specified) lacking a particular gene should be counted as 0 if TRUE or not (omitted)
mode	one of c("gene", "family", "allele", "asis") defining the degree of specificity regarding allele calls. Determines whether to return counts for genes (calling getGene), families (calling getFamily), alleles (calling getAllele) or using the value as it is in the column gene, without any processing.
remove_na	removes rows with NA values in the gene column if TRUE and issues a warning. Otherwise, keeps those rows and considers NA as a gene in the final counts and relative abundances.

Value

A data.frame summarizing family, gene or allele counts and frequencies with columns:

- `gene`: name of the family, gene or allele.
- `seq_count`: total number of sequences for the gene.
- `seq_freq`: frequency of the gene as a fraction of the total number of sequences within each grouping.
- `copy_count`: sum of the copy counts in the copy column. for each gene. Only present if the copy argument is specified.
- `copy_freq`: frequency of the gene as a fraction of the total copy number within each group. Only present if the copy argument is specified.
- `clone_count`: total number of clones for the gene. Only present if the clone argument is specified.
- `clone_freq`: frequency of the gene as a fraction of the total number of clones within each grouping. Only present if the clone argument is specified.

Additional columns defined by the groups argument will also be present.

Examples

```
# Without copy numbers
genes <- countGenes(ExampleDb, gene="v_call", groups="sample_id", mode="family")
genes <- countGenes(ExampleDb, gene="v_call", groups="sample_id", mode="gene")
genes <- countGenes(ExampleDb, gene="v_call", groups="sample_id", mode="allele")

# With copy numbers and multiple groups
genes <- countGenes(ExampleDb, gene="v_call", groups=c("sample_id", "c_call"),
                    copy="duplicate_count", mode="family")

# Count by clone
genes <- countGenes(ExampleDb, gene="v_call", groups=c("sample_id", "c_call"),
                    clone="clone_id", mode="family")

# Count absent genes
genes <- countGenes(ExampleDb, gene="v_call", groups="sample_id",
                    mode="allele", fill=TRUE)
```

countPatterns

Count sequence patterns

Description

`countPatterns` counts the fraction of times a set of character patterns occur in a set of sequences.

Usage

```
countPatterns(seq, patterns, nt = TRUE, trim = FALSE, label = "region")
```

Arguments

seq	character vector of either DNA or amino acid sequences.
patterns	list of sequence patterns to count in each sequence. If the list is named, then names will be assigned as the column names of output data.frame.
nt	if TRUE then seq are DNA sequences and will be translated before performing the pattern search.
trim	if TRUE remove the first and last codon or amino acid from each sequence before the pattern search. If FALSE do not modify the input sequences.
label	string defining a label to add as a prefix to the output column names.

Value

A data.frame containing the fraction of times each sequence pattern was found.

Examples

```
seq <- c("TGTC AACAGGCTAACAGTTCCGGACGTTC",
        "TGTCAGCAATATTATATTGCTCCCTTCACTTTC",
        "TGTC AAAAGTATAACAGTGCCCCCTGGACGTTC")
patterns <- c("A", "V", "[LI]")
names(patterns) <- c("arg", "val", "iso_leu")
countPatterns(seq, patterns, nt=TRUE, trim=TRUE, label="cdr3")
```

cpuCount

Available CPU cores

Description

cpuCount determines the number of CPU cores available.

Usage

```
cpuCount()
```

Value

Count of available cores. Returns 1 if undeterminable.

Examples

```
cpuCount()
```

DEFAULT_COLORS	<i>Default colors</i>
----------------	-----------------------

Description

Default color palettes for DNA characters, Ig isotypes, and TCR chains.

Usage

DNA_COLORS

IG_COLORS

TR_COLORS

Format

Named character vectors with hexcode colors as values.

- DNA_COLORS: DNA character colors `c("A", "C", "G", "T")`.
- IG_COLORS: Ig isotype colors `c("IGHA", "IGHD", "IGHE", "IGHG", "IGHM", "IGHK", "IGHL")`.
- TR_COLORS: TCR chain colors `c("TRA", "TRB", "TRD", "TRG")`.

An object of class character of length 4.

An object of class character of length 7.

An object of class character of length 4.

Examples

```
# IG_COLORS as an isotype color set for ggplot
isotype <- c("IGHG", "IGHM", "IGHM", "IGHA")
db <- data.frame(x=1:4, y=1:4, iso=isotype)
g1 <- ggplot(db, aes(x=x, y=y, color=iso)) +
  scale_color_manual(name="Isotype", values=IG_COLORS) +
  geom_point(size=10)
plot(g1)

# DNA_COLORS to translate nucleotide values to a vector of colors
# for use in base graphics plots
seq <- c("A", "T", "T", "C")
colors <- translateStrings(seq, setNames(names(DNA_COLORS), DNA_COLORS))
plot(1:4, 1:4, col=colors, pch=16, cex=6)
```

DiversityCurve-class *S4 class defining a diversity curve*

Description

DiversityCurve defines diversity (D) scores over multiple diversity orders (Q).

Usage

```
## S4 method for signature 'DiversityCurve'
print(x)

## S4 method for signature 'DiversityCurve,missing'
plot(x, y, ...)

## S4 method for signature 'DiversityCurve,numeric'
plot(x, y, ...)
```

Arguments

x	DiversityCurve object
y	diversity order to plot (q).
...	arguments to pass to plotDiversityCurve or plotDiversityTest .

Slots

diversity data.frame defining the diversity curve with the following columns:

- group: group label.
- q: diversity order.
- d: mean diversity index over all bootstrap realizations.
- d_sd: standard deviation of the diversity index over all bootstrap realizations.
- d_lower: diversity lower confidence interval bound.
- d_upper: diversity upper confidence interval bound.
- e: evenness index calculated as D divided by D at $Q=0$.
- e_lower: evenness lower confidence interval bound.
- e_upper: evenness upper confidence interval bound.

tests data.frame describing the significance test results with columns:

- test: string listing the two groups tested.
- delta_mean: mean of the D bootstrap delta distribution for the test.
- delta_sd: standard deviation of the D bootstrap delta distribution for the test.
- pvalue: p-value for the test.

group_by string specifying the name of the grouping column in diversity calculation.

groups vector specifying the names of unique groups in group column in diversity calculation.

method string specifying the type of diversity calculated.
 q vector of diversity hill diversity indices used for computing diversity.
 n numeric vector indication the number of sequences sampled in each group.
 ci confidence interval defining the upper and lower bounds (a value between 0 and 1).

EdgeTest-class *S4 class defining edge significance*

Description

EdgeTest defines the significance of parent-child annotation enrichment.

Usage

```
## S4 method for signature 'EdgeTest'
print(x)

## S4 method for signature 'EdgeTest,missing'
plot(x, y, ...)
```

Arguments

x	EdgeTest object.
y	ignored.
...	arguments to pass to plotEdgeTest .

Slots

tests data.frame describing the significance test results with columns:

- parent: parent node annotation.
- child: child node annotation
- count: count of observed edges with the given parent-child annotation set.
- expected: mean count of expected edges for the given parent-child relationship.
- pvalue: one-sided p-value for the hypothesis that the observed edge abundance is greater than expected.

permutations data.frame containing the raw permutation test data with columns:

- parent: parent node annotation.
- child: child node annotation
- count: count of edges with the given parent-child annotation set.
- iter: numerical index define which permutation realization each observation corresponds to.

nperm number of permutation realizations.

estimateAbundance *Estimates the complete clonal relative abundance distribution*

Description

estimateAbundance estimates the complete clonal relative abundance distribution and confidence intervals on clone sizes using bootstrapping.

Usage

```
estimateAbundance(
  data,
  clone = "clone_id",
  copy = NULL,
  group = NULL,
  min_n = 30,
  max_n = NULL,
  uniform = TRUE,
  ci = 0.95,
  nboot = 200,
  progress = FALSE
)
```

Arguments

data	data.frame with Change-O style columns containing clonal assignments.
clone	name of the data column containing clone identifiers.
copy	name of the data column containing copy numbers for each sequence. If copy=NULL (the default), then clone abundance is determined by the number of sequences. If a copy column is specified, then clone abundances is determined by the sum of copy numbers within each clonal group.
group	name of the data column containing group identifiers. If NULL then no grouping is performed and the group column of the output will contain the value NA for each row.
min_n	minimum number of observations to sample. A group with less observations than the minimum is excluded.
max_n	maximum number of observations to sample. If NULL then no maximum is set.
uniform	if TRUE then uniformly resample each group to the same number of observations. If FALSE then allow each group to be resampled to its original size or, if specified, max_size.
ci	confidence interval to calculate; the value must be between 0 and 1.
nboot	number of bootstrap realizations to generate.
progress	if TRUE show a progress bar.

Value

A [AbundanceCurve](#) object summarizing the abundances.

References

1. Chao A. Nonparametric Estimation of the Number of Classes in a Population. *Scand J Stat.* 1984 11, 265270.
2. Chao A, et al. Rarefaction and extrapolation with Hill numbers: A framework for sampling and estimation in species diversity studies. *Ecol Monogr.* 2014 84:45-67.
3. Chao A, et al. Unveiling the species-rank abundance distribution by generalizing the Good-Turing sample coverage theory. *Ecology.* 2015 96, 11891201.

See Also

See [plotAbundanceCurve](#) for plotting of the abundance distribution. See [alphaDiversity](#) for a similar application to clonal diversity.

Examples

```
abund <- estimateAbundance(ExampleDb, group="sample_id", nboot=100)
```

Example10x

Small example 10x Genomics Ig V(D)J sequences from CD19+ B cells isolated from PBMCs of a healthy human donor. Down-sampled from data provided by 10x Genomics under a Creative Commons Attribute license, and processed with their Cell Ranger pipeline.

Description

Small example 10x Genomics Ig V(D)J sequences from CD19+ B cells isolated from PBMCs of a healthy human donor. Down-sampled from data provided by 10x Genomics under a Creative Commons Attribute license, and processed with their Cell Ranger pipeline.

Usage

```
Example10x
```

Format

A data.frame with the following AIRR style columns:

- `sequence_id`: Sequence identifier
- `sequence_alignment`: IMGT-gapped observed sequence.
- `germline_alignment`: IMGT-gapped germline sequence.
- `v_call`: V region allele assignments.

- `d_call`: D region allele assignments.
- `j_call`: J region allele assignments.
- `c_call`: Isotype (C region) assignment.
- `junction`: Junction region sequence.
- `junction_length`: Length of the junction region in nucleotides.
- `np1_length`: Combined length of the N and P regions proximal to the V region.
- `np2_length`: Combined length of the N and P regions proximal to the J region.
- `umi_count`: Number of unique molecular identifies attributed to sequence.
- `cell_id`: Cell identifier.
- `locus`: Genomic locus of sequence.

References

1. Data source: https://support.10xgenomics.com/single-cell-vdj/datasets/2.2.0/vdj_v1_hs_cd19_b
2. License: <https://creativecommons.org/licenses/by/4.0/>

ExampleDb

Example AIRR database

Description

A small example database subset from Laserson and Vigneault et al, 2014.

Usage

ExampleDb

Format

A data.frame with the following AIRR style columns:

- `sequence_id`: Sequence identifier
- `sequence_alignment`: IMGT-gapped observed sequence.
- `germline_alignment`: IMGT-gapped germline sequence.
- `germline_alignment_d_mask`: IMGT-gapped germline sequence with N, P and D regions masked.
- `v_call`: V region allele assignments.
- `v_call_genotyped`: TIGGER corrected V region allele assignment.
- `d_call`: D region allele assignments.
- `j_call`: J region allele assignments.
- `c_call`: Isotype (C region) assignment.
- `junction`: Junction region sequence.

- junction_length: Length of the junction region in nucleotides.
- np1_length: Combined length of the N and P regions proximal to the V region.
- np2_length: Combined length of the N and P regions proximal to the J region.
- duplicate_count: Copy count (number of duplicates) of the sequence.
- clone_id: Change-O assignment clonal group identifier.
- sample_id: Sample identifier. Time in relation to vaccination.

References

1. Laserson U and Vigneault F, et al. High-resolution antibody dynamics of vaccine-induced immune responses. Proc Natl Acad Sci USA. 2014 111:4928-33.

See Also

[ExampleDbChangeo](#) [ExampleTrees](#)

ExampleDbChangeo

Example Change-O database

Description

A small example database subset from Laserson and Vigneault et al, 2014.

Usage

ExampleDbChangeo

Format

A data.frame with the following Change-O style columns:

- SEQUENCE_ID: Sequence identifier
- SEQUENCE_IMGT: IMGT-gapped observed sequence.
- GERMLINE_IMGT_D_MASK: IMGT-gapped germline sequence with N, P and D regions masked.
- V_CALL: V region allele assignments.
- V_CALL_GENOTYPED: TIGGER corrected V region allele assignment.
- D_CALL: D region allele assignments.
- J_CALL: J region allele assignments.
- JUNCTION: Junction region sequence.
- JUNCTION_LENGTH: Length of the junction region in nucleotides.
- NP1_LENGTH: Combined length of the N and P regions proximal to the V region.
- NP2_LENGTH: Combined length of the N and P regions proximal to the J region.
- SAMPLE: Sample identifier. Time in relation to vaccination.
- ISOTYPE: Isotype assignment.
- DUPCOUNT: Copy count (number of duplicates) of the sequence.
- CLONE: Change-O assignment clonal group identifier.

References

1. Laserson U and Vigneault F, et al. High-resolution antibody dynamics of vaccine-induced immune responses. Proc Natl Acad Sci USA. 2014 111:4928-33.

See Also

[ExampleDb](#) [ExampleTrees](#)

ExampleTrees	<i>Example Ig lineage trees</i>
--------------	---------------------------------

Description

A set of Ig lineage trees generated from the ExampleDb file, subset to only those trees with at least four nodes.

Usage

```
ExampleTrees
```

Format

A list of igraph objects output by [buildPhyloLineage](#). Each node of each tree has the following annotations (vertex attributes):

- `sample_id`: Sample identifier(s). Time in relation to vaccination.
- `c_call`: Isotype assignment(s).
- `duplication_count`: Copy count (number of duplicates) of the sequence.

See Also

[ExampleTrees](#)

extractVRegion	<i>Extracts FWRs and CDRs from IMGT-gapped sequences</i>
----------------	--

Description

extractVRegion extracts the framework and complementarity determining regions of the V segment for IMGT-gapped immunoglobulin (Ig) nucleotide sequences according to the IMGT numbering scheme.

Usage

```
extractVRegion(sequences, region = c("fwr1", "cdr1", "fwr2", "cdr2", "fwr3"))
```

Arguments

sequences character vector of IMGT-gapped nucleotide sequences.
region string defining the region(s) of the V segment to extract. May be a single region or multiple regions (as a vector) from `c("fwr1", "cdr1", "fwr2", "cdr2", "fwr3")`. By default, all regions will be returned.

Value

If only one region is specified in the `region` argument, a character vector of the extracted subsequences will be returned. If multiple regions are specified, then a character matrix will be returned with columns corresponding to the specified regions and a row for each entry in sequences.

References

1. Lefranc M-P, et al. IMGT unique numbering for immunoglobulin and T cell receptor variable domains and Ig superfamily V-like domains. *Dev Comp Immunol.* 2003 27(1):55-77.

See Also

IMGT-gapped region boundaries are defined in [IMGT_REGIONS](#).

Examples

```
# Assign example clone
clone <- subset(ExampleDb, clone_id == 3138)

# Get all regions
extractVRegion(clone$sequence_alignment)

# Get single region
extractVRegion(clone$sequence_alignment, "fwr1")

# Get all CDRs
extractVRegion(clone$sequence_alignment, c("cdr1", "cdr2"))

# Get all FWs
extractVRegion(clone$sequence_alignment, c("fwr1", "fwr2", "fwr3"))
```

getAAMatrix

Build an AA distance matrix

Description

`getAAMatrix` returns a Hamming distance matrix for IUPAC ambiguous amino acid characters.

Usage

```
getAAMatrix(gap = 0)
```

Arguments

gap value to assign to characters in the set `c("-", ".")`.

Value

A matrix of amino acid character distances with row and column names indicating the character pair.

See Also

Creates an amino acid distance matrix for [seqDist](#). See [getDNAMatrix](#) for nucleotide distances.

Examples

```
getAAMatrix()
```

getDNAMatrix	<i>Build a DNA distance matrix</i>
--------------	------------------------------------

Description

`getDNAMatrix` returns a Hamming distance matrix for IUPAC ambiguous DNA characters with modifications for gap, `c("-", ".")`, and missing, `c("?")`, character values.

Usage

```
getDNAMatrix(gap = -1)
```

Arguments

gap value to assign to characters in the set `c("-", ".")`.

Value

A matrix of DNA character distances with row and column names indicating the character pair. By default, distances will be either 0 (equivalent), 1 (non-equivalent or missing), or -1 (gap).

See Also

Creates DNA distance matrix for [seqDist](#). See [getAAMatrix](#) for amino acid distances.

Examples

```
# Set gap characters to Inf distance
# Distinguishes gaps from Ns
getDNAMatrix()

# Set gap characters to 0 distance
# Makes gap characters equivalent to Ns
getDNAMatrix(gap=0)
```

getMRCA

Retrieve the first non-root node of a lineage tree

Description

getMRCA returns the set of lineage tree nodes with the minimum weighted or unweighted path length from the root (germline) of the lineage tree, allowing for exclusion of specific groups of nodes.

Usage

```
getMRCA(
  graph,
  path = c("distance", "steps"),
  root = "Germline",
  field = NULL,
  exclude = NULL
)
```

Arguments

graph	igraph object containing an annotated lineage tree.
path	string defining whether to use unweighted (steps) or weighted (distance) measures for determining the founder node set..
root	name of the root (germline) node.
field	annotation field to use for both unweighted path length exclusion and consideration as an MRCA node. If NULL do not exclude any nodes.
exclude	vector of annotation values in field to exclude from the potential MRCA set. If NULL do not exclude any nodes. Has no effect if field=NULL.

Value

A data.frame of the MRCA node(s) containing the columns:

- name: node name
- steps: path length as the number of nodes traversed
- distance: path length as the sum of edge weights

Along with additional columns corresponding to the annotations of the input graph.

See Also

Path lengths are determined with [getPathLengths](#).

Examples

```
# Define example graph
graph <- ExampleTrees[[23]]

# Use unweighted path length and do not exclude any nodes
getMRCA(graph, path="steps", root="Germline")

# Exclude nodes without an isotype annotation and use weighted path length
getMRCA(graph, path="distance", root="Germline", field="c_call", exclude=NA)
```

getPathLengths	<i>Calculate path lengths from the tree root</i>
----------------	--

Description

getPathLengths calculates the unweighted (number of steps) and weighted (distance) path lengths from the root of a lineage tree.

Usage

```
getPathLengths(graph, root = "Germline", field = NULL, exclude = NULL)
```

Arguments

graph	igraph object containing an annotated lineage tree.
root	name of the root (germline) node.
field	annotation field to use for exclusion of nodes from step count.
exclude	annotation values specifying which nodes to exclude from step count. If NULL consider all nodes. This does not affect the weighted (distance) path length calculation.

Value

A data.frame with columns:

- name: node name
- steps: path length as the number of nodes traversed
- distance: path length as the sum of edge weights

See Also

See [buildPhyloLineage](#) for generating input trees.

Examples

```
# Define example graph
graph <- ExampleTrees[[24]]

# Consider all nodes
getPathLengths(graph, root="Germline")

# Exclude nodes without an isotype annotation from step count
getPathLengths(graph, root="Germline", field="c_call", exclude=NA)
```

getPositionQuality *Get a data.frame with sequencing qualities per position*

Description

getPositionQuality takes a data.frame with sequence quality scores in the form of a strings of comma separated numeric values, split the quality scores values by ",", and returns a data.frame with the values for each position.

Usage

```
getPositionQuality(
  data,
  sequence_id = "sequence_id",
  sequence = "sequence_alignment",
  quality_num = "quality_alignment_num"
)
```

Arguments

data	data.frame containing sequence data.
sequence_id	column in data with sequence identifiers.
sequence	column in data with sequence data.
quality_num	column in data with quality scores (as strings of numeric values, comma separated) for sequence.

Value

data with one additional field with masked sequences. The name of this field is created concatenating sequence and '_masked'.

See Also

[readFastqDb](#) and [maskPositionsByQuality](#)

Examples

```
db <- airr::read_rearrangement(system.file("extdata", "example_quality.tsv", package="alakazam"))
fastq_file <- system.file("extdata", "example_quality.fastq", package="alakazam")
db <- readFastqDb(db, fastq_file, quality_offset=-33)
head(getPositionQuality(db))
```

getSegment

Get Ig segment allele, gene and family names

Description

getSegment performs generic matching of delimited segment calls with a custom regular expression. [getAllele](#), [getGene](#) and [getFamily](#) extract the allele, gene and family names, respectively, from a character vector of immunoglobulin (Ig) or TCR segment allele calls in IMGT format.

Usage

```
getSegment(  
  segment_call,  
  segment_regex,  
  first = TRUE,  
  collapse = TRUE,  
  strip_d = TRUE,  
  omit_nl = FALSE,  
  sep = ", "  
)
```

```
getAllele(  
  segment_call,  
  first = TRUE,  
  collapse = TRUE,  
  strip_d = TRUE,  
  omit_nl = FALSE,  
  sep = ", "  
)
```

```
getGene(  
  segment_call,  
  first = TRUE,  
  collapse = TRUE,  
  strip_d = TRUE,  
  omit_nl = FALSE,  
  sep = ", "  
)
```

```
getFamily(  
  segment_call,
```

```
    first = TRUE,  
    collapse = TRUE,  
    strip_d = TRUE,  
    omit_nl = FALSE,  
    sep = ","  
  )  
  
  getLocus(  
    segment_call,  
    first = TRUE,  
    collapse = TRUE,  
    strip_d = TRUE,  
    omit_nl = FALSE,  
    sep = ","  
  )  
  
  getChain(  
    segment_call,  
    first = TRUE,  
    collapse = TRUE,  
    strip_d = TRUE,  
    omit_nl = FALSE,  
    sep = ","  
  )
```

Arguments

segment_call	character vector containing segment calls delimited by commas.
segment_regex	string defining the segment match regular expression.
first	if TRUE return only the first call in segment_call; if FALSE return all calls delimited by commas.
collapse	if TRUE check for duplicates and return only unique segment assignments; if FALSE return all assignments (faster). Has no effect if first=TRUE.
strip_d	if TRUE remove the "D" from the end of gene annotations (denoting a duplicate gene in the locus); if FALSE do not alter gene names.
omit_nl	if TRUE remove non-localized (NL) genes from the result. Only applies at the gene or allele level.
sep	character defining both the input and output segment call delimiter.

Value

A character vector containing allele, gene or family names.

References

<https://www.imgt.org/>

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

```

# Light chain examples
kappa_call <- c("Homsap IGKV1D-39*01 F,Homsap IGKV1-39*02 F,Homsap IGKV1-39*01",
               "Homsap IGKJ5*01 F")

getAllele(kappa_call)
getAllele(kappa_call, first=FALSE)
getAllele(kappa_call, first=FALSE, strip_d=FALSE)

getGene(kappa_call)
getGene(kappa_call, first=FALSE)
getGene(kappa_call, first=FALSE, strip_d=FALSE)

getFamily(kappa_call)
getFamily(kappa_call, first=FALSE)
getFamily(kappa_call, first=FALSE, collapse=FALSE)
getFamily(kappa_call, first=FALSE, strip_d=FALSE)

getLocus(kappa_call)
getChain(kappa_call)

# Heavy chain examples
heavy_call <- c("Homsap IGHV1-69*01 F,Homsap IGHV1-69D*01 F",
               "Homsap IGHD1-1*01 F",
               "Homsap IGHJ1*01 F")

getAllele(heavy_call, first=FALSE)
getAllele(heavy_call, first=FALSE, strip_d=FALSE)

getGene(heavy_call, first=FALSE)
getGene(heavy_call, first=FALSE, strip_d=FALSE)

getFamily(heavy_call)
getLocus(heavy_call)
getChain(heavy_call)

# Filtering non-localized genes
nl_call <- c("IGHV3-NL1*01,IGHV3-30-3*01,IGHV3-30*01",
            "Homsap IGHV3-30*01 F,Homsap IGHV3-NL1*01 F",
            "IGHV1-NL1*01")

getAllele(nl_call, first=FALSE, omit_nl=TRUE)
getGene(nl_call, first=FALSE, omit_nl=TRUE)
getFamily(nl_call, first=FALSE, omit_nl=TRUE)

# Temporary designation examples
tmp_call <- c("IGHV9S3*01", "IGKV10S12*01")

```

```
getAllele(tmp_call)
getGene(tmp_call)
getFamily(tmp_call)
```

graphToPhylo	<i>Convert a tree in igraph graph format to ape phylo format.</i>
--------------	---

Description

graphToPhylo a tree in igraph graph format to ape phylo format.

Usage

```
graphToPhylo(graph)
```

Arguments

graph An igraph graph object.

Details

Convert from igraph graph object to ape phylo object. If graph object was previously rooted with the germline as the direct ancestor, this will re-attach the germline as a descendant node with a zero branch length to a new universal common ancestor (UCA) node and store the germline node ID in the germline attribute and UCA node number in the uca attribute. Otherwise these attributes will not be specified in the phylo object. Using phyloToGraph(phylo, germline=phylo\$germline) creates a graph object with the germline back as the direct ancestor. Tip and internal node names are stored in the tip.label and node.label vectors, respectively.

Value

A phylo object representing the input tree. Tip and internal node names are stored in the tip.label and node.label vectors, respectively.

References

1. Hoehn KB, Lunter G, Pybus OG - A Phylogenetic Codon Substitution Model for Antibody Lineages. *Genetics* 2017 206(1):417-427 <https://doi.org/10.1534/genetics.116.196303>
2. Hoehn KB, Vander Heiden JA, Zhou JQ, Lunter G, Pybus OG, Kleinsteinst SHK - Repertoire-wide phylogenetic models of B cell molecular evolution reveal evolutionary signatures of aging and vaccination. *bioRxiv* 2019 <https://doi.org/10.1101/558825>

Examples

```
## Not run:
library(igraph)
library(ape)

#convert to phylo
phylo = graphToPhylo(graph)

#plot tree using ape
plot(phylo,show.node.label=TRUE)

#store as newick tree
write.tree(phylo,file="tree.newick")

#read in tree from newick file
phylo_r = read.tree("tree.newick")

#convert to igraph
graph_r = phyloToGraph(phylo_r,germline="Germline")

#plot graph - same as before, possibly rotated
plot(graph_r,layout=layout_as_tree)

## End(Not run)
```

gravity

Calculates the hydrophobicity of amino acid sequences

Description

gravity calculates the Grand Average of Hydrophobicity (gravity) index of amino acid sequences using the method of Kyte & Doolittle. Non-informative positions are excluded, where non-informative is defined as any character in c("X", "-", ".", "*").

Usage

```
gravity(seq, hydrophathy = NULL)
```

Arguments

seq	vector of strings containing amino acid sequences.
hydrophathy	named numerical vector defining hydrophathy index values for each amino acid, where names are single-letter amino acid character codes. If NULL, then the Kyte & Doolittle scale is used.

Value

A vector of gravity scores for the sequence(s).

References

1. Kyte J, Doolittle RF. A simple method for displaying the hydropathic character of a protein. J Mol Biol. 157, 105-32 (1982).

See Also

For additional hydrophobicity indices see [aaindex](#).

Examples

```
# Default scale
seq <- c("CARDRSTPWRRGIASSTTVRTSW", "XXTQMYVRT")
gravy(seq)

# Use the Kidera et al, 1985 scores from the seqinr package
library(seqinr)
data(aaindex)
x <- aaindex[["KIDA850101"]][extract_itex]I
# Rename the score vector to use single-letter codes
names(x) <- translateStrings(names(x), ABBREV_AA)
# Calculate hydrophobicity
gravy(seq, hydrophathy=x)
```

gridPlot

Plot multiple ggplot objects

Description

Plots multiple ggplot objects in an equally sized grid.

Usage

```
gridPlot(..., ncol = 1)
```

Arguments

...	ggplot objects to plot.
ncol	number of columns in the plot.

References

Modified from: [http://www.cookbook-r.com/Graphs/Multiple_graphs_on_one_page_\(ggplot2\)](http://www.cookbook-r.com/Graphs/Multiple_graphs_on_one_page_(ggplot2))

See Also

[ggplot](#).

groupGenes

*Group sequences by gene assignment***Description**

groupGenes will group rows by shared V and J gene assignments, and optionally also by junction lengths. IGH:IGK/IGL, TRB:TRA, and TRD:TRG paired single-cell BCR/TCR sequencing and unpaired bulk sequencing (IGH, TRB, TRD chain only) are supported. In the case of ambiguous (multiple) gene assignments, the grouping may be specified to be a union across all ambiguous V and J gene pairs, analogous to single-linkage clustering (i.e., allowing for chaining).

Usage

```
groupGenes(
  data,
  v_call = "v_call",
  j_call = "j_call",
  junc_len = NULL,
  cell_id = NULL,
  locus = "locus",
  only_heavy = TRUE,
  first = FALSE
)
```

Arguments

data	data.frame containing sequence data.
v_call	name of the column containing the heavy/long chain V-segment allele calls.
j_call	name of the column containing the heavy/long chain J-segment allele calls.
junc_len	name of column containing the junction length. If NULL then 1-stage partitioning is performed considering only the V and J genes is performed. See Details for further clarification.
cell_id	name of the column containing cell identifiers or barcodes. If specified, grouping will be performed in single-cell mode with the behavior governed by the locus and only_heavy arguments. If set to NULL then the bulk sequencing data is assumed.
locus	name of the column containing locus information. Only applicable to single-cell data. Ignored if cell_id=NULL.
only_heavy	use only the IGH (BCR) or TRB/TRD (TCR) sequences for grouping. Only applicable to single-cell data. Ignored if cell_id=NULL.
first	if TRUE only the first call of the gene assignments is used. if FALSE the union of ambiguous gene assignments is used to group all sequences with any overlapping gene calls.

Details

To invoke single-cell mode the `cell_id` argument must be specified and the `locus` column must be correct. Otherwise, `groupGenes` will be run with bulk sequencing assumptions, using all input sequences regardless of the values in the `locus` column.

Values in the `locus` column must be one of `c("IGH", "IGI", "IGK", "IGL")` for BCR or `c("TRA", "TRB", "TRD", "TRG")` for TCR sequences. Otherwise, the function returns an error message and stops.

Under single-cell mode with paired chained sequences, there is a choice of whether grouping should be done by (a) using IGH (BCR) or TRB/TRD (TCR) sequences only or (b) using IGH plus IGK/IGL (BCR) or TRB/TRD plus TRA/TRG (TCR). This is governed by the `only_heavy` argument.

Specifying `junc_len` will force `groupGenes` to perform a 1-stage partitioning of the sequences/cells based on V gene, J gene, and junction length simultaneously. If `junc_len=NULL` (no column specified), then `groupGenes` performs only the first stage of a 2-stage partitioning in which sequences/cells are partitioned in the first stage based on V gene and J gene, and then in the second stage further splits the groups based on junction length (the second stage must be performed independently, as this only returns the first stage results).

In the input data, the `v_call`, `j_call`, `cell_id`, and `locus` columns, if present, must be of type character (as opposed to factor).

It is assumed that ambiguous gene assignments are separated by commas.

All rows containing NA values in any of the `v_call`, `j_call`, and `junc_len` (if `junc_len != NULL`) columns will be removed. A warning will be issued when a row containing an NA is removed.

Value

Returns a modified data.frame with disjoint union indices in a new `vj_group` column.

If `junc_len` is supplied, the grouping this `vj_group` will have been based on V, J, and junction length simultaneously. However, the output column name will remain `vj_group`.

The output `v_call`, `j_call`, `cell_id`, and `locus` columns will be converted to type character if they were of type factor in the input data.

Expectations for single-cell data

Single-cell paired chain data assumptions:

- every row represents a sequence (chain).
- heavy/long and light/short chains of the same cell are linked by `cell_id`.
- the value in `locus` column indicates whether the chain is the heavy/long or light/short chain.
- each cell possibly contains multiple heavy/long and/or light/short chains.
- every chain has its own V(D)J annotation, in which ambiguous V(D)J annotations, if any, are separated by a comma.

Single-cell example:

- A cell has 1 heavy chain and 2 light chains.

- There should be 3 rows corresponding to this cell.
- One of the light chains may have an ambiguous V annotation which looks like "Homsap IGKV1-39*01 F,Homsap IGKV1D-39*01 F".

Examples

```
# Group by genes
db <- groupGenes(ExampleDb)
head(db$vj_group)
```

IMGT_REGIONS	<i>IMGT V-segment regions</i>
--------------	-------------------------------

Description

A list defining the boundaries of V-segment framework regions (FWRs) and complementarity determining regions (CDRs) for IMGT-gapped immunoglobulin (Ig) nucleotide sequences according to the IMGT numbering scheme.

Usage

```
IMGT_REGIONS
```

Format

A list with regions named one of c("fwr1", "cdr1", "fwr2", "cdr2", "fwr3") with values containing a numeric vector of length two defining the c(start, end) positions of the named region.

References

<https://www.imgt.org/>

isValidAASeq	<i>Validate amino acid sequences</i>
--------------	--------------------------------------

Description

isValidAASeq checks that a set of sequences are valid non-ambiguous amino acid sequences. A sequence is considered valid if it contains only characters in the the non-ambiguous IUPAC character set or any characters in c("X", ".", "-", "*").

Usage

```
isValidAASeq(seq)
```

Arguments

seq character vector of sequences to check.

Value

A logical vector with TRUE for each valid amino acid sequences and FALSE for each invalid sequence.

See Also

See [ABBREV_AA](#) for the set of non-ambiguous amino acid characters. See [IUPAC_AA](#) for the full set of ambiguous amino acid characters.

Examples

```
seq <- c("CARDRSTPWRRGIASSTTVRTSW", "XXTQMYVR--XX", "CARJ", "10")
isValidAASeq(seq)
```

IUPAC_CODES

IUPAC ambiguous characters

Description

A translation list mapping IUPAC ambiguous characters code to corresponding nucleotide amino acid characters.

Usage

IUPAC_DNA

IUPAC_AA

DNA_IUPAC

Format

A list with single character codes as names and values containing character vectors that define the set of standard characters that match to each each ambiguous character.

- IUPAC_DNA: DNA ambiguous character translations.
- IUPAC_AA: Amino acid ambiguous character translations.
- DNA_IUPAC: Ordered DNA to ambiguous characters

An object of class `list` of length 15.

An object of class `list` of length 25.

An object of class `list` of length 15.

junctionAlignment *Calculate junction region alignment properties*

Description

junctionAlignment determines the number of deleted germline nucleotides in the junction region and the number of V gene and J gene nucleotides in the CDR3.

Usage

```
junctionAlignment(
  data,
  germline_db,
  v_call = "v_call",
  d_call = "d_call",
  j_call = "j_call",
  v_germline_start = "v_germline_start",
  v_germline_end = "v_germline_end",
  d_germline_start = "d_germline_start",
  d_germline_end = "d_germline_end",
  j_germline_start = "j_germline_start",
  j_germline_end = "j_germline_end",
  np1_length = "np1_length",
  np2_length = "np2_length",
  junction = "junction",
  junction_length = "junction_length",
  sequence_alignment = "sequence_alignment"
)
```

Arguments

data	data.frame containing sequence data.
germline_db	reference germline database for the V, D and J genes. in data
v_call	V gene assignment column.
d_call	D gene assignment column.
j_call	J gene assignment column.
v_germline_start	column containing the start position of the alignment in the V reference germline.
v_germline_end	column containing the end position of the alignment in the V reference germline.
d_germline_start	column containing the start position of the alignment in the D reference germline.
d_germline_end	column containing the start position of the alignment in the D reference germline.
j_germline_start	column containing the start position of the alignment in the J reference germline.

j_germline_end	column containing the start position of the alignment in the J reference germline.
np1_length	combined length of the N and P regions between the V and D regions (heavy chain) or V and J regions (light chain).
np2_length	combined length of the N and P regions between the D and J regions (heavy chain).
junction	column containing the junction sequence.
junction_length	column containing the length of the junction region in nucleotides.
sequence_alignment	column containing the aligned sequence.

Value

A modified input data.frame with the following additional columns storing junction alignment information:

1. e3v_length: number of 3' V germline nucleotides deleted.
2. e5d_length: number of 5' D germline nucleotides deleted.
3. e3d_length: number of 3' D germline nucleotides deleted.
4. e5j_length: number of 5' J germline nucleotides deleted.
5. v_cdr3_length: number of sequence_alignment V nucleotides in the CDR3.
6. j_cdr3_length: number of sequence_alignment J nucleotides in the CDR3.

Examples

```
germline_db <- list(
  "IGHV3-11*05"="CAGGTGCAGCTGGTGGAGTCTGGGGGA...GGCTTGGTCAAGCCTGGAGGGTCCCTGAGACT
  CTCCTGTGCAGCCTCTGGATTCACCTTC.....AGTGACTACTACATGAGCTGGATCCGCCAGGCTCCAG
  GGAAGGGGCTGGAGTGGGTTTCATACATTAGTAGTAGT.....AGTAGTTACACAAACTACGCAGACTCTGTGAAG
  ...GGCCGATTCACCATCTCCAGAGACAACGCCAAGAAGAACTACTGTATCTGCAAATGAACAGCCTGAGAGCCGAGGA
  CACGGCCGTGTATTACTGTGCGAGAGA",
  "IGHD3-10*01"="GTATTACTATGGTTCGGGGAGTTATTATAAC",
  "IGHJ5*02"="AACACTGGTTCGACCCCTGGGGCCAGGGAACCTGGTCACCGTCTCCTCAG"
)

db <- junctionAlignment(SingleDb, germline_db)
```

makeChangeoClone

Generate a ChangeoClone object for lineage construction

Description

makeChangeoClone takes a data.frame with AIRR or Change-O style columns as input and masks gap positions, masks ragged ends, removes duplicate sequences, and merges annotations associated with duplicate sequences. It returns a ChangeoClone object which serves as input for lineage reconstruction.

Usage

```

makeChangeoClone(
  data,
  id = "sequence_id",
  seq = "sequence_alignment",
  germ = "germline_alignment",
  v_call = "v_call",
  j_call = "j_call",
  junc_len = "junction_length",
  clone = "clone_id",
  mask_char = "N",
  max_mask = 0,
  pad_end = FALSE,
  text_fields = NULL,
  num_fields = NULL,
  seq_fields = NULL,
  add_count = TRUE,
  verbose = FALSE
)

```

Arguments

data	data.frame containing the AIRR or Change-O data for a clone. See Details for the list of required columns and their default values.
id	name of the column containing sequence identifiers.
seq	name of the column containing observed DNA sequences. All sequences in this column must be multiple aligned.
germ	name of the column containing germline DNA sequences. All entries in this column should be identical for any given clone, and they must be multiple aligned with the data in the seq column.
v_call	name of the column containing V-segment allele assignments. All entries in this column should be identical to the gene level.
j_call	name of the column containing J-segment allele assignments. All entries in this column should be identical to the gene level.
junc_len	name of the column containing the length of the junction as a numeric value. All entries in this column should be identical for any given clone.
clone	name of the column containing the identifier for the clone. All entries in this column should be identical.
mask_char	character to use for masking and padding.
max_mask	maximum number of characters to mask at the leading and trailing sequence ends. If NULL then the upper masking bound will be automatically determined from the maximum number of observed leading or trailing Ns amongst all sequences. If set to 0 (default) then masking will not be performed.
pad_end	if TRUE pad the end of each sequence with mask_char to make every sequence the same length.

<code>text_fields</code>	text annotation columns to retain and merge during duplicate removal.
<code>num_fields</code>	numeric annotation columns to retain and sum during duplicate removal.
<code>seq_fields</code>	sequence annotation columns to retain and collapse during duplicate removal. Note, this is distinct from the <code>seq</code> and <code>germ</code> arguments, which contain the primary sequence data for the clone and should not be repeated in this argument.
<code>add_count</code>	if TRUE add an additional annotation column called <code>collapse_count</code> during duplicate removal that indicates the number of sequences that were collapsed.
<code>verbose</code>	passed on to <code>collapseDuplicates</code> . If TRUE, report the numbers of input, discarded and output sequences; otherwise, process sequences silently.

Details

The input `data.frame` (`data`) must columns for each of the required column name arguments: `id`, `seq`, `germ`, `v_call`, `j_call`, `junc_len`, and `clone`. The default values are as follows:

- `id = "sequence_id"`: unique sequence identifier.
- `seq = "sequence_alignment"`: IMGT-gapped sample sequence.
- `germ = "germline_alignment"`: IMGT-gapped germline sequence.
- `v_call = "v_call"`: V segment allele call.
- `j_call = "j_call"`: J segment allele call.
- `junc_len = "junction_length"`: junction sequence length.
- `clone = "clone_id"`: clone identifier.

Additional annotation columns specified in the `text_fields`, `num_fields` or `seq_fields` arguments will be retained in the `data` slot of the return object, but are not required. If the input `data.frame` data already contains a column named `sequence`, which is not used as the `seq` argument, then that column will not be retained.

The default columns are IMGT-gapped sequence columns, but this is not a requirement. However, all sequences (both observed and germline) must be multiple aligned using some scheme for both proper duplicate removal and lineage reconstruction.

The value for the germline sequence, V-segment gene call, J-segment gene call, junction length, and clone identifier are determined from the first entry in the `germ`, `v_call`, `j_call`, `junc_len` and `clone` columns, respectively. For any given clone, each value in these columns should be identical.

Value

A [ChangeoClone](#) object containing the modified clone.

See Also

Executes in order [maskSeqGaps](#), [maskSeqEnds](#), [padSeqEnds](#), and [collapseDuplicates](#). Returns a [ChangeoClone](#) object which serves as input to [buildPhylipLineage](#).

Examples

```
# Example data
db <- data.frame(sequence_id=LETTERS[1:4],
                 sequence_alignment=c("CCCCTGGG", "CCCCTGGN", "NAACTGGN", "NNNCTGNN"),
                 germline_alignment="CCCCAGGG",
                 v_call="Homsap IGKV1-39*01 F",
                 j_call="Homsap IGKJ5*01 F",
                 junction_length=2,
                 clone_id=1,
                 c_call=c("IGHM", "IGHG", "IGHG", "IGHA"),
                 duplicate_count=1:4,
                 stringsAsFactors=FALSE)

# Without end masking
makeChangeoClone(db, text_fields="c_call", num_fields="duplicate_count")

# With end masking
makeChangeoClone(db, max_mask=3, text_fields="c_call", num_fields="duplicate_count")
```

makeTempDir

Create a temporary folder

Description

makeTempDir creates a randomly named temporary folder in the system temp location.

Usage

```
makeTempDir(prefix)
```

Arguments

prefix prefix name for the folder.

Value

The path to the temporary folder.

See Also

This is just a wrapper for [tempfile](#) and [dir.create](#).

Examples

```
makeTempDir("Clone50")
```

`maskPositionsByQuality`*Mask sequence positions with low quality*

Description

`maskPositionsByQuality` will replace positions that have a sequencing quality score lower than `min_quality` with an "N" character.

Usage

```
maskPositionsByQuality(  
  data,  
  min_quality = 70,  
  sequence = "sequence_alignment",  
  quality_num = "quality_alignment_num"  
)
```

Arguments

<code>data</code>	data.frame containing sequence data.
<code>min_quality</code>	minimum quality score. Positions with sequencing quality less than <code>min_qual</code> will be masked.
<code>sequence</code>	column in data with sequence data to be masked.
<code>quality_num</code>	column in data with quality scores (a string of numeric values, comma separated) that can be used to mask sequence.

Value

Modified data data.frame with an additional field containing quality masked sequences. The name of this field is created concatenating the sequence name and "_masked".

See Also

[readFastqDb](#) and [getPositionQuality](#)

Examples

```
db <- airr::read_rearrangement(system.file("extdata", "example_quality.tsv", package="alakazam"))  
fastq_file <- system.file("extdata", "example_quality.fastq", package="alakazam")  
db <- readFastqDb(db, fastq_file, quality_offset=-33)  
maskPositionsByQuality(db, min_quality=90, quality_num="quality_alignment_num")
```

maskSeqEnds	<i>Masks ragged leading and trailing edges of aligned DNA sequences</i>
-------------	---

Description

maskSeqEnds takes a vector of DNA sequences, as character strings, and replaces the leading and trailing characters with "N" characters to create a sequence vector with uniformly masked outer sequence segments.

Usage

```
maskSeqEnds(seq, mask_char = "N", max_mask = NULL, trim = FALSE)
```

Arguments

seq	character vector of DNA sequence strings.
mask_char	character to use for masking.
max_mask	the maximum number of characters to mask. If set to 0 then no masking will be performed. If set to NULL then the upper masking bound will be automatically determined from the maximum number of observed leading or trailing "N" characters amongst all strings in seq.
trim	if TRUE leading and trailing characters will be cut rather than masked with "N" characters.

Value

A modified seq vector with masked (or optionally trimmed) sequences.

See Also

See [maskSeqGaps](#) for masking internal gaps. See [padSeqEnds](#) for padding sequence of unequal length.

Examples

```
# Default behavior uniformly masks ragged ends
seq <- c("CCCCTGGG", "NAACTGGN", "NNNCTGNN")
maskSeqEnds(seq)

# Does nothing
maskSeqEnds(seq, max_mask=0)

# Cut ragged sequence ends
maskSeqEnds(seq, trim=TRUE)

# Set max_mask to limit extent of masking and trimming
maskSeqEnds(seq, max_mask=1)
maskSeqEnds(seq, max_mask=1, trim=TRUE)
```

```
# Mask dashes instead of Ns
seq <- c("CCCCTGGG", "-AACTGG-", "---CTG--")
maskSeqEnds(seq, mask_char="-")
```

maskSeqGaps

Masks gap characters in DNA sequences

Description

maskSeqGaps substitutes gap characters, c("-", "."), with "N" in a vector of DNA sequences.

Usage

```
maskSeqGaps(seq, mask_char = "N", outer_only = FALSE)
```

Arguments

seq	character vector of DNA sequence strings.
mask_char	character to use for masking.
outer_only	if TRUE replace only contiguous leading and trailing gaps; if FALSE replace all gap characters.

Value

A modified seq vector with "N" in place of c("-", ".") characters.

See Also

See [maskSeqEnds](#) for masking ragged edges.

Examples

```
# Mask with Ns
maskSeqGaps(c("ATG-C", "CC..C"))
maskSeqGaps("--ATG-C-")
maskSeqGaps("--ATG-C-", outer_only=TRUE)

# Mask with dashes
maskSeqGaps(c("ATG-C", "CC..C"), mask_char="-")
```

MRCATest-class *S4 class defining edge significance*

Description

MRCATest defines the significance of enrichment for annotations appearing at the MRCA of the tree.

Usage

```
## S4 method for signature 'MRCATest'  
print(x)  
  
## S4 method for signature 'MRCATest,missing'  
plot(x, y, ...)
```

Arguments

x	MRCATest object.
y	ignored.
...	arguments to pass to plotMRCATest .

Slots

tests data.frame describing the significance test results with columns:

- annotation: annotation value.
- count: observed count of MRCA positions with the given annotation.
- expected: expected mean count of MRCA occurrence for the annotation.
- pvalue: one-sided p-value for the hypothesis that the observed annotation abundance is greater than expected.

permutations data.frame containing the raw permutation test data with columns:

- annotation: annotation value.
- count: count of MRCA positions with the given annotation.
- iter: numerical index define which permutation realization each observation corresponds to.

nperm number of permutation realizations.

nonsquareDist *Calculate pairwise distances between sequences*

Description

nonsquareDist calculates all pairwise distance between a set of sequences and a subset of it.

Usage

```
nonsquareDist(seq, indx, dist_mat = getDNAMatrix())
```

Arguments

seq	character vector containing a DNA sequences. The sequence vector needs to be named.
indx	numeric vector containing the indices (a subset of indices of seq).
dist_mat	Character distance matrix. Defaults to a Hamming distance matrix returned by getDNAMatrix . If gap characters, c("-", "."), are assigned a value of -1 in dist_mat then contiguous gaps of any run length, which are not present in both sequences, will be counted as a distance of 1. Meaning, indels of any length will increase the sequence distance by 1. Gap values other than -1 will return a distance that does not consider indels as a special case.

Value

A matrix of numerical distance between each entry in seq and sequences specified by indx indices.

Note that the input subsampled indices will be ordered ascendingly. Therefore, it is necessary to assign unique names to the input sequences, seq, to recover the input order later. Row and column names will be added accordingly.

Amino acid distance matrix may be built with [getAAMatrix](#). Uses [seqDist](#) for calculating distances between pairs. See [pairwiseEqual](#) for generating an equivalence matrix.

Examples

```
# Gaps will be treated as Ns with a gap=0 distance matrix
seq <- c(A="ATGGC", B="ATGGG", C="ATGGG", D="AT--C")
pairwiseDist(seq,
             dist_mat=getDNAMatrix(gap=0))

nonsquareDist(seq, indx=c(1,3),
             dist_mat=getDNAMatrix(gap=0))
```

padSeqEnds

Pads ragged ends of aligned DNA sequences

Description

padSeqEnds takes a vector of DNA sequences, as character strings, and appends the ends of each sequence with an appropriate number of "N" characters to create a sequence vector with uniform lengths.

Usage

```
padSeqEnds(seq, len = NULL, start = FALSE, pad_char = "N", mod3 = TRUE)
```

Arguments

seq	character vector of DNA sequence strings.
len	length to pad to. Only applies if longer than the maximum length of the data in seq.
start	if TRUE pad the beginning of each sequence instead of the end.
pad_char	character to use for padding.
mod3	if TRUE pad sequences to be of length multiple three.

Value

A modified seq vector with padded sequences.

See Also

See [maskSeqEnds](#) for creating uniform masking from existing masking.

Examples

```
# Default behavior uniformly pads ragged ends
seq <- c("CCCCTGGG", "ACCCTG", "CCCC")
padSeqEnds(seq)

# Pad to fixed length
padSeqEnds(seq, len=15)

# Add padding to the beginning of the sequences instead of the ends
padSeqEnds(seq, start=TRUE)
padSeqEnds(seq, len=15, start=TRUE)
```

pairwiseDist	<i>Calculate pairwise distances between sequences</i>
--------------	---

Description

pairwiseDist calculates all pairwise distance between a set of sequences.

Usage

```
pairwiseDist(seq, dist_mat = getDNAMatrix())
```

Arguments

seq	character vector containing a DNA sequences.
dist_mat	Character distance matrix. Defaults to a Hamming distance matrix returned by getDNAMatrix . If gap characters, c("-", "."), are assigned a value of -1 in dist_mat then contiguous gaps of any run length, which are not present in both sequences, will be counted as a distance of 1. Meaning, indels of any length will increase the sequence distance by 1. Gap values other than -1 will return a distance that does not consider indels as a special case.

Value

A matrix of numerical distance between each entry in seq. If seq is a named vector, row and columns names will be added accordingly.

Amino acid distance matrix may be built with [getAAMatrix](#). Uses [seqDist](#) for calculating distances between pairs. See [pairwiseEqual](#) for generating an equivalence matrix.

Examples

```
# Gaps will be treated as Ns with a gap=0 distance matrix
pairwiseDist(c(A="ATGGC", B="ATGGG", C="ATGGG", D="AT--C"),
             dist_mat=getDNAMatrix(gap=0))

# Gaps will be treated as universally non-matching characters with gap=1
pairwiseDist(c(A="ATGGC", B="ATGGG", C="ATGGG", D="AT--C"),
             dist_mat=getDNAMatrix(gap=1))

# Gaps of any length will be treated as single mismatches with a gap=-1 distance matrix
pairwiseDist(c(A="ATGGC", B="ATGGG", C="ATGGG", D="AT--C"),
             dist_mat=getDNAMatrix(gap=-1))
```

pairwiseEqual	<i>Calculate pairwise equivalence between sequences</i>
---------------	---

Description

pairwiseEqual determined pairwise equivalence between a pairs in a set of sequences, excluding ambiguous positions (Ns and gaps).

Usage

```
pairwiseEqual(seq)
```

Arguments

seq character vector containing a DNA sequences.

Value

A logical matrix of equivalence between each entry in seq. Values are TRUE when sequences are equivalent and FALSE when they are not.

See Also

Uses [seqEqual](#) for testing equivalence between pairs. See [pairwiseDist](#) for generating a sequence distance matrix.

Examples

```
# Gaps and Ns will match any character
seq <- c(A="ATGGC", B="ATGGG", C="ATGGG", D="AT--C", E="NTGGG")
d <- pairwiseEqual(seq)
rownames(d) <- colnames(d) <- seq
d
```

permuteLabels	<i>Permute the node labels of a tree</i>
---------------	--

Description

permuteLabels permutes the node annotations of a lineage tree.

Usage

```
permuteLabels(graph, field, exclude = c("Germline", NA))
```


Arguments

graph	igraph object containing an annotated lineage tree.
field	string defining the annotation field to permute.
exclude	vector of strings defining field values to exclude from permutation.

Value

A modified igraph object with vertex annotations permuted.

See Also

[testEdges](#).

Examples

```
# Define and plot example graph
library(igraph)
graph <- ExampleTrees[[23]]
plot(graph, layout=layout_as_tree, vertex.label=V(graph)$c_call,
      vertex.size=50, edge.arrow.mode=0, vertex.color="grey80")

# Permute annotations and plot new tree
g <- permuteLabels(graph, "c_call")
plot(g, layout=layout_as_tree, vertex.label=V(g)$c_call,
      vertex.size=50, edge.arrow.mode=0, vertex.color="grey80")
```

phyloToGraph

Convert a tree in ape phylo format to igraph graph format.

Description

phyloToGraph converts a tree in phylo format to and graph format.

Usage

```
phyloToGraph(phylo, germline = "Germline")
```

Arguments

phylo	An ape phylo object.
germline	If specified, places specified tip sequence as the direct ancestor of the tree

Details

Convert from phylo to graph object. Uses the node.label vector to label internal nodes. Nodes may rotate but overall topology will remain constant.

Value

A graph object representing the input tree.

References

1. Hoehn KB, Lunter G, Pybus OG - A Phylogenetic Codon Substitution Model for Antibody Lineages. *Genetics* 2017 206(1):417-427 <https://doi.org/10.1534/genetics.116.196303>
2. Hoehn KB, Vander Heiden JA, Zhou JQ, Lunter G, Pybus OG, Kleinstejn SHK - Repertoire-wide phylogenetic models of B cell molecular evolution reveal evolutionary signatures of aging and vaccination. *bioRxiv* 2019 <https://doi.org/10.1101/558825>

Examples

```
## Not run:
library(igraph)
library(ape)

#convert to phylo
phylo = graphToPhylo(graph)

#plot tree using ape
plot(phylo,show.node.label=TRUE)

#store as newick tree
write.tree(phylo,file="tree.newick")

#read in tree from newick file
phylo_r = read.tree("tree.newick")

#convert to igraph
graph_r = phyloToGraph(phylo_r,germline="Germline")

#plot graph - same as before, possibly rotated
plot(graph_r,layout=layout_as_tree)

## End(Not run)
```

plotAbundanceCurve *Plots a clonal abundance distribution*

Description

plotAbundanceCurve plots the results from estimating the complete clonal relative abundance distribution. The distribution is plotted as a log rank abundance distribution.

Usage

```
plotAbundanceCurve(  
  data,  
  colors = NULL,  
  main_title = "Rank Abundance",  
  legend_title = NULL,  
  xlim = NULL,  
  ylim = NULL,  
  annotate = c("none", "depth"),  
  silent = FALSE,  
  ...  
)
```

Arguments

<code>data</code>	AbundanceCurve object returned by estimateAbundance .
<code>colors</code>	named character vector whose names are values in the group column of data and whose values are colors to assign to those group names.
<code>main_title</code>	string specifying the plot title.
<code>legend_title</code>	string specifying the legend title.
<code>xlim</code>	numeric vector of two values specifying the <code>c(lower, upper)</code> x-axis limits.
<code>ylim</code>	numeric vector of two values specifying the <code>c(lower, upper)</code> y-axis limits.
<code>annotate</code>	string defining whether to added values to the group labels of the legend. When "none" (default) is specified no annotations are added. Specifying ("depth") adds sequence counts to the labels.
<code>silent</code>	if TRUE do not draw the plot and just return the ggplot2 object; if FALSE draw the plot.
<code>...</code>	additional arguments to pass to <code>ggplot2::theme</code> .

Value

A ggplot object defining the plot.

See Also

See [AbundanceCurve](#) for the input object and [estimateAbundance](#) for generating the input abundance distribution. Plotting is performed with [ggplot](#).

Examples

```
# Estimate abundance by sample and plot  
abund <- estimateAbundance(ExampleDb, group="sample_id", nboot=100)  
plotAbundanceCurve(abund, legend_title="Sample")
```

plotDiversityCurve *Plot the results of alphaDiversity*

Description

plotDiversityCurve plots a DiversityCurve object.

Usage

```
plotDiversityCurve(
  data,
  colors = NULL,
  main_title = "Diversity",
  legend_title = "Group",
  log_x = FALSE,
  log_y = FALSE,
  xlim = NULL,
  ylim = NULL,
  annotate = c("none", "depth"),
  score = c("diversity", "evenness"),
  silent = FALSE,
  ...
)
```

Arguments

data	DiversityCurve object returned by alphaDiversity .
colors	named character vector whose names are values in the group column of the data slot of data, and whose values are colors to assign to those group names.
main_title	string specifying the plot title.
legend_title	string specifying the legend title.
log_x	if TRUE then plot q on a log scale; if FALSE plot on a linear scale.
log_y	if TRUE then plot the diversity/evenness scores on a log scale; if FALSE plot on a linear scale.
xlim	numeric vector of two values specifying the $c(\text{lower}, \text{upper})$ x-axis limits.
ylim	numeric vector of two values specifying the $c(\text{lower}, \text{upper})$ y-axis limits.
annotate	string defining whether to added values to the group labels of the legend. When "none" (default) is specified no annotations are added. Specifying ("depth") adds sequence counts to the labels.
score	one of "diversity" or "evenness" specifying which score to plot on the y-axis.
silent	if TRUE do not draw the plot and just return the ggplot2 object; if FALSE draw the plot.
...	additional arguments to pass to <code>ggplot2::theme</code> .

Value

A ggplot object defining the plot.

See Also

See [alphaDiversity](#) and [alphaDiversity](#) for generating [DiversityCurve](#) objects for input. Plotting is performed with [ggplot](#).

Examples

```
# Calculate diversity
div <- alphaDiversity(ExampleDb, group="sample_id", nboot=100)

# Plot diversity
plotDiversityCurve(div, legend_title="Sample")

#' # Plot diversity
plotDiversityCurve(div, legend_title="Sample", score="evenness")
```

plotDiversityTest	<i>Plot the results of diversity testing</i>
-------------------	--

Description

plotDiversityTest plots summary data for a DiversityCurve object with mean and a line range indicating plus/minus one standard deviation.

Usage

```
plotDiversityTest(
  data,
  q,
  colors = NULL,
  main_title = "Diversity",
  legend_title = "Group",
  log_d = FALSE,
  annotate = c("none", "depth"),
  silent = FALSE,
  ...
)
```

Arguments

data	DiversityCurve object returned by alphaDiversity .
q	diversity order to plot the test for.

colors	named character vector whose names are values in the group column of the data slot of data, and whose values are colors to assign to those group names.
main_title	string specifying the plot title.
legend_title	string specifying the legend title.
log_d	if TRUE then plot the diversity scores D on a log scale; if FALSE plot on a linear scale.
annotate	string defining whether to added values to the group labels of the legend. When "none" (default) is specified no annotations are added. Specifying ("depth") adds sequence counts to the labels.
silent	if TRUE do not draw the plot and just return the ggplot2 object; if FALSE draw the plot.
...	additional arguments to pass to ggplot2::theme.

Value

A ggplot object defining the plot.

See Also

See [alphaDiversity](#) for generating input. Plotting is performed with [ggplot](#).

Examples

```
# Calculate diversity
div <- alphaDiversity(ExampleDb, group="sample_id", min_q=0, max_q=2, step_q=1, nboot=100)

# Plot results at q=0 (equivalent to species richness)
plotDiversityTest(div, 0, legend_title="Sample")

# Plot results at q=2 (equivalent to Simpson's index)
plotDiversityTest(div, q=2, legend_title="Sample")
```

plotEdgeTest

Plot the results of an edge permutation test

Description

plotEdgeTest plots the results of an edge permutation test performed with testEdges as either a histogram or cumulative distribution function.

Usage

```
plotEdgeTest(
  data,
  color = "black",
  main_title = "Edge Test",
  style = c("histogram", "cdf"),
  silent = FALSE,
  ...
)
```

Arguments

data	EdgeTest object returned by testEdges .
color	color of the histogram or lines.
main_title	string specifying the plot title.
style	type of plot to draw. One of: <ul style="list-style-type: none"> • "histogram": histogram of the edge count distribution with a red dotted line denoting the observed value. • "cdf": cumulative distribution function of edge counts with a red dotted line denoting the observed value and a blue dotted line indicating the p-value.
silent	if TRUE do not draw the plot and just return the <code>ggplot2</code> object; if FALSE draw the plot.
...	additional arguments to pass to <code>ggplot2::theme</code> .

Value

A `ggplot` object defining the plot.

See Also

See [testEdges](#) for performing the test.

Examples

```
# Define example tree set
graphs <- ExampleTrees[1-10]

# Perform edge test on isotypes
x <- testEdges(graphs, "c_call", nperm=10)

# Plot
plotEdgeTest(x, color="steelblue", style="hist")
plotEdgeTest(x, style="cdf")
```

`plotMRCATest`*Plot the results of a founder permutation test*

Description

`plotMRCATest` plots the results of a founder permutation test performed with `testMRCA`.

Usage

```
plotMRCATest(  
  data,  
  color = "black",  
  main_title = "MRCA Test",  
  style = c("histogram", "cdf"),  
  silent = FALSE,  
  ...  
)
```

Arguments

<code>data</code>	MRCATest object returned by <code>testMRCA</code> .
<code>color</code>	color of the histogram or lines.
<code>main_title</code>	string specifying the plot title.
<code>style</code>	type of plot to draw. One of: <ul style="list-style-type: none">• "histogram": histogram of the annotation count distribution with a red dotted line denoting the observed value.• "cdf": cumulative distribution function of annotation counts with a red dotted line denoting the observed value and a blue dotted line indicating the p-value.
<code>silent</code>	if TRUE do not draw the plot and just return the <code>ggplot2</code> object; if FALSE draw the plot.
<code>...</code>	additional arguments to pass to <code>ggplot2::theme</code> .

Value

A `ggplot` object defining the plot.

See Also

See [testEdges](#) for performing the test.

Examples

```
# Define example tree set
graphs <- ExampleTrees[1-10]

# Perform MRCA test on isotypes
x <- testMRCA(graphs, "c_call", nperm=10)

# Plot
plotMRCATest(x, color="steelblue", style="hist")
plotMRCATest(x, style="cdf")
```

plotSubtrees	<i>Plots subtree statistics for multiple trees</i>
--------------	--

Description

plotSubtree plots distributions of normalized subtree statistics for a set of lineage trees, broken down by annotation value.

Usage

```
plotSubtrees(
  graphs,
  field,
  stat,
  root = "Germline",
  exclude = c("Germline", NA),
  colors = NULL,
  main_title = "Subtrees",
  legend_title = "Annotation",
  style = c("box", "violin"),
  silent = FALSE,
  ...
)
```

Arguments

graphs	list of igraph objects containing annotated lineage trees.
field	string defining the annotation field.
stat	string defining the subtree statistic to plot. One of: <ul style="list-style-type: none"> • outdegree: distribution of normalized node outdegrees. • size: distribution of normalized subtree sizes. • depth: distribution of subtree depths.

	<ul style="list-style-type: none"> • <code>pathlength</code>: distribution of maximum pathlength beneath nodes.
<code>root</code>	name of the root (germline) node.
<code>exclude</code>	vector of strings defining field values to exclude from plotting.
<code>colors</code>	named vector of colors for values in <code>field</code> , with names defining annotation names <code>field</code> column and values being colors. Also controls the order in which values appear on the plot. If <code>NULL</code> alphabetical ordering and a default color palette will be used.
<code>main_title</code>	string specifying the plot title.
<code>legend_title</code>	string specifying the legend title.
<code>style</code>	string specifying the style of plot to draw. One of: <ul style="list-style-type: none"> • <code>"histogram"</code>: histogram of the annotation count distribution with a red dotted line denoting the observed value. • <code>"cdf"</code>: cumulative distribution function of annotation counts with a red dotted line denoting the observed value and a blue dotted line indicating the p-value.
<code>silent</code>	if <code>TRUE</code> do not draw the plot and just return the <code>ggplot2</code> object; if <code>FALSE</code> draw the plot.
<code>...</code>	additional arguments to pass to <code>ggplot2::theme</code> .

Value

A `ggplot` object defining the plot.

See Also

Subtree statistics are calculated with [summarizeSubtrees](#).

Examples

```
# Define example tree set
graphs <- ExampleTrees[1-10]

# Violin plots of node outdegree by sample
plotSubtrees(graphs, "sample_id", "out", style="v")

# Violin plots of subtree size by sample
plotSubtrees(graphs, "sample_id", "size", style="v")

# Boxplot of node depth by isotype
plotSubtrees(graphs, "c_call", "depth", style="b")
```

polar	<i>Calculates the average polarity of amino acid sequences</i>
-------	--

Description

polar calculates the average polarity score of amino acid sequences. Non-informative positions are excluded, where non-informative is defined as any character in `c("X", "-", ".", "*")`.

Usage

```
polar(seq, polarity = NULL)
```

Arguments

seq	vector of strings containing amino acid sequences.
polarity	named numerical vector defining polarity scores for each amino acid, where names are single-letter amino acid character codes. If NULL, then the Grantham, 1974 scale is used.

Value

A vector of bulkiness scores for the sequence(s).

References

1. Grantham R. Amino acid difference formula to help explain protein evolution. *Science* 185, 862-864 (1974).

See Also

For additional size related indices see [aaindex](#).

Examples

```
# Default scale
seq <- c("CARDRSTPWRRGIASSTTVRTSW", "XXTQMYVRT")
polar(seq)

# Use the Zimmerman et al, 1968 polarity scale from the seqinr package
library(seqinr)
data(aaindex)
x <- aaindex[["ZIMJ680103"]][extract_itex]I
# Rename the score vector to use single-letter codes
names(x) <- translateStrings(names(x), ABBREV_AA)
# Calculate polarity
polar(seq, polarity=x)
```

progressBar	<i>Standard progress bar</i>
-------------	------------------------------

Description

progressBar defines a common progress bar format.

Usage

```
progressBar(n)
```

Arguments

n maximum number of ticks

Value

A [progress_bar](#) object.

rarefyDiversity	<i>Generate a clonal diversity index curve</i>
-----------------	--

Description

rarefyDiversity divides a set of clones by a group annotation, resamples the sequences from each group, and calculates diversity scores (D) over an interval of diversity orders (q).

Usage

```
rarefyDiversity(  
  data,  
  group,  
  clone = "CLONE",  
  copy = NULL,  
  min_q = 0,  
  max_q = 4,  
  step_q = 0.05,  
  min_n = 30,  
  max_n = NULL,  
  ci = 0.95,  
  nboot = 2000,  
  uniform = TRUE,  
  progress = FALSE  
)
```

Arguments

data	data.frame with Change-O style columns containing clonal assignments.
group	name of the data column containing group identifiers.
clone	name of the data column containing clone identifiers.
copy	name of the data column containing copy numbers for each sequence. If copy=NULL (the default), then clone abundance is determined by the number of sequences. If a copy column is specified, then clone abundances is determined by the sum of copy numbers within each clonal group.
min_q	minimum value of q .
max_q	maximum value of q .
step_q	value by which to increment q .
min_n	minimum number of observations to sample. A group with less observations than the minimum is excluded.
max_n	maximum number of observations to sample. If NULL then no maximum is set.
ci	confidence interval to calculate; the value must be between 0 and 1.
nboot	number of bootstrap realizations to generate.
uniform	if TRUE then uniformly resample each group to the same number of observations. If FALSE then allow each group to be resampled to its original size or, if specified, max_size.
progress	if TRUE show a progress bar.

Details

Clonal diversity is calculated using the generalized diversity index (Hill numbers) proposed by Hill (Hill, 1973). See [calcDiversity](#) for further details.

Diversity is calculated on the estimated complete clonal abundance distribution. This distribution is inferred by using the Chao1 estimator to estimate the number of seen clones, and applying the relative abundance correction and unseen clone frequency described in Chao et al, 2015.

To generate a smooth curve, D is calculated for each value of q from min_q to max_q incremented by step_q. When uniform=TRUE variability in total sequence counts across unique values in the group column is corrected by repeated resampling from the estimated complete clonal distribution to a common number of sequences.

The diversity index (D) for each group is the mean value of over all resampling realizations. Confidence intervals are derived using the standard deviation of the resampling realizations, as described in Chao et al, 2015.

Value

A [DiversityCurve](#) object summarizing the diversity scores.

References

1. Hill M. Diversity and evenness: a unifying notation and its consequences. *Ecology*. 1973 54(2):427-32.
2. Chao A. Nonparametric Estimation of the Number of Classes in a Population. *Scand J Stat*. 1984 11, 265270.
3. Chao A, et al. Rarefaction and extrapolation with Hill numbers: A framework for sampling and estimation in species diversity studies. *Ecol Monogr*. 2014 84:45-67.
4. Chao A, et al. Unveiling the species-rank abundance distribution by generalizing the Good-Turing sample coverage theory. *Ecology*. 2015 96, 11891201.

See Also

[alphaDiversity](#)

Examples

```
## Not run:
# Group by sample identifier
div <- rarefyDiversity(ExampleDb, "sample_id", step_q=1, max_q=10, nboot=100)
plotDiversityCurve(div, legend_title="Sample")

# Grouping by isotype rather than sample identifier
div <- rarefyDiversity(ExampleDb, "c_call", min_n=40, step_q=1, max_q=10,
                     nboot=100)
plotDiversityCurve(div, legend_title="Isotype")

## End(Not run)
```

readChangeoDb

Read a Change-O tab-delimited database file

Description

readChangeoDb reads a tab-delimited database file created by a Change-O tool into a data.frame.

Usage

```
readChangeoDb(file, select = NULL, drop = NULL, seq_upper = TRUE)
```

Arguments

file	tab-delimited database file output by a Change-O tool.
select	columns to select from database file.
drop	columns to drop from database file.
seq_upper	if TRUE convert sequence columns to upper case; if FALSE do not alter sequence columns. See Value for a list of which columns are effected.

Value

A data.frame of the database file. Columns will be imported as is, except for the following columns which will be explicitly converted into character values:

- SEQUENCE_ID
- CLONE
- SAMPLE

And the following sequence columns which will be converted to upper case if seq_upper=TRUE (default).

- SEQUENCE_INPUT
- SEQUENCE_VDJ
- SEQUENCE_IMGT
- JUNCTION
- GERMLINE_IMGT
- GERMLINE_IMGT_D_MASK

See Also

Wraps [read_delim](#). See [writeChangeoDb](#) for writing to Change-O files.

Examples

```
## Not run:
# Read all columns in and convert sequence fields to upper case
db <- readChangeoDb("changeo.tsv")

# Subset columns and convert sequence fields to upper case
db <- readChangeoDb("changeo.tsv", select=c("SEQUENCE_ID", "SEQUENCE_IMGT"))

# Drop columns and do not alter sequence field case
db <- readChangeoDb("changeo.tsv", drop=c("D_CALL", "DUPCOUNT"),
  seq_upper=FALSE)

## End(Not run)
```

readFastqDb

Load sequencing quality scores from a FASTQ file

Description

readFastqDb adds the sequencing quality scores to a data.frame from a FASTQ file. Matching is done by 'sequence_id'.

Usage

```

readFastqDb(
  data,
  fastq_file,
  quality_offset = -33,
  header = c("presto", "asis"),
  sequence_id = "sequence_id",
  sequence = "sequence",
  sequence_alignment = "sequence_alignment",
  v_cigar = "v_cigar",
  d_cigar = "d_cigar",
  j_cigar = "j_cigar",
  np1_length = "np1_length",
  np2_length = "np2_length",
  v_sequence_end = "v_sequence_end",
  d_sequence_end = "d_sequence_end",
  style = c("num", "ascii", "both"),
  quality_sequence = FALSE
)

```

Arguments

data	data.frame containing sequence data.
fastq_file	path to the fastq file
quality_offset	offset value to be used by ape::read.fastq. It is the value to be added to the quality scores (the default -33 applies to the Sanger format and should work for most recent FASTQ files).
header	FASTQ file header format; one of "presto" or "asis". Use "presto" to specify that the fastq file headers are using the pRESTO format and can be parsed to extract the sequence_id. Use "asis" to skip any processing and use the sequence names as they are.
sequence_id	column in data that contains sequence identifiers to be matched to sequence identifiers in fastq_file.
sequence	column in data that contains sequence data.
sequence_alignment	column in data that contains IMGT aligned sequence data.
v_cigar	column in data that contains CIGAR strings for the V gene alignments.
d_cigar	column in data that contains CIGAR strings for the D gene alignments.
j_cigar	column in data that contains CIGAR strings for the J gene alignments.
np1_length	column in data that contains the number of nucleotides between the V gene and first D gene alignments or between the V gene and J gene alignments.
np2_length	column in data that contains the number of nucleotides between either the first D gene and J gene alignments or the first D gene and second D gene alignments.
v_sequence_end	column in data that contains the end position of the V gene in sequence.

`d_sequence_end` column in data that contains the end position of the D gene in sequence.

`style` how the sequencing quality should be returned; one of "num", "phred", or "both". Specify "num" to store the quality scores as strings of comma separated numeric values. Use "phred" to have the function return the scores as Phred (ASCII) scores. Use "both" to retrieve both.

`quality_sequence` specify TRUE to keep the quality scores for sequence. If false, only the quality score for `sequence_alignment` will be added to data.

Value

Modified data with additional fields:

1. `quality_alignment`: A character vector with ASCII Phred scores for `sequence_alignment`.
2. `quality_alignment_num`: A character vector, with comma separated numerical quality values for each position in `sequence_alignment`.
3. `quality`: A character vector with ASCII Phred scores for `sequence`.
4. `quality_num`: A character vector, with comma separated numerical quality values for each position in `sequence`.

See Also

[maskPositionsByQuality](#) and [getPositionQuality](#)

Examples

```
db <- airr::read_rearrangement(system.file("extdata", "example_quality.tsv", package="alakazam"))
fastq_file <- system.file("extdata", "example_quality.fastq", package="alakazam")
db <- readFastqDb(db, fastq_file, quality_offset=-33)
```

readIgphym1

Read in output from IgPhyML

Description

`readIgphym1` reads output from the IgPhyML phylogenetics inference package for B cell repertoires

Usage

```
readIgphym1(
  file,
  id = NULL,
  format = c("graph", "phylo"),
  collapse = FALSE,
  branches = c("mutations", "distance")
)
```

Arguments

file	IgPhyML output file (.tab).
id	ID to assign to output object.
format	if "graph" return trees as igraph graph objects. if "phylo" return trees as ape phylo objects.
collapse	if TRUE transform branch lengths to units of substitutions, rather than substitutions per site, and collapse internal nodes separated by branches < 0.1 substitutions. Will also remove all internal node labels, as it makes them inconsistent.
branches	if "distance" branch lengths are in expected mutations per site. If "mutations" branches are in expected mutations.

Details

readIgphym1 reads output from the IgPhyML repertoire phylogenetics inference package. The resulting object is divided between parameter estimates (usually under the HLP19 model), which provide information about mutation and selection pressure operating on the sequences.

Trees returned from this function are either igraph objects or phylo objects, and each may be visualized accordingly. Further, branch lengths in tree may represent either the expected number of substitutions per site (codon, if estimated under HLP or GY94 models), or the total number of expected substitutions per site. If the latter, internal nodes - but not tips - separated by branch lengths less than 0.1 are collapsed to simplify viewing.

Value

A list containing IgPhyML model parameters and estimated lineage trees.

Object attributes:

- param: Data.frame of parameter estimates for each clonal lineage. Columns include: CLONE, which is the clone id; NSEQ, the total number of sequences in the lineage; NSITE, the number of codon sites; TREE_LENGTH, the sum of all branch lengths in the estimated lineage tree; and LHOOD, the log likelihood of the clone's sequences given the tree and parameters. Subsequent columns are parameter estimates from IgPhyML, which will depend on the model used. Parameter columns ending with _MLE are maximum likelihood estimates; those ending with _LCI are the lower 95 with _UCI are the upper 95 estimate. The first line of param is for clone REPERTOIRE, which is a summary of all lineages within the repertoire. For this row, NSEQ is the total number of sequences, NSITE is the average number of sites, and TREE_LENGTH is the mean tree length. For most applications, parameter values will be the same for all lineages within the repertoire, so access them simply by: <object>\$param\$OMEGA_CDR_MLE[1] to, for instance, get the estimate of dN/dS on the CDRs at the repertoire level.
- trees: List of tree objects estimated by IgPhyML. If format="graph" these are igraph graph objects. If format="phylo", these are ape phylo objects.
- command: Command used to run IgPhyML.

References

1. Hoehn KB, Lunter G, Pybus OG - A Phylogenetic Codon Substitution Model for Antibody Lineages. Genetics 2017 206(1):417-427 <https://doi.org/10.1534/genetics.116.196303>

2. Hoehn KB, Vander Heiden JA, Zhou JQ, Lunter G, Pybus OG, Kleinstejn SHK - Repertoire-wide phylogenetic models of B cell molecular evolution reveal evolutionary signatures of aging and vaccination. bioRxiv 2019 <https://doi.org/10.1101/558825>

Examples

```
## Not run:
# Read in and plot a tree from an igphym1 run
library(igraph)
s1 <- readIghym1("IB+7d_lineages_gy.tsv_igphym1_stats_hlp.tab", id="+7d")
print(s1$param$OMEGA_CDR_MLE[1])
plot(s1$trees[[1]], layout=layout_as_tree, edge.label=E(s1$trees[[1]])$weight)

## End(Not run)
```

seqDist

Calculate distance between two sequences

Description

seqDist calculates the distance between two DNA sequences.

Usage

```
seqDist(seq1, seq2, dist_mat = getDNAMatrix())
```

Arguments

seq1	character string containing a DNA sequence.
seq2	character string containing a DNA sequence.
dist_mat	Character distance matrix. Defaults to a Hamming distance matrix returned by getDNAMatrix . If gap characters, c("-", "."), are assigned a value of -1 in dist_mat then contiguous gaps of any run length, which are not present in both sequences, will be counted as a distance of 1. Meaning, indels of any length will increase the sequence distance by 1. Gap values other than -1 will return a distance that does not consider indels as a special case.

Value

Numerical distance between seq1 and seq2.

See Also

Nucleotide distance matrix may be built with [getDNAMatrix](#). Amino acid distance matrix may be built with [getAAMatrix](#). Used by [pairwiseDist](#) for generating distance matrices. See [seqEqual](#) for testing sequence equivalence.

Examples

```

# Ungapped examples
seqDist("ATGGC", "ATGGG")
seqDist("ATGGC", "ATG??")

# Gaps will be treated as Ns with a gap=0 distance matrix
seqDist("ATGGC", "AT--C", dist_mat=getDNAMatrix(gap=0))

# Gaps will be treated as universally non-matching characters with gap=1
seqDist("ATGGC", "AT--C", dist_mat=getDNAMatrix(gap=1))

# Gaps of any length will be treated as single mismatches with a gap=-1 distance matrix
seqDist("ATGGC", "AT--C", dist_mat=getDNAMatrix(gap=-1))

# Gaps of equivalent run lengths are not counted as gaps
seqDist("ATG-C", "ATG-C", dist_mat=getDNAMatrix(gap=-1))

# Overlapping runs of gap characters are counted as a single gap
seqDist("ATG-C", "AT--C", dist_mat=getDNAMatrix(gap=-1))
seqDist("A-GGC", "AT--C", dist_mat=getDNAMatrix(gap=-1))
seqDist("AT--C", "AT--C", dist_mat=getDNAMatrix(gap=-1))

# Discontiguous runs of gap characters each count as separate gaps
seqDist("-TGGC", "AT--C", dist_mat=getDNAMatrix(gap=-1))

```

seqEqual

Test DNA sequences for equality.

Description

seqEqual checks if two DNA sequences are identical.

Usage

```
seqEqual(seq1, seq2, ignore = as.character(c("N", "-", ".", "?")))
```

Arguments

seq1	character string containing a DNA sequence.
seq2	character string containing a DNA sequence.
ignore	vector of characters to ignore when testing for equality. Default is to ignore c("N", ".", "-", "?")

Value

Returns TRUE if sequences are equal and FALSE if they are not. Sequences of unequal length will always return FALSE regardless of their character values.

See Also

Used by [pairwiseEqual](#) within [collapseDuplicates](#). See [seqDist](#) for calculation Hamming distances between sequences.

Examples

```
# Ignore gaps
seqEqual("ATG-C", "AT--C")
seqEqual("ATGGC", "ATGGN")
seqEqual("AT--T", "ATGGC")

# Ignore only Ns
seqEqual("ATG-C", "AT--C", ignore="N")
seqEqual("ATGGC", "ATGGN", ignore="N")
seqEqual("AT--T", "ATGGC", ignore="N")
```

SingleDb

Single sequence AIRR database

Description

A database with just one sequence from [ExampleDb](#) and additional AIRR Rearrangement fields containing alignment information. The sequence was reanalyzed with a recent versions of alignment software (IgBLAST 1.16.0) and reference germlines (IMGT 2020-08-12).

Usage

```
SingleDb
```

Format

An object of class `spec_tbl_df` (inherits from `tbl_df`, `tbl`, `data.frame`) with 1 rows and 32 columns.

See Also

[ExampleDb](#)

`sortGenes`*Sort V(D)J genes*

Description

`sortGenes` sorts a vector of V(D)J gene names by either lexicographic ordering or locus position.

Usage

```
sortGenes(genes, method = c("name", "position"))
```

Arguments

<code>genes</code>	vector of strings representing V(D)J gene names.
<code>method</code>	string defining the method to use for sorting genes. One of: <ul style="list-style-type: none">• "name": sort in lexicographic order. Order is by family first, then gene, and then allele.• "position": sort by position in the locus, as determined by the final two numbers in the gene name. Non-localized genes are assigned to the highest positions.

Value

A sorted character vector of gene names.

See Also

See `getAllele`, `getGene` and `getFamily` for parsing gene names.

Examples

```
# Create a list of allele names
genes <- c("IGHV1-69D*01", "IGHV1-69*01", "IGHV4-38-2*01", "IGHV1-69-2*01",
          "IGHV2-5*01", "IGHV1-NL1*01", "IGHV1-2*01, IGHV1-2*05",
          "IGHV1-2", "IGHV1-2*02", "IGHV1-69*02")

# Sort genes by name
sortGenes(genes)

# Sort genes by position in the locus
sortGenes(genes, method="pos")
```

stoufferMeta	<i>Weighted meta-analysis of p-values via Stouffer's method</i>
--------------	---

Description

stoufferMeta combines multiple weighted p-values into a meta-analysis p-value using Stouffer's Z-score method.

Usage

```
stoufferMeta(p, w = NULL)
```

Arguments

p	numeric vector of p-values.
w	numeric vector of weights.

Value

A named numeric vector with the combined Z-score and p-value in the form c(Z, pvalue).

Examples

```
# Define p-value and weight vectors
p <- c(0.1, 0.05, 0.3)
w <- c(5, 10, 1)

# Unweighted
stoufferMeta(p)

# Weighted
stoufferMeta(p, w)
```

summarizeSubtrees	<i>Generate subtree summary statistics for a tree</i>
-------------------	---

Description

summarizeSubtrees calculates summary statistics for each node of a tree. Includes both node properties and subtree properties.

Usage

```
summarizeSubtrees(graph, fields = NULL, root = "Germline")
```

Arguments

graph	igraph object containing an annotated lineage tree.
fields	annotation fields to add to the output.
root	name of the root (germline) node.

Value

A data.frame with columns:

- name: node name.
- parent: name of the parent node.
- outdegree: number of edges leading from the node.
- size: total number of nodes within the subtree rooted at the node.
- depth: the depth of the subtree that is rooted at the node.
- pathlength: the maximum pathlength beneath the node.
- outdegree_norm: outdegree normalized by the total number of edges.
- size_norm: size normalized by the largest subtree size (the germline).
- depth_norm: depth normalized by the largest subtree depth (the germline).
- pathlength_norm: pathlength normalized by the largest subtree pathlength (the germline).

An additional column corresponding to the value of field is added when specified.

See Also

See [buildPhylipLineage](#) for generating input trees. See [getPathLengths](#) for calculating path length to nodes.

Examples

```
# Summarize a tree
graph <- ExampleTrees[[23]]
summarizeSubtrees(graph, fields="c_call", root="Germline")
```

tableEdges	<i>Tabulate the number of edges between annotations within a lineage tree</i>
------------	---

Description

tableEdges creates a table of the total number of connections (edges) for each unique pair of annotations within a tree over all nodes.

Usage

```
tableEdges(graph, field, indirect = FALSE, exclude = NULL)
```


Arguments

graph	igraph object containing an annotated lineage tree.
field	string defining the annotation field to count.
indirect	if FALSE count direct connections (edges) only. If TRUE walk through any nodes with annotations specified in the argument to count indirect connections. Specifying indirect=TRUE with exclude=NULL will have no effect.
exclude	vector of strings defining field values to exclude from counts. Edges that either start or end with the specified annotations will not be counted. If NULL count all edges.

Value

A data.frame defining total annotation connections in the tree with columns:

- parent: parent annotation
- child: child annotation
- count: count of edges for the parent-child relationship

See Also

See [testEdges](#) for performed a permutation test on edge relationships.

Examples

```
# Define example graph
graph <- ExampleTrees[[23]]

# Count direct edges between isotypes including inferred nodes
tableEdges(graph, "c_call")

# Count direct edges excluding edges to and from germline and inferred nodes
tableEdges(graph, "c_call", exclude=c("Germline", NA))

# Count indirect edges walking through germline and inferred nodes
tableEdges(graph, "c_call", indirect=TRUE, exclude=c("Germline", NA))
```

testDiversity

Pairwise test of the diversity index

Description

testDiversity performs pairwise significance tests of the diversity index (D) at a given diversity order (q) for a set of annotation groups via rarefaction and bootstrapping.

Usage

```
testDiversity(
  data,
  q,
  group,
  clone = "CLONE",
  copy = NULL,
  min_n = 30,
  max_n = NULL,
  nboot = 2000,
  progress = FALSE,
  ci = 0.95
)
```

Arguments

data	data.frame with Change-O style columns containing clonal assignments.
q	diversity order to test.
group	name of the data column containing group identifiers.
clone	name of the data column containing clone identifiers.
copy	name of the data column containing copy numbers for each sequence. If copy=NULL (the default), then clone abundance is determined by the number of sequences. If a copy column is specified, then clone abundances is determined by the sum of copy numbers within each clonal group.
min_n	minimum number of observations to sample. A group with less observations than the minimum is excluded.
max_n	maximum number of observations to sample. If NULL the maximum is automatically determined from the size of the largest group.
nboot	number of bootstrap realizations to perform.
progress	if TRUE show a progress bar.
ci	confidence interval to calculate; the value must be between 0 and 1.

Details

Clonal diversity is calculated using the generalized diversity index proposed by Hill (Hill, 1973). See [calcDiversity](#) for further details.

Diversity is calculated on the estimated complete clonal abundance distribution. This distribution is inferred by using the Chao1 estimator to estimate the number of seen clones, and applying the relative abundance correction and unseen clone frequency described in Chao et al, 2014.

Variability in total sequence counts across unique values in the group column is corrected by repeated resampling from the estimated complete clonal distribution to a common number of sequences. The diversity index estimate (D) for each group is the mean value of over all bootstrap realizations.

Significance of the difference in diversity index (D) between groups is tested by constructing a bootstrap delta distribution for each pair of unique values in the group column. The bootstrap delta

distribution is built by subtracting the diversity index D_a in *group - a* from the corresponding value D_b in *group - b*, for all bootstrap realizations, yielding a distribution of nboot total deltas; where *group - a* is the group with the greater mean D . The p-value for hypothesis $D_a = D_b$ is the value of $P(0)$ from the empirical cumulative distribution function of the bootstrap delta distribution, multiplied by 2 for the two-tailed correction.

Value

A [DiversityCurve](#) object containing slot test with p-values and summary statistics.

Note

This method may inflate statistical significance when clone sizes are uniformly small, such as when most clones sizes are 1, sample size is small, and `max_n` is near the total count of the smallest data group. Use caution when interpreting the results in such cases. We are currently investigating this potential problem.

References

1. Hill M. Diversity and evenness: a unifying notation and its consequences. *Ecology*. 1973 54(2):427-32.
2. Chao A. Nonparametric Estimation of the Number of Classes in a Population. *Scand J Stat*. 1984 11, 265270.
3. Wu Y-CB, et al. Influence of seasonal exposure to grass pollen on local and peripheral blood IgE repertoires in patients with allergic rhinitis. *J Allergy Clin Immunol*. 2014 134(3):604-12.
4. Chao A, et al. Rarefaction and extrapolation with Hill numbers: A framework for sampling and estimation in species diversity studies. *Ecol Monogr*. 2014 84:45-67.
5. Chao A, et al. Unveiling the species-rank abundance distribution by generalizing the Good-Turing sample coverage theory. *Ecology*. 2015 96, 11891201.

See Also

[alphaDiversity](#)

Examples

```
## Not run:  
# Groups under the size threshold are excluded and a warning message is issued.  
testDiversity(ExampleDb, "sample_id", q=0, min_n=30, nboot=100)  
  
## End(Not run)
```

`testEdges`*Tests for parent-child annotation enrichment in lineage trees*

Description

`testEdges` performs a permutation test on a set of lineage trees to determine the significance of an annotation's association with parent-child relationships.

Usage

```
testEdges(  
  graphs,  
  field,  
  indirect = FALSE,  
  exclude = c("Germline", NA),  
  nperm = 200,  
  progress = FALSE  
)
```

Arguments

<code>graphs</code>	list of igraph objects with vertex annotations.
<code>field</code>	string defining the annotation field to permute.
<code>indirect</code>	if FALSE count direct connections (edges) only. If TRUE walk through any nodes with annotations specified in the argument to count indirect connections. Specifying <code>indirect=TRUE</code> with <code>exclude=NULL</code> will have no effect.
<code>exclude</code>	vector of strings defining field values to exclude from permutation.
<code>nperm</code>	number of permutations to perform.
<code>progress</code>	if TRUE show a progress bar.

Value

An [EdgeTest](#) object containing the test results and permutation realizations.

See Also

Uses [tableEdges](#) and [permuteLabels](#). See [plotEdgeTest](#) for plotting the permutation distributions.

Examples

```
# Define example tree set  
graphs <- ExampleTrees[1-10]  
  
# Perform edge test on isotypes  
x <- testEdges(graphs, "c_call", nperm=10)  
print(x)
```

testMRCA	<i>Tests for MRCA annotation enrichment in lineage trees</i>
----------	--

Description

testMRCA performs a permutation test on a set of lineage trees to determine the significance of an annotation's association with the MRCA position of the lineage trees.

Usage

```
testMRCA(  
  graphs,  
  field,  
  root = "Germline",  
  exclude = c("Germline", NA),  
  nperm = 200,  
  progress = FALSE  
)
```

Arguments

graphs	list of igraph object containing annotated lineage trees.
field	string defining the annotation field to test.
root	name of the root (germline) node.
exclude	vector of strings defining field values to exclude from the set of potential founder annotations.
nperm	number of permutations to perform.
progress	if TRUE show a progress bar.

Value

An [MRCATest](#) object containing the test results and permutation realizations.

See Also

Uses [getMRCA](#) and [getPathLengths](#). See [plotMRCATest](#) for plotting the permutation distributions.

Examples

```
# Define example tree set
graphs <- ExampleTrees[1-10]

# Perform MRCA test on isotypes
x <- testMRCA(graphs, "c_call", nperm=10)
print(x)
```

translatedDNA

Translate nucleotide sequences to amino acids

Description

translatedDNA translates nucleotide sequences to amino acid sequences.

Usage

```
translatedDNA(seq, trim = FALSE)
```

Arguments

seq	vector of strings defining DNA sequence(s) to be converted to translated.
trim	boolean flag to remove 3 nts from both ends of seq (converts IMGT junction to CDR3 region).

Value

A vector of translated sequence strings.

See Also

[translate](#).

Examples

```
# Translate a single sequence
translateDNA("ACTGACTCGA")

# Translate a vector of sequences
translateDNA(ExampleDb$junction[1:3])

# Remove the first and last codon from the translation
translateDNA(ExampleDb$junction[1:3], trim=TRUE)
```

translateStrings	<i>Translate a vector of strings</i>
------------------	--------------------------------------

Description

translateStrings modifies a character vector by substituting one or more strings with a replacement string.

Usage

```
translateStrings(strings, translation)
```

Arguments

strings	vector of character strings to modify.
translation	named character vector or a list of character vectors specifying the strings to replace (values) and their replacements (names).

Details

Does not perform partial replacements. Each translation value must match a complete strings value or it will not be replaced. Values that do not have a replacement named in the translation parameter will not be modified.

Replacement is accomplished using [gsub](#).

Value

A modified strings vector.

See Also

See [gsub](#) for single value replacement in the base package.

Examples

```
# Using a vector translation
strings <- LETTERS[1:5]
translation <- c("POSITION1"="A", "POSITION5"="E")
translateStrings(strings, translation)

# Using a list translation
strings <- LETTERS[1:5]
translation <- list("1-3"=c("A", "B", "C"), "4-5"=c("D", "E"))
translateStrings(strings, translation)
```

writeChangeoDb	<i>Write a Change-O tab-delimited database file</i>
----------------	---

Description

writeChangeoDb is a simple wrapper around [write_delim](#) with defaults appropriate for writing a Change-O tab-delimited database file from a data.frame.

Usage

```
writeChangeoDb(data, file)
```

Arguments

data	data.frame of Change-O data.
file	output file name.

See Also

Wraps [write_delim](#). See [readChangeoDb](#) for reading to Change-O files.

Examples

```
## Not run:  
# Write a database  
writeChangeoDb(data, "changeo.tsv")  
  
## End(Not run)
```


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