

# Package ‘MSCsimtester’

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**Type** Package

**Title** Tests of Multispecies Coalescent Gene Tree Simulator Output

**Version** 1.2

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**Description** Statistical tests for validating multispecies coalescent gene tree simulators, using pairwise distances and rooted triple counts. See Allman ES, Baños HD, Rhodes JA 2023. Testing multispecies coalescent simulators using summary statistics, IEEE/ACM Trans Comput Biol Bioinformat, 20(2):1613–1618. <[doi:10.1109/TCBB.2022.3177956](https://doi.org/10.1109/TCBB.2022.3177956)>.

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## Contents

|                                    |   |
|------------------------------------|---|
| MSCsimtester-package . . . . .     | 2 |
| ADtest . . . . .                   | 3 |
| genetreeSample . . . . .           | 4 |
| pairwiseDist . . . . .             | 5 |
| plotEdgeOrder . . . . .            | 6 |
| plotPops . . . . .                 | 7 |
| print.ADtestOutput . . . . .       | 7 |
| print.rootedTripleOutput . . . . . | 8 |
| rootedTriple . . . . .             | 9 |

## Index

11

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|----------------------|--------------------------------------------------------------------------------------------|
| MSCsimtester-package | <i>Validity tests of simulators of the multispecies coalescent model in phylogenomics.</i> |
|----------------------|--------------------------------------------------------------------------------------------|

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## Description

The package performs comparisons of certain summary statistics for simulated gene tree samples to theoretical predictions under the multispecies coalescent model. The primary functions are `rootedTriple` for comparison of frequencies of topological rooted triples on gene trees, and `pairwiseDist` and `ADtest` for comparison of the distributions of pairwise distances between taxa on gene trees.

## Details

Required input is a collection of gene trees, stored as a `multiPhylo` object by the `ape` package, and a rooted species tree, as a `Phylo` object, with edge lengths in generations, together with constant population sizes for each edge.

MSCsimtester builds on the packages `ape` and `kSamples`.

For further examples of use and citation purposes, see Allman ES, Baños HD, Rhodes JA (2023). “Testing Multispecies Coalescent Simulators Using Summary Statistics.” *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, **20**(02), 1613-1618. ISSN 1557-9964, doi:10.1109/TCBB.2022.3177956..

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## References

Allman ES, Baños HD, Rhodes JA (2023). “Testing Multispecies Coalescent Simulators Using Summary Statistics.” *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, **20**(02), 1613-1618. ISSN 1557-9964, doi:10.1109/TCBB.2022.3177956.

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|        |                                                                                                |
|--------|------------------------------------------------------------------------------------------------|
| ADtest | <i>Anderson-Darling test comparing sample and theoretical pairwise distance distributions.</i> |
|--------|------------------------------------------------------------------------------------------------|

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## Description

Takes as input theoretical pairwise distance densities under the MSC and empirical pairwise distances from gene trees in a sample, as returned by the function `pairwiseDist`. Uses the package `kSamples` to perform either one test on the entire dataset or multiple tests on subsamples.

## Usage

```
ADtest(distanceDensities, subsampleSize = FALSE)
```

## Arguments

- `distanceDensities` A list containing values needed for performing Anderson-Darling test(s) on a gene tree sample and species tree, as output by `pairwiseDist`. For details, see code for `pairwiseDist`.
- `subsampleSize` A positive integer to perform multiple tests on subsamples, or `FALSE` (default) to perform one test on full sample.

## Details

The Anderson-Darling test compares the empirical distance distribution for a supplied gene tree sample to a sample drawn from the theoretical distribution. The output, passed from the `kSamples` package, thus says that 2 samples are being compared, to test a null-hypothesis that they come from the same distribution. See `kSamples` documentation for function `ad.test` for more details.

Repeated runs of this function will give different results, since the sample from the theoretical distribution will vary. Under the null hypothesis p-values for different runs should be approximately uniformly distributed.

Numerical issues may result in poor performance of Anderson-Darling tests when the sample size is very large, so an optional parameter `subsampleSize` can be set to create subsamples of smaller size. If `subsampleSize` is a positive integer, Anderson-Darling tests are performed on each subset, comparing them to a random sample of the same size from the theoretical distribution. Good fit is indicated by an approximately uniform distribution of the subsample p-values.

## Value

An object of type `ADtestOutput` including a sample `$Sample` from the theoretical distance distribution of the same size as the empirical one, and `$ADtest` which is of type `kSamples` and has all output from the Anderson-Darling test if only one test was performed, or the number of tests if tests were performed on subsamples.

## See Also

[pairwiseDist](#)

## Examples

```
stree=read.tree(text="(((a:10000,b:10000):10000,c:20000):10000,d:30000):10000,e:40000);")
pops=c(15000,25000,10000,1,1,1,1,1,12000)
gts=read.tree(file=system.file("extdata","genetreeSample",package="MSCsimtester"))
distDen=pairwiseDist(stree,pops,gts,"a","b")
ADtest(distDen)
ADtest(distDen,1000)
```

---

|                |                                     |
|----------------|-------------------------------------|
| genetreeSample | <i>Simulated gene tree dataset.</i> |
|----------------|-------------------------------------|

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## Description

A dataset of 10,000 gene trees on 5 taxa simulated under the MSC on a species tree.

## Format

A text file with 10,000 metric Newick gene trees on the taxa a,b,c,d,e

## Details

This simulated dataset was produced by SimPhy Mallo D, De Oliveira Martins L, Posada D (2016). "SimPhy: Phylogenomic Simulation of Gene, Locus, and Species Trees." *Systematic Biology*, **65**(2), 334-344. doi:10.1093/sysbio/syv082., using the species tree

```
((((a:10000,b:10000):10000,c:20000):10000,d:30000):10000,e:40000);
```

with population sizes

```
c(15000,25000,10000,1,1,1,1,1,12000)
```

and edges ordered by the ape function read.tree.

File is accessed as system.file("extdata","genetreeSample",package="MSCsimtester"), for example using the ape command:

```
gts=read.tree(file=system.file("extdata","genetreeSample",package="MSCsimtester"))
```

## References

Mallo D, De Oliveira Martins L, Posada D (2016). "SimPhy: Phylogenomic Simulation of Gene, Locus, and Species Trees." *Systematic Biology*, **65**(2), 334-344. doi:10.1093/sysbio/syv082.

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|              |                                                                             |
|--------------|-----------------------------------------------------------------------------|
| pairwiseDist | <i>Compute and plot sample and theoretical pairwise distance densities.</i> |
|--------------|-----------------------------------------------------------------------------|

---

## Description

Computes theoretical pairwise distance densities under the MSC on a species tree and empirical pairwise distances from gene trees in a sample. A histogram of empirical values is plotted over the theoretical pdf.

## Usage

```
pairwiseDist(
  stree,
  popSizes,
  gtSample,
  taxon1,
  taxon2,
  numSteps = 1000,
  tailProb = 0.01,
  numBreaks = 40
)
```

## Arguments

|           |                                                                                                                                                                                                                                                                                                                                                                                                    |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| stree     | An object of class <code>phylo</code> containing a rooted metric species tree. Edge lengths are in number of generations.                                                                                                                                                                                                                                                                          |
| popSizes  | A vector containing constant population sizes, one entry for each edge/population in the species tree, for a haploid population. Sizes should be doubled for diploids. If <code>stree</code> has <code>k</code> edges, then <code>popSizes</code> must have <code>k+1</code> elements, with final entry the size of the population ancestral to the root.                                          |
| gtSample  | An object of class <code>multiPhylo</code> holding a sample of gene trees from a simulation. Taxon labels on gene trees must be identical to those on <code>stree</code> .                                                                                                                                                                                                                         |
| taxon1    | A string specifying one taxon on <code>stree</code> .                                                                                                                                                                                                                                                                                                                                              |
| taxon2    | A string specifying a second taxon on <code>stree</code> , distinct from <code>taxon1</code> .                                                                                                                                                                                                                                                                                                     |
| numSteps  | A positive integer number of values to be computed for graphing the theoretical pairwise distance density. Default is <code>numSteps = 1000</code> . A larger value produces a smoother plot.                                                                                                                                                                                                      |
| tailProb  | A cutoff value, between 0 and 1, for the theoretical density, with a default of 0.01.                                                                                                                                                                                                                                                                                                              |
| numBreaks | Number of breaks in histogram. Default is <code>numBreaks = 40</code> . The theoretical pairwise distance is plotted from (0, <code>xMax</code> ), where <code>xMax</code> is the larger of the maximum pairwise distance in the gene tree sample and the value cutting off a tail of area <code>tailProb</code> under the pdf. A message returns the proportion of sample distances in this tail. |

Value

A list of items needed for Anderson-Darling test(s), for use by ADtest, returned invisibly. See function code for more details.

See Also

[plotEdgeOrder](#), [plotPops](#), [ADtest](#)

Examples

```
stree=read.tree(text="(((a:10000,b:10000):10000,c:20000):10000,d:30000):10000,e:40000);")
pops=c(15000,25000,10000,1,1,1,1,1,12000)
gts=read.tree(file=system.file("extdata","genetreeSample",package="MSCsimtester"))
pairwiseDist(stree,pops,gts,"a","b")
```

---

|               |                                                       |
|---------------|-------------------------------------------------------|
| plotEdgeOrder | <i>Plot species tree, with edge numbers on edges.</i> |
|---------------|-------------------------------------------------------|

---

Description

Under the MSC, each edge in the species tree must be assigned a population size. This function displays the species tree with the edges numbered, to aid the user in entering constant population sizes as an appropriately ordered list.

Usage

```
plotEdgeOrder(stree)
```

Arguments

stree                    An object of class phylo containing a rooted metric species tree.

Value

NONE

See Also

[pairwiseDist](#), [rootedTriple](#), [plotPops](#)

Examples

```
stree=read.tree(text="(((a:10000,b:10000):10000,c:20000):10000,d:30000);")
plotEdgeOrder(stree)
pops=c(30000,20000,1,1,1,1,10000)
plotPops(stree,pops)
```

---

|          |                                                           |
|----------|-----------------------------------------------------------|
| plotPops | <i>Plot species tree, with population sizes on edges.</i> |
|----------|-----------------------------------------------------------|

---

**Description**

Plot species tree, with population sizes on edges.

**Usage**

```
plotPops(stree, populations)
```

**Arguments**

|             |                                                                                                                                                                  |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| stree       | An object of class phylo containing a rooted metric species tree.                                                                                                |
| populations | A vector containing constant population sizes, one entry for each edge/population in the species tree, with last entry for the population ancestral to the root. |

**Value**

NONE

**See Also**

[pairwiseDist](#), [rootedTriple](#), [plotEdgeOrder](#)

**Examples**

```
stree=read.tree(text="(((a:10000,b:10000):10000,c:20000):10000,d:30000);")
plotEdgeOrder(stree)
pops=c(30000,20000,1,1,1,1,10000)
plotPops(stree,pops)
```

---

|                    |                                                          |
|--------------------|----------------------------------------------------------|
| print.ADtestOutput | <i>Print function for objects of class ADtestOutput.</i> |
|--------------------|----------------------------------------------------------|

---

**Description**

Print function for objects of class ADtestOutput.

**Usage**

```
## S3 method for class 'ADtestOutput'
print(x, ...)
```

**Arguments**

|     |                                                                  |
|-----|------------------------------------------------------------------|
| x   | An object of class ADtestOutput, as produced by ADtest function. |
| ... | Further arguments to be passed to or from other methods.         |

**Value**

NONE

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print.rootedTripleOutput

*Print function for objects of class rootedTripleOutput.*

---

**Description**

Print function for objects of class rootedTripleOutput.

**Usage**

```
## S3 method for class 'rootedTripleOutput'  
print(x, ...)
```

**Arguments**

|     |                                                                              |
|-----|------------------------------------------------------------------------------|
| x   | An object of class rootedTripleOutput, as produced by rootedTriple function. |
| ... | Further arguments to be passed to or from other methods.                     |

**Details**

Print function for objects of class rootedTripleOutput.

**Value**

NONE



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|              |                                                                               |
|--------------|-------------------------------------------------------------------------------|
| rootedTriple | <i>Compare expected and sample frequencies of topological rooted triples.</i> |
|--------------|-------------------------------------------------------------------------------|

---

## Description

For a given species tree with population sizes, compares the expected frequencies of rooted triples to empirical frequencies in a sample of gene trees, using Chi-squared tests with 2 d.f. The exact and estimated internal branch length (in coalescent units) of the rooted triple in the species tree are also computed for comparison. A single test can be performed on the entire gene tree sample, or multiple tests on subsamples.

## Usage

```
rootedTriple(
  stree,
  popSizes,
  gtSample,
  taxon1,
  taxon2,
  taxon3,
  subsampleSize = FALSE
)
```

## Arguments

|               |                                                                                                                                                                                                                                                                                                                               |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| stree         | An object of class <code>phylo</code> containing a rooted metric species tree. Edge lengths are in number of generations.                                                                                                                                                                                                     |
| popSizes      | An ordered list containing constant population sizes for each species tree edge, for a haploid organism. Sizes should be doubled for diploids. If <code>stree</code> has <code>k</code> edges, then <code>popSizes</code> must have <code>k+1</code> elements, with the final entry for the population ancestral to the root. |
| gtSample      | An object of class <code>multiPhylo</code> holding a sample of gene trees from a simulation. Taxon labels on gene trees must be identical to those on <code>stree</code> .                                                                                                                                                    |
| taxon1        | A string specifying one taxon on <code>stree</code> .                                                                                                                                                                                                                                                                         |
| taxon2        | A string specifying a second taxon on <code>stree</code> , distinct from <code>taxon1</code> .                                                                                                                                                                                                                                |
| taxon3        | A string specifying a third taxon on <code>stree</code> , distinct from <code>taxon1</code> , <code>taxon2</code> .                                                                                                                                                                                                           |
| subsampleSize | A positive integer or <code>FALSE</code> , giving size of subsamples of <code>gtSample</code> to analyze.                                                                                                                                                                                                                     |

## Details

When `subsampleSize` is `FALSE` the Chi-squared test is performed using all gene trees in `gtSample`. Results are reported in tabular form in the console.

When `subsampleSize` is positive, the `N` trees in `gtSample` will be partitioned into `N/subsampleSize` subsamples, with a Chi-squared test performed for each. Histograms are plotted for (1) the p-values

for the Chi-squared tests on subsamples, and (2) subsample estimates of the internal branch length for the rooted triple on the species tree, with the true value marked.

Three distinct taxon names must be supplied, all of which must occur on `stree` and in each of the gene trees in the sample.

### Value

If `subsampleSize` is `FALSE`, returns an object of type `rootedTripleOutput` which contains a table `$TripletCounts` of empirical and expected rooted triple counts, a p-value `$pv` from the Chi-squared test, and a column `$InternalEdge` of estimated and exact internal edge lengths. If `subsampleSize` is `TRUE`, returns `NULL` but produces several plots.

### See Also

[plotEdgeOrder](#), [plotPops](#)

### Examples

```
stree=read.tree(text="(((a:10000,b:10000):10000,c:20000):10000,d:30000):10000,e:40000);")
pops=c(15000,25000,10000,1,1,1,1,1,12000)
gts=read.tree(file=system.file("extdata","genetreeSample",package="MSCsimtester"))
rootedTriple(stree,pops,gts,"a","b","c")
rootedTriple(stree,pops,gts,"a","b","c",1000)
```

# Index

ADtest, [3](#), [6](#)

genetreeSample, [4](#)

MSCsimtester (MSCsimtester-package), [2](#)

MSCsimtester-package, [2](#)

pairwiseDist, [3](#), [5](#), [6](#), [7](#)

plotEdgeOrder, [6](#), [6](#), [7](#), [10](#)

plotPops, [6](#), [7](#), [10](#)

print.ADtestOutput, [7](#)

print.rootedTripleOutput, [8](#)

rootedTriple, [6](#), [7](#), [9](#)