

# Package ‘loci2path’

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**Type** Package

**Title** Loci2path: regulatory annotation of genomic intervals based on tissue-specific expression QTLs

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**Description** loci2path performs statistics-rigorous enrichment analysis of eQTLs in genomic regions of interest. Using eQTL collections provided by the Genotype-Tissue Expression (GTEx) project and pathway collections from MSigDB.

**License** Artistic-2.0

**Encoding** UTF-8

**LazyData** true

**Depends** R (>= 3.4)

**Imports** pheatmap, wordcloud, RColorBrewer, data.table, methods, grDevices, stats, graphics, GenomicRanges, BiocParallel, S4Vectors

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**VignetteBuilder** knitr

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**URL** <https://github.com/StanleyXu/loci2path>

**BugReports** <https://github.com/StanleyXu/loci2path/issues>

**Collate** 'allClasses.R' 'allGenerics.R' 'allAccessor.R'  
'check.geneid.R' 'loci2path.demo-data.R'  
'loci2pathResult-methods.R' 'query-methods.R' 'show-methods.R'

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biocarta	<i>eQTL geneset enrichment query demo data</i>
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## Description

Demo Data to show how to perform eQTL-geneset enrichment query.

## Usage

```
data(loci2path.demo)
```

## Format

An object of class `geneSet` of length 1.

## Details

`eqtl.set.list` A list of eQTLset objects; eQTL data are collected from GTeX.

`biocarta` A Geneset object; Geneset are from Broad Institute's MSigDB: curated gene set, category 'cp': BIOCARTA

`query.gr` A Genomic Region object; Query regions are from immunoBase, crohn's disease.

### Examples

```
data(loci2path.demo)
```

---

check.geneid	<i>check compatibility of gene identifiers between eQTL set and gene set</i>
--------------	--

---

### Description

This function perform enrichment test between one eQTL set and one gene set

### Usage

```
check.geneid(e.set, g.set)
```

### Arguments

e.set	an eqtlSet object; the eQTL set to be queried against
g.set	an object of geneSet class; the gene set to be tested

### Value

a data.frame shows the number of genes from (1) eqtl Set (2) gene Set (3) shared

### Examples

```
check.geneid(eset.list$Skin, biocarta)
```

---

eqtlSet-class	<i>eqtlSet Class</i>
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---

### Description

eqtlSet Class contains information for eqtl-gene association, gene identifier, position of SNPs, etc.

### Usage

```
tissue(x)  
eqtlId(x)  
eqtlRange(x)  
eqtlGene(x)  
## S4 method for signature 'eqtlSet'
```

```
tissue(x)

## S4 method for signature 'eqtlSet'
eqtlId(x)

## S4 method for signature 'eqtlSet'
eqtlRange(x)

## S4 method for signature 'eqtlSet'
eqtlGene(x)
```

### Arguments

x                    An eqtlSet object

### Value

Object of class eqtlSet

### Slots

tissue character; name of the cell/tissue of the eQTL study  
eqtlId character; name of the SNPs  
eqtlRange GenomicRanges; position of the SNPs  
gene character; gene identifier

### Examples

```
require(GenomicRanges)
brain.file <- system.file("extdata", "eqtl/brain.gtex.txt",
  package="loci2path")
tab <- read.table(brain.file, stringsAsFactors=FALSE, header=TRUE)
eqtlRange <- GRanges(seqnames=Rle(tab$snp.chr),
  ranges=IRanges(start=tab$snp.pos,
  width=1))
brain.eset <- eqtlSet(tissue="brain",
  eqtlId=tab$snp.id,
  eqtlRange=eqtlRange,
  gene=as.character(tab$gene.entrez.id))
tissue(brain.eset)
head(eqtlId(brain.eset))
eqtlRange(brain.eset)
head(eqtlGene(brain.eset))
```

---

eset.list	<i>eQTL geneset enrichment query demo data</i>
-----------	--

---

**Description**

Demo Data to show how to perform eQTL-geneset enrichment query.

**Usage**

```
data(loci2path.demo)
```

**Format**

An object of class `list` of length 3.

**Details**

`eset.list` A list of `eQTLset` objects; eQTL data are collected from GTeX.

`biocarta` A `Geneset` object; Geneset are from Broad Institute's MSigDB: curated gene set, category 'cp': BIOCARTA

`query.gr` A `Genomic Region` object; Query regions are from immunoBase, Psoriasis disease.

**Examples**

```
data(loci2path.demo)
```

---

geneSet-class	<i>geneSet Class</i>
---------------	----------------------

---

**Description**

`geneSet Class` contains information for names of gene sets and a list of gene sets

**Usage**

```
numGene(x)
```

```
description(x)
```

```
geneSetList(x)
```

```
## S4 method for signature 'geneSet'
numGene(x)
```

```
## S4 method for signature 'geneSet'
```

```
description(x)

## S4 method for signature 'geneSet'
geneSetList(x)
```

### Arguments

x                    An geneSet object

### Value

Object of class geneSet

### Slots

numGene numeric; the total number of all genes; This number is used in enrichment tests

description vector of character; additional information for gene sets, such as names, URLs, a short description, etc.

geneSetList list; a list of gene sets; each member is a vector containing a group of gene identifiers

### Examples

```
biocarta.link.file <- system.file("extdata",
  "geneSet/biocarta.txt", package="loci2path")
biocarta.link <- read.delim(biocarta.link.file, header=FALSE,
  stringsAsFactors=FALSE)
biocarta.set.file <- system.file("extdata", "geneSet/biocarta.set.txt",
  package="loci2path")
set.geneid <- read.table(biocarta.set.file, stringsAsFactors=FALSE)
set.geneid <- strsplit(set.geneid[,1], split=",")
names(set.geneid) <- biocarta.link[,1]
biocarta <- geneSet(
  geneSetList=set.geneid,
  description=biocarta.link[,2],
  numGene=31847)
numGene(biocarta)
head(description(biocarta))
head(geneSetList(biocarta))
```

---

getHeatmap

*Generate heatmap of enrichment matrix from query result*

---

### Description

This function generate the enrichment heatmap using pheatmap package.

**Usage**

```
getHeatmap(res, ...)

## S4 method for signature 'loci2pathResult'
getHeatmap(res, main = "",
  test.method = c("gene", "eqtl", "glm"), filter.quantile = 0.5,
  max.ptw.gene = 5000)
```

**Arguments**

res	query result from function query.egset.list()
...	additional params
main	title of the heatmap, default is ""
test.method	Choose which enrichment test should be used to retrieve p-values from. Options include:"gene"(default, gene-based fisher's exact test),"eqtl" (eqtl based fisher's exact test), "glm" (ordered query)
filter.quantile	Filter option; choose the max quantile of all p-values being kept in the matrix; default is 0.5, which means p-values larger than median p-values are discarded
max.ptw.gene	Filter option; minimum number of genes in a pathway; default is 5000 (pathway with >5000 genes are not included in the matrix)

**Value**

pathways	frequent pathways
tissues	frequent tissues

**Examples**

```
result <- query(query.gr=query.gr,
  loci=eset.list, path=biocarta)
getHeatmap(result)
```

---

getMat

---

*Extract tissue/geneset enrichment matrix from query result*


---

**Description**

This function extracts the enrichment matrix from eQTL list query result. The rows of the matrix are pathways; and the columns of the matrix are tissues/cell lines of the eQTL sets. P-Values from enrichment tests are summarized in this matrix

**Usage**

```
getMat(res, ...)

## S4 method for signature 'loci2pathResult'
getMat(res, test.method = c("gene", "eqtl",
  "glm"), filter.quantile = 0.5, max.ptw.gene = 5000)
```

**Arguments**

res	query result from function query.egset.list()
...	additional params
test.method	Choose which enrichment test should be used to retrieve p-values from. Options include:"gene"(default, gene-based fisher's exact test),"eqtl" (eqtl based fisher's exact test), "glm" (ordered query)
filter.quantile	Filter option; choose the max quantile of all p-values being kept in the matrix; default is 0.5, which means p-values larger than median p-values are discarded
max.ptw.gene	Filter option; minimum number of genes in a pathway; default is 5000 (pathway with >5000 genes are not included in the matrix)

**Value**

p-value matrix collected from enrichment result table

**Examples**

```
result <- query(query.gr=query.gr,
  loci=eset.list, path=biocarta)
mat <- getMat(result, test.method="gene")
```

---

getPathDescription	<i>Extract description for enriched pathways from query result and gene-Set object</i>
--------------------	--

---

**Description**

This function extracts the pathway description from geneSet object.

**Usage**

```
getPathDescription(res, ...)

## S4 method for signature 'loci2pathResult'
getPathDescription(res, geneset)
```



**Arguments**

res	query result from function query.egset.list()
...	additional params
geneset	A geneSet object

**Value**

a vector of gene set description from geneSet description slot

**Examples**

```
result <- query(query.gr=query.gr,
  loci=eset.list, path=biocarta)
path.des <- getPathDescription(result, biocarta)
```

---

getPval	<i>Extract tissue/geneset enrichment p-value distribution from query result</i>
---------	---

---

**Description**

This function extracts the enrichment p-value distribution from eQTL list query result. P-values from different tissues/cell types are organized, and QQ-plot is generated against uniform distribution

**Usage**

```
getPval(res, ...)

## S4 method for signature 'loci2pathResult'
getPval(res, test.method = c("gene", "eqtl",
  "glm"))
```

**Arguments**

res	query result from function query.egset.list()
...	additional params
test.method	Choose which enrichment test should be used to retrieve p-values from. Options include:"gene"(default, gene-based fisher's exact test),"eqtl" (eqtl based fisher's exact test), "glm" (ordered query)

**Value**

generate pval distribution plot

**Examples**

```
result <- query(query.gr=query.gr,
  loci=eset.list, path=biocarta)
getPval(result, test.method="gene")
```

---

getTissueDegree	<i>Extract tissue degree from query result</i>
-----------------	--

---

### Description

This function extracts the tissue degree from eQTL list query result for each pathway.

### Usage

```
getTissueDegree(res, ...)  
  
## S4 method for signature 'loci2pathResult'  
getTissueDegree(res, loci)
```

### Arguments

res	query result from function query.egset.list()
...	additional params
loci	a list of eqtlSet; each member should be an eqtlSet object

### Value

gene.tissue.map	shows mapping:gene<->tissue
gene.tissue.degree	shows tissue degree for each gene
mean.tissue.degree	shows the average tissue digree for each pathway in the result table

### Examples

```
result <- query(query.gr=query.gr,  
  loci=eset.list, path=biocarta)  
tissue.degree=getTissueDegree(result, eset.list)  
head(tissue.degree$gene.tissue.map)  
head(tissue.degree$gene.tissue.degree)  
head(tissue.degree$mean.tissue.degree)
```

---

getWordcloud	<i>Plot word cloud using frequent terms of pathways and genes</i>
--------------	---

---

**Description**

This function draw the enrichment heatmap using wordcloud package.

**Usage**

```
getWordcloud(res, ...)  
  
## S4 method for signature 'loci2pathResult'  
getWordcloud(res, min.freq.tissue = 5,  
  min.freq.gset = 5, max.words = 50)
```

**Arguments**

res	query result from function query.egset.list()
...	additional params
min.freq.tissue	minimum frequency of tissue/cell to be plotted in the word cloud
min.freq.gset	minimum frequency of geneset to be plotted in the word cloud
max.words	maximum words to be generated

**Value**

empty

**Examples**

```
result <- query(query.gr=query.gr,  
  loci=eset.list, path=biocarta)  
getWordcloud(result, min.freq.tissue=2, min.freq.gset=1)
```

---

loci2pathResult-class *loci2pathResult Class*

---

**Description**

loci2pathResult Class contains information for the query result from query function query. Result object contains a ranked pathway table, and a vector of gene names that are associated with loci covered by query regions

**Usage**

```
resultTable(x)

coveredGene(x)

## S4 method for signature 'loci2pathResult'
resultTable(x)

## S4 method for signature 'loci2pathResult'
coveredGene(x)
```

**Arguments**

x                    An geneSet object

**Value**

Object of CClass loci2pathResult

**Slots**

resultTable data.frame; contains enrichment statistics, summary of eQTL and gene numbers, pathway names and gene names, etc.

coveredGene list; each member is a vector of genes associated with one tissue, whose associating loci are covered by query regions

**Examples**

```
result <- query(query.gr=query.gr,
  loci=eset.list, path=biocarta)
result
resultTable(result) # a data.frame for enriched pathways
coveredGene(result)
```

---

query

*Query enrichment in geneset through multiple eQTL sets.*

---

**Description**

This is the main function for loci2path query. Query can be made on either pathway enrichment or tissue-specificity, depending on the input Class. See **Details** for more.

**Usage**

```

query(query.gr, loci, path, ...)

## S4 method for signature 'GenomicRanges,list,ANY'
query(query.gr, loci, N = 2897310462)

## S4 method for signature 'GenomicRanges,eqtlSet,geneSet'
query(query.gr, loci, path,
      query.score = NULL, verbose = FALSE)

## S4 method for signature 'GenomicRanges,list,geneSet'
query(query.gr, loci, path,
      query.score = NULL, parallel = FALSE, verbose = FALSE)

```

**Arguments**

query.gr	a GenomicRange object, representing query regions
loci	a list of eqtlSet; each member should be an eqtlSet; Or it can be a single eqtlSet.
path	Pathways or geneSets to be tested for enrichment
...	additional params
N	the total number of non-N nucleotides in the genome; default N=2897310462 is for hg19
query.score	optional, set to NULL if the regions are not ordered. If the query regions are ordered, query.score is the quantity based on which the regions are ordered
verbose	bool; whether to show eqtlSet/geneSet summary information; default is FALSE
parallel	bool; whether to enable parallel computing; default is FALSE

**Details**

The user need to specify

1. Query region;
2. loci; one or more eQTL set; this is usually more than one eQTL set. Only multiple eQTL set derived from different cells/tissues will show cell/tissue specificity.
3. path; pre-defined Pathways, or gene sets. the gene sets that enrichment tests would be performed to.

loci must be provided; path is optional. When path is missing, the tissue-specificity query for the regions is performed.

The most common case for loci is an eQTL set list. This function perform enrichment test between one eQTL set and a group of gene sets. Usually query are based on eQTL set list, rather than only one eQTL set. Several result exploring functions (getMat, getHeatmap, getPval, etc...) are designed for query result from eQTL set list and gene sets. The class loci2pathResult is also designed for eQTL set list query result only. The result returns a loci2pathResult only the class of loci is a list of eqtlSet.

If user input one eQTL set as argument loci, a simple list object will be returned for specific research purpose.

**Value**

a data.frame showing the tissue enrichment of the query regions by binomial test.  
 a list; `result.table` is the major result table showing enrichment assessment; `cover.gene` is the vector showing the genes from the eqtl Sets covered by the query region(s)  
 a `loci2pathResult` class object

**See Also**

`loci2pathResult`

**Examples**

```
gr.tissue <- query(query.gr, eset.list)
#build one eqtlset
skin.eset <- eset.list$Skin
#query one egset
res.one <- query(query.gr, skin.eset, biocarta)
#enrichment result table
res.one$result.table
#all the genes associated with eQTLs covered by the query region
res.one$cover.gene
result <- query(query.gr=query.gr,
  loci=eset.list, path=biocarta)
#enrichment result table
resultTable(result)
#all the genes associated with eQTLs covered by the query region
coveredGene(result)
```

---

query.gr

*eQTL geneset enrichment query demo data*

---

**Description**

Demo Data to show how to perform eQTL-geneset enrichment query.

**Usage**

```
data(loci2path.demo)
```

**Format**

An object of class `GRanges` of length 47.

**Details**

`eqtl.set.list` A list of `eQTLset` objects; eQTL data are collected from GTeX.

`biocarta` A `Geneset` object; Geneset are from Broad Institute's MSigDB: curated gene set, category 'cp': BIOCARTA

`query.gr` A `Genomic Region` object; Query regions are from immunoBase, crohn's disease.

**Examples**

```
data(loci2path.demo)
```

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