

Description of the biomaRt package

Steffen Durinck^{‡,*}, Wolfgang Huber^{¶,†},
Yves Moreau[‡], Bart De Moor[‡]

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[‡]Department of Electronical Engineering, ESAT-SCD, K.U.Leuven,
Kasteelpark Arenberg 10, 3001 Leuven-Heverlee, Belgium,
<http://www.esat.kuleuven.ac.be/~dna/BioI>
and [¶]European Bioinformatics Institute, Hinxton, UK

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*Steffen.Durinck@esat.kuleuven.ac.be

†huber@ebi.ac.uk

1 Introduction

The BioConductor *biomaRt* package enables to directly query databases based on biomaRt such as Ensembl, a software system which produces and maintains automatic annotation on metazoan genomes. This way you can annotate the features on your array with the latest annotations starting from identifiers such as affy id's, locuslink, RefSeq and more. Annotation includes gene names, GO and OMIM annotation (depending on species).

2 objects

2.1 Mart-class

An object of the `Mart` class represents a connection to a BioMart. And has the following slots:

- `ensembl`: stores the `RMySQLConnection` to Ensembl
- `vega`: stores the `RMySQLConnection` to VEGA
- `sequence`: stores the `RMySQLConnection` to sequence mart
- `snp`: stores the `RMySQLConnection` to snp mart
- `arrayToSpecies`: Stores mapping from affy arrays to species

2.2 martTable-class

An object of the `martTable` class is the output of most biomaRt functions and has the following slots:

- `id`: stores the id used for querying
- `table`: is a list of vectors storing the retrieved data

3 Functions

3.1 martConnect

A first step in using the biomaRt package is to connect to a BioMart database. The function `martConnect` establishes a connection with one of the following BioMart databases: `snp`, `ensembl` and `vega`.

Examples:

```
> library(biomaRt)
```

```

Loading required package: Biobase
Welcome to Bioconductor
  Vignettes contain introductory material.  To view,
  simply type: openVignette()
  For details on reading vignettes, see
  the openVignette help page.
Loading required package: RMySQL
Loading required package: DBI

```

```

> mart <- martConnect()

- Connected to: ensembl_mart_30 -

```

3.2 martDisconnect

You can only hold a limited number of connections with different BioMarts. The function `martDisconnect` can be used to close a mart connection.

Examples:

```

> martDisconnect(mart)

[1] TRUE

```

3.3 getGene

The function `getGene` uses a query id to look up identification and chromosomal information of the corresponding gene. Depending on the selected output, this function returns a `martTable` or an object of class `Gene`. When no information about the identifier is found in Ensembl, an empty `Gene` object will be created. If however multiple genes match a certain identifier, then an object of class `MultiGene` will be return containing information of all matches. Currently the `getGene` function takes identifiers from Entrez-Gene, Affymetrix, RefSeq and embl. Besides the id argument, this function also has a species, array and type argument.

The id argument is either a vector of identifiers or a single identifier to be annotated.

The species argument should have the species from which the identifier comes as value. For the value of species, we use the full name of the species where separate words are separated by an underscore, e.g. 'gallusgallus'. A list of possible species to choose from can be obtained by executing the function `getSpecies`.

The array argument takes affy array identifiers as values. A list of possible identifiers supported by the package can be obtained by executing the function `getAffyArrays`.

The mart argument is a mart connection, which was obtained using the method `martConnect`

The type takes the values of 'entrezgene', 'refseq' and 'embl' to clarify which type of identifier is specified in the id argument.

The output can be changed using the output argument. One can choose between a mart-Table (default) and an output of Gene/Multi-Gene objects. Depending on the identifier, different additional arguments will have to be given, summarized below:

- Affy id's: id, array, mart
- Entrez-Gene: id, type, species, mart
- RefSeq: id, type, species, mart
- embl: id, type, species, mart

Examples:

```
> mart <- martConnect()
```

```
- Connected to: ensembl_mart_30 -
```

```
> getGene(id = "1939_at", array = "hg_u95av2", mart = mart)
```

```
An object of class "martTable"
```

```
Slot "id":
```

```
[1] "1939_at"
```

```
Slot "table":
```

```
$symbol
```

```
[1] "TP53"
```

```
$description
```

```
[1] "Cellular tumor antigen p53 (Tumor suppressor p53) (Phosphoprotein p53) (Antigen NY-
```

```
$band
```

```
[1] "p13.1"
```

```
$chromosome
```

```
[1] "17"
```

```
$start
```

```
[1] 7512464
```

```
$end
```

```
[1] 7531642
```

```
$martID
```

```
[1] "ENSG00000141510"
```

```

> getGene(id = 672, type = "entrezgene", species = "hsapiens",
+       mart = mart)

An object of class "martTable"
Slot "id":
[1] "672"

Slot "table":
$symbol
[1] "BRCA1"

$description
[1] "Breast cancer type 1 susceptibility protein (RING finger protein 53). [Source:Unipr

$band
[1] "q21.31"

$chromosome
[1] "17"

$start
[1] 38449844

$end
[1] 38530934

$martID
[1] "ENSG00000012048"

```

3.4 getGO

The function `getGO` uses a query id to look up GO annotation of the corresponding gene. It return an object of class `GO`. When no information about the identifier is found in Ensembl, an empty `GO` object will be created. Currently the `getGO` function takes identifiers from Entrez-Gene, Affymetrix, RefSeq and embl. Besides the `id` argument, this function also has a `species`, `array` and `type` argument.

The `id` argument is either a vector of identifiers or a single identifier to be annotated.

The `species` argument should have the species from which the identifier comes as value. A list of possible species to choose from can be obtained by executing the function `getSpecies`. The `array` argument takes affy array identifiers as values. A list of possible identifiers supported by the package can be obtained by executing the function `getAffyArrays`.

The `mart` argument is a mart connection, which was obtained using the method `martConnect`

A last argument of this function is the `type` argument which, takes the values of 'entrezgene', 'refseq' and 'embl' to clarify which type of identifier is specified in the `id` argument.

Depending on the identifier, different additional arguments will have to be given, summarized below:

- Affy id's: id, array, mart
- Entrez-Gene: id, type, species, mart
- RefSeq: id, type, species, mart
- embl: id, type, species, mart

Examples:

```
> getGO(id = "1939_at", array = "hg_u95av2", mart = mart)
```

An object of class "martTable"

Slot "id":

```
[1] "1939_at" "1939_at" "1939_at" "1939_at" "1939_at" "1939_at" "1939_at"
[8] "1939_at" "1939_at" "1939_at" "1939_at" "1939_at" "1939_at" "1939_at"
[15] "1939_at" "1939_at" "1939_at" "1939_at" "1939_at" "1939_at" "1939_at"
[22] "1939_at" "1939_at" "1939_at" "1939_at" "1939_at" "1939_at" "1939_at"
```

Slot "table":

\$GOID

```
[1] "GO:0000739" "GO:0003700" "GO:0004518" "GO:0005507" "GO:0005515"
[6] "GO:0005524" "GO:0008270" "GO:0000075" "GO:0006284" "GO:0006289"
[11] "GO:0006310" "GO:0006355" "GO:0006915" "GO:0007050" "GO:0007569"
[16] "GO:0008283" "GO:0008628" "GO:0008630" "GO:0008635" "GO:0030154"
[21] "GO:0030308" "GO:0045786" "GO:0046902" "GO:0051097" "GO:0005730"
[26] "GO:0005739" NA
```

\$description

```
[1] "DNA strand annealing activity"
[2] "transcription factor activity"
[3] "nuclease activity"
[4] "copper ion binding"
[5] "protein binding"
[6] "ATP binding"
[7] "zinc ion binding"
[8] "cell cycle checkpoint"
[9] "base-excision repair"
[10] "nucleotide-excision repair"
[11] "DNA recombination"
[12] "regulation of transcription, DNA-dependent"
[13] "apoptosis"
```

```

[14] "cell cycle arrest"
[15] "cell aging"
[16] "cell proliferation"
[17] "induction of apoptosis by hormones"
[18] "DNA damage response, signal transduction resulting in induction of apoptosis"
[19] "caspase activation via cytochrome c"
[20] "cell differentiation"
[21] "negative regulation of cell growth"
[22] "negative regulation of cell cycle"
[23] "regulation of mitochondrial membrane permeability"
[24] "negative regulation of helicase activity"
[25] "nucleolus"
[26] "mitochondrion"
[27] NA

```

\$evidence

```

[1] "IDA" "IDA" "TAS" "IDA" "IPI" "IDA" "TAS" "TAS" "TAS" "IMP" "TAS" "IDA"
[13] "IDA" "TAS" "IMP" "TAS" "TAS" "TAS" "IDA" "TAS" "IMP" "IEA" "TAS" "TAS"
[25] "IDA" "IDA" NA

```

\$martID

```

[1] "ENSG00000141510" "ENSG00000141510" "ENSG00000141510" "ENSG00000141510"
[5] "ENSG00000141510" "ENSG00000141510" "ENSG00000141510" "ENSG00000141510"
[9] "ENSG00000141510" "ENSG00000141510" "ENSG00000141510" "ENSG00000141510"
[13] "ENSG00000141510" "ENSG00000141510" "ENSG00000141510" "ENSG00000141510"
[17] "ENSG00000141510" "ENSG00000141510" "ENSG00000141510" "ENSG00000141510"
[21] "ENSG00000141510" "ENSG00000141510" "ENSG00000141510" "ENSG00000141510"
[25] "ENSG00000141510" "ENSG00000141510" "ENSG00000141510"

```

```
> getGO(id = 672, type = "entrezgene", species = "hsapiens", mart = mart)
```

An object of class "martTable"

Slot "id":

```

[1] "672" "672" "672" "672" "672" "672" "672" "672" "672" "672" "672" "672"
[13] "672" "672" "672" "672" "672" "672" "672" "672" "672" "672" "672" "672"
[25] "672" "672"

```

Slot "table":

\$GOID

```

[1] "GO:0003684" "GO:0003713" "GO:0004842" "GO:0005515" "GO:0008270"
[6] "GO:0015631" "GO:0016563" "GO:0006357" "GO:0006359" "GO:0006978"
[11] "GO:0016567" "GO:0042127" "GO:0042981" "GO:0045739" "GO:0045786"
[16] "GO:0046600" "GO:0000151" "GO:0005615" "GO:0005634" "GO:0005667"
[21] "GO:0008274" "GO:0005554" "GO:0000075" "GO:0008372" "GO:0005622"
[26] "GO:0008270"

```

\$description

- [1] "damaged DNA binding"
- [2] "transcription coactivator activity"
- [3] "ubiquitin-protein ligase activity"
- [4] "protein binding"
- [5] "zinc ion binding"
- [6] "tubulin binding"
- [7] "transcriptional activator activity"
- [8] "regulation of transcription from Pol II promoter"
- [9] "regulation of transcription from Pol III promoter"
- [10] "DNA damage response, signal transduction by p53 class mediator resulting in transco"
- [11] "protein ubiquitination"
- [12] "regulation of cell proliferation"
- [13] "regulation of apoptosis"
- [14] "positive regulation of DNA repair"
- [15] "negative regulation of cell cycle"
- [16] "negative regulation of centriole replication"
- [17] "ubiquitin ligase complex"
- [18] "extracellular space"
- [19] "nucleus"
- [20] "transcription factor complex"
- [21] "gamma-tubulin ring complex"
- [22] "molecular_function unknown"
- [23] "cell cycle checkpoint"
- [24] "cellular_component unknown"
- [25] "intracellular"
- [26] "zinc ion binding"

\$evidence

- [1] "NR" "TAS" "IEA" "IPI" "TAS" "NAS" "TAS" "TAS" "TAS" "TAS" "IEA" "TAS"
- [13] "TAS" "NAS" "IEA" "NAS" "IEA" "TAS" "TAS" "TAS" "NAS" "ND" "NAS" "ND"
- [25] "IEA" "IEA"

\$martID

- [1] "ENSG00000012048" "ENSG00000012048" "ENSG00000012048" "ENSG00000012048"
- [5] "ENSG00000012048" "ENSG00000012048" "ENSG00000012048" "ENSG00000012048"
- [9] "ENSG00000012048" "ENSG00000012048" "ENSG00000012048" "ENSG00000012048"
- [13] "ENSG00000012048" "ENSG00000012048" "ENSG00000012048" "ENSG00000012048"
- [17] "ENSG00000012048" "ENSG00000012048" "ENSG00000012048" "ENSG00000012048"
- [21] "ENSG00000012048" "ENSG00000012048" "ENSG00000012048" "ENSG00000012048"
- [25] "ENSG00000012048" "ENSG00000012048"

3.5 getOMIM

The function `getOMIM` uses a query id to look up OMIM annotation of the corresponding gene. It return an object of class `OMIM`. When no information about the identifier is found in Ensembl, an empty `OMIM` object will be created. Currently the `getOMIM` function takes identifiers from entrezgene, affy, RefSeq and embl. Besides the `id` argument, this function also has an `array`, `type` and `mart` argument.

The `id` argument is either a vector of identifiers or a single identifier to be annotated.

The `array` argument takes affy array identifiers as values. A list of possible identifiers supported by the package can be obtained by executing the function `getAffyArrays`.

The `type` argument takes the values of 'entrezgene', 'refseq' and 'embl' to clarify which type of identifier is specified in the `id` argument. If the `array` argument is used then `biomaRt` knows the identifiers given correspond to affy id's. The `mart` argument is a `mart` connection, which was obtained using the method `martConnect`

Depending on the identifier, different additional arguments will have to be given, summarized below:

- Affy id's: `id`, `array`, `mart`
- Entrez-Gene: `id`, `type`, `mart`
- RefSeq: `id`, `type`, `mart`
- embl: `id`, `type`, `mart`

Examples:

```
> getOMIM(id = "1939_at", array = "hg_u95av2", mart = mart)
```

```
An object of class "martTable"
```

```
Slot "id":
```

```
[1] "1939_at" "1939_at"
```

```
Slot "table":
```

```
$OMIMID
```

```
[1] 191170 191170
```

```
$disease
```

```
[1] "Colorectal cancer, 114500 (3)" "Li-Fraumeni syndrome (3)"
```

```
$martID
```

```
[1] "ENSG00000141510" "ENSG00000141510"
```

```
> getOMIM(id = 672, type = "entrezgene", mart = mart)
```

```

An object of class "martTable"
Slot "id":
[1] "672" "672"

Slot "table":
$OMIMID
[1] 113705 113705

$disease
[1] "Breast cancer-1 (3)" "Ovarian cancer (3)"

$martID
[1] "ENSG00000012048" "ENSG00000012048"

```

3.6 getFeature

The function `getFeature` looks up affy identifiers on a given affy array which correspond to a given symbol. As output this function returns a `martTable`. Currently the `getFeature` function takes identifiers from affy only. Besides the symbol argument, this function also has array and mart argument.

The mart argument is a mart connection, which was obtained using the method `martConnect`

A last argument of this function is the type argument which, takes the values of 'affy', 'locuslink', 'refseq' and 'embl' to clarify which type of identifier is specified in the id argument.

Examples:

```
> getFeature(symbol = "P53", array = "hg_u95av2", mart = mart)
```

```

An object of class "martTable"
Slot "id":
[1] "36079_at" "1939_at" "1974_s_at" "31618_at" "1711_at" "33749_at"
[7] "1860_at" "34822_at"

Slot "table":
$symbol
[1] "TP53I3" "TP53" "TP53" "TP53" "TP53BP1" "TP53AP1" "TP53BP2"
[8] "TP53BP2"

$description
[1] "tumor protein p53 inducible protein 3 [Source:RefSeq_peptide;Acc:NP_671713]"
[2] "Cellular tumor antigen p53 (Tumor suppressor p53) (Phosphoprotein p53) (Antigen NY-"
[3] "Cellular tumor antigen p53 (Tumor suppressor p53) (Phosphoprotein p53) (Antigen NY-"
[4] "Cellular tumor antigen p53 (Tumor suppressor p53) (Phosphoprotein p53) (Antigen NY-"

```

```
[5] "Tumor suppressor p53-binding protein 1 (p53-binding protein 1) (53BP1). [Source:Uni
[6] "TP53 activated protein 1 [Source:RefSeq_peptide;Acc:NP_009164]"
[7] "Apoptosis stimulating of p53 protein 2 (Tumor suppressor p53-binding protein 2) (p5
[8] "Apoptosis stimulating of p53 protein 2 (Tumor suppressor p53-binding protein 2) (p5
```

```
$martID
```

```
[1] "ENSG000000115129" "ENSG000000141510" "ENSG000000141510" "ENSG000000141510"
[5] "ENSG000000067369" "ENSG000000182165" "ENSG000000143514" "ENSG000000143514"
```

3.7 getSequence

The function `getSequence` retrieves the sequence given it's chromosome, start and end position. As output this function returns a `martTable`. The `mart` argument is a mart connection, which was obtained using the method `martConnect` and should in this case be the sequence `mart`.

Examples:

```
> getSequence(species = "ggallus", chromosome = 1, start = 400,
+             end = 500, mart = mart)
```

An object of class "martTable"

```
Slot "id":
```

```
[1] "1_400_500"
```

```
Slot "table":
```

```
$chromosome
```

```
[1] 1
```

```
$start
```

```
[1] 400
```

```
$end
```

```
[1] 500
```

```
$sequence
```

```
[1] "GTGACATTTCCAGCATTCAAGTGTGTCAAAGCCTAGCTTCATTTTTGAATGTATTGAGGGGCAGATGTCCATCTCATGAATCAT
```

3.8 getSNP

The function `getSNP` retrieves all SNP's between a given a start and end position on a gives chromosome.. As output this function returns a `martTable`. The `mart` argument is a mart connection, which was obtained using the method `martConnect` and should in this case be

the snp mart.

Examples:

```
> getSNP(chromosome = 8, start = 148350, end = 148612, species = "hsapiens",  
+       mart = mart)
```

An object of class "martTable"

Slot "id":

```
[1] "TSC1421398" "TSC1421399" "TSC1421400" NA          "TSC1421401"  
[6] NA           "TSC1421402" "TSC1737607" NA          NA
```

Slot "table":

\$snpStart

```
[1] 148394 148411 148462 148471 148499 148525 148533 148535 148539 148601
```

\$allele

```
[1] "C/A" "A/G" "C/T" "T/G" "G/A" "G/A" "G/A" "C/T" "C/T" "G/A"
```

\$coding

```
[1] NA NA NA NA NA NA NA NA NA NA NA
```

\$intronic

```
[1] NA NA NA NA NA NA NA NA NA NA NA
```

\$syn

```
[1] NA NA NA NA NA NA NA NA NA NA NA
```

\$utr5

```
[1] NA NA NA NA NA NA NA NA NA NA NA
```

\$utr3

```
[1] 1 1 1 1 1 1 1 1 1 1
```

3.9 getSpecies

The function `getSpecies` looks up which species are present in the BioMart. This function currently works only for ensembl.

Examples:

```
> getSpecies(mart = mart)
```

```

[1] "agambiae"      "amelliifera"  "celegans"     "cfamiliaris"
[5] "dmelanogaster" "drerio"       "frubripes"    "ggallus"
[9] "hsapiens"      "mmusculus"    "ptroglodytes" "rnorvegicus"
[13] "scerevisiae"   "tnigroviridis" "xtropicalis"

```

3.10 getAffyArrays

The function `getAffyArrays` retrieves the Affymetrix array identifiers which are present in ensembl and which can be queried using the biomaRt package.

Examples:

```
> getAffyArrays(mart = mart)
```

	V1	V2
1	canine	cfamiliaris
2	zebrafish	drerio
3	hg_focus	hsapiens
4	hg_u133_plus_2	hsapiens
5	hg_u133a_2	hsapiens
6	hg_u133a	hsapiens
7	hg_u133b	hsapiens
8	hg_u95av2	hsapiens
9	hg_u95b	hsapiens
10	hg_u95c	hsapiens
11	hg_u95d	hsapiens
12	hg_u95e	hsapiens
13	u133_x3p	hsapiens
14	mg_u74av2	mmusculus
15	mg_u74bv2	mmusculus
16	mg_u74cv2	mmusculus
17	mouse430_2	mmusculus
18	mouse430a_2	mmusculus
19	mu11ksuba	mmusculus
20	mu11ksubb	mmusculus
21	rat230_2	rnorvegicus
22	rg_u34a	rnorvegicus
23	rg_u34b	rnorvegicus
24	rg_u34c	rnorvegicus

3.11 getHomolog

This function retrieves homologs of genes of one species in another species

Example:

```
> getHomolog(id = 1:20, from.species = "hsapiens", to.species = "mmusculus",
+           from.type = "entrezgene", to.type = "refseq", mart = mart)
```

An object of class "martTable"

Slot "id":

```
[1] "1" "2" "2" "2" "2" "3" "4" "5" "6" "7" "8" "9" "9" "9" "10"
[16] "11" "12" "12" "12" "12" "12" "13" "14" "15" "16" "17" "18" "19" "20"
```

Slot "table":

\$MappedID

```
[1] NA "NM_175628" "NM_008646" "NM_008645" "NM_007376" NA
[7] NA NA NA NA NA "NM_010874"
[13] "NM_008673" "NM_008674" "NM_010874" NA "NM_009252" "NM_173024"
[19] "NM_008458" "NM_011458" "NM_009253" "NM_023383" "NM_146110" "NM_009591"
[25] "NM_146217" NA "NM_172961" "NM_013454" "NM_007379"
```

3.12 getPossibleXrefs

This function retrieves the possible cross-references present in Ensembl. This is a very general function to see what can be extracted from Ensembl. The results of this function can be used in the getXref function to extract the data of interest.

Example:

```
> xref <- getPossibleXrefs(mart = mart)
> xref[1:10, ]
```

	species	xref
[1,]	"agambiae"	"anopheles_symbol"
[2,]	"agambiae"	"celera_gene"
[3,]	"agambiae"	"celera_pep"
[4,]	"agambiae"	"celera_trans"
[5,]	"agambiae"	"embl"
[6,]	"agambiae"	"pdb"
[7,]	"agambiae"	"prediction_sptrembl"
[8,]	"agambiae"	"protein_id"
[9,]	"agambiae"	"uniprot_accession"
[10,]	"agambiae"	"uniprot_id"

3.13 getXref

This powerful function retrieves any cross reference in Ensembl

Example:

```
> getXref(id = "1939_at", from.species = "hsapiens", to.species = "mmusculus",  
+         from.xref = "affy_hg_u95av2", to.xref = "affy_mouse430_2",  
+         mart = mart)
```

An object of class "martTable"

Slot "id":

```
[1] "1939_at" "1939_at"
```

Slot "table":

\$from.id

```
[1] "1939_at" "1939_at"
```

\$to.id

```
[1] "1427739_a_at" "1426538_a_at"
```

\$martID

```
[1] 75949 75949
```