

Package ‘cosmosR’

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Type Package

Title COSMOS (Causal Oriented Search of Multi-Omic Space)

Version 1.4.0

Description COSMOS (Causal Oriented Search of Multi-Omic Space) is a method that integrates phosphoproteomics, transcriptomics, and metabolomics data sets based on prior knowledge of signaling, metabolic, and gene regulatory networks. It estimated the activities of transcription factors and kinases and finds a network-level causal reasoning. Thereby, COSMOS provides mechanistic hypotheses for experimental observations across mult-omics datasets.

URL <https://github.com/saezlab/COSMOSR>

BugReports <https://github.com/saezlab/COSMOSR/issues>

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License GPL-3

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cosmos_data

Create Cosmos Data

Description

An S3 class that combines the required data into a comprehensive list. Use the [preprocess_COSMOS_signaling_to_metabolism](#) or [preprocess_COSMOS_metabolism_to_signaling](#) to create an instance.

Usage

```
cosmos_data(
  meta_network,
  tf_regulon = NULL,
  signaling_data,
  metabolic_data,
  expression_data,
  verbose = TRUE
)
```

Arguments

meta_network	Prior knowledge network (PKN). By default COSMOS use a PKN derived from Omnipath, STITCHdb and Recon3D. See details on the data meta_network .
tf_regulon	Collection of transcription factor - target interactions. A default collection from dorothea can be obtained by the load_tf_regulon_dorothea function.
signaling_data	Numerical vector, where names are signaling nodes in the PKN and values are from {1, 0, -1}. Continuous data will be discretized using the sign function.
metabolic_data	Numerical vector, where names are metabolic nodes in the PKN and values are continuous values that represents log2 fold change or t-values from a differential analysis. These values are compared to the simulation results (simulated nodes can take value -1, 0 or 1).
expression_data	Numerical vector that represents the results of a differential gene expression analysis. Names are gene names using EntrezID starting with an X and values are log fold change or t-values. Genes with NA values are considered none expressed and they will be removed from the TF-gene expression interactions.
verbose	(default: TRUE) Reports details about the cosmos_data object.

Value

cosmos data class instance.

default_CARNIVAL_options

Setting Default CARNIVAL Options

Description

Returns the default CARNIVAL options as a list. You can modify the elements of the list and then use it as an argument in [run_COSMOS_metabolism_to_signaling](#) or [run_COSMOS_signaling_to_metabolism](#). If you choose CPLEX or CBC, you must modify then the solverPath field and point to the CPLEX/CBC executable (See Details).

Usage

```
default_CARNIVAL_options(solver = NULL)
```

Arguments

solver	one of 'cplex' (recommended, but require 3rd party tool), 'cbc' (also require 3rd party tool) or 'lpSolve' (only for small networks)
--------	--

Details

COSMOS is dependent on CARNIVAL for exhibiting the signalling pathway optimisation. CARNIVAL requires the interactive version of IBM Cplex, Gurobi or CBC-COIN solver as the network optimiser. The IBM ILOG Cplex is freely available through Academic Initiative [here](#). Gurobi license is also free for academics, request a license following instructions [here](#). The CBC solver is open source and freely available for any user, but has a significantly lower performance than CPLEX or Gurobi. Obtain CBC executable directly usable for cosmos [here](#). Alternatively for small networks, users can rely on the freely available [lpSolve R-package](#), which is automatically installed with the package.

Value

returns a list with all possible options implemented in CARNIVAL. see the documentation on [runCARNIVAL](#).

Examples

```
# load and change default options:
my_options = default_CARNIVAL_options(solver = "cplex")

my_options$solverPath = "/Applications/CPLEX_Studio128/cplex/bin/x86-64_osx/cplex"
my_options$threads = 2
my_options$timelimit = 3600*15
```

```
display_node_neighborhood
      display_node_neighborhood
```

Description

display input and measurements within n steps of a given set of nodes

Usage

```
display_node_neighborhood(central_node, sif, att, n = 100)
```

Arguments

central_node	character or character vector; node ID(s) around which a network will be branched out until measurements and input are reached
sif	df; COSMOS network solution in sif format like the first list element returned by the format_cosmos_res function
att	df; attributes of the nodes of the COSMOS network solution like the second list element returned by the format_cosmos_res function
n	numeric; maximum number of steps in the network to look for inputs and measurements

Value

a visnetwork object

Examples

```
CARNIVAL_options <- cosmosR::default_CARNIVAL_options("lpSolve")
data(toy_network)
data(toy_signaling_input)
data(toy_metabolic_input)
data(toy_RNA)
test_for <- preprocess_COSMOS_signaling_to_metabolism(meta_network = toy_network,
signaling_data = toy_signaling_input,
metabolic_data = toy_metabolic_input,
diff_expression_data = toy_RNA,
maximum_network_depth = 15,
remove_unexpressed_nodes = TRUE,
CARNIVAL_options = CARNIVAL_options
)
test_result_for <- run_COSMOS_signaling_to_metabolism(data = test_for,
CARNIVAL_options = CARNIVAL_options)
test_result_for <- format_COSMOS_res(test_result_for)
network_plot <- display_node_neighborhood(central_node = 'MYC',
sif = test_result_for[[1]],
att = test_result_for[[2]],
n = 7)
network_plot
```

extract_nodes_for_ORA *Extract COSMOS nodes for ORA analysis*

Description

Function to extract the nodes that appear in the COSMOS output network and the background genes (all genes present in the prior knowledge network)

Usage

```
extract_nodes_for_ORA(sif, att)
```

Arguments

sif	df; COSMOS network solution in sif format like the first list element returned by the format_cosmos_res function
att	df; attributes of the nodes of the COMSOS network solution like the second list element returned by the format_cosmos_res function

Value

List with 2 objects: the success and the background genes

Examples

```
CARNIVAL_options <- cosmosR::default_CARNIVAL_options("lpSolve")
data(toy_network)
data(toy_signaling_input)
data(toy_metabolic_input)
data(toy_RNA)
test_for <- preprocess_COSMOS_signaling_to_metabolism(meta_network = toy_network,
signaling_data = toy_signaling_input,
metabolic_data = toy_metabolic_input,
diff_expression_data = toy_RNA,
maximum_network_depth = 15,
remove_unexpressed_nodes = TRUE,
CARNIVAL_options = CARNIVAL_options
)
test_result_for <- run_COSMOS_signaling_to_metabolism(data = test_for,
CARNIVAL_options = CARNIVAL_options)
test_result_for <- format_COSMOS_res(test_result_for)
extracted_nodes <- extract_nodes_for_ORA(
sif = test_result_for[[1]],
att = test_result_for[[2]]
)
```

format_COSMOS_res	<i>format_COSMOS_res</i>
-------------------	--------------------------

Description

formats the network with readable names

Usage

```
format_COSMOS_res(cosmos_res, metab_mapping = NULL)
```

Arguments

cosmos_res	results of COSMOS run
metab_mapping	a named vector with HMDB Ids as names and desired metabolite names as values.

Value

list with network and attribute tables.

gmt_to_dataframe	<i>Convert gmt file to data frame</i>
------------------	---------------------------------------

Description

This function is designed to convert a gmt file (gene set file from MSigDB) into a two column data frame where the first column corresponds to omic features (genes) and the second column to associated terms (pathway the gene belongs to). One gene can belong to several pathways.

Usage

```
gmt_to_dataframe(gmtfile)
```

Arguments

gmtfile a full path name of the gmt file to be converted

Value

a two column data frame where the first column corresponds to omic features and the second column to associated terms (pathways).

HMDB_mapper_vec	<i>Toy Input Transcription Data Set</i>
-----------------	---

Description

This exemplary transcription data are the specific deregulated gene expression of the 786-O cell line from the NCI60 dataset.

Usage

```
data(HMDB_mapper_vec)
```

Format

An object of class “character” containing the marching between HMDB metabolite IDs and there corresponding metabolite names.

Source

<https://bioconductor.org/packages/release/data/annotation/html/metaboliteIDmapping.html>

Examples

```
data(HMDB_mapper_vec)
```

```
load_tf_regulon_dorothea
```

load transcription factor regulon

Description

load the transcription factors from DOROTHEA package and converts gene symbols to EntrezID using org.Hs.eg.db

Usage

```
load_tf_regulon_dorothea(confidence = c("A", "B", "C"))
```

Arguments

confidence strong vector (by default: c("A","B","C")). Subset of {A, B, C, D, E}. See the 'dorothea' for the meaning of confidence levels. package for further details.

Value

returns a PKN of a form of a data table. Each row is an interaction. Columns names are:

- 'tf' transcription factor - 'confidence' class of confidence - 'target' target gene - 'sign' indicates if interaction is up (1) or down-regulation (-1).

Examples

```
load_tf_regulon_dorothea()
```

```
meta_network
```

Meta Prior Knowledge Network

Description

Comprehensive Prior Knowledge Network (PKN), which combines signaling and metabolic interaction networks. The network was constructed using the Recon3D and STITCH metabolic networks as well as the signaling network from OmniPath.

Usage

```
data(meta_network)
```


Format

An object of class “tibble” with 117065 rows (interactions) and three variables:

source Source node, either metabolite or protein

interaction Type of interaction, 1 = Activation, -1 = Inhibition

target Target node, either metabolite or protein A detailed description of the identifier formatting can be found under https://metapkn.omnipathdb.org/00_README.txt.

Source

The network is available in Omnipath: https://metapkn.omnipathdb.org/metapkn__20200122.txt, the scripts used for the build of the network are available under https://github.com/saezlab/Meta_PKN.

References

Dugourd, A., Kuppe, C. and Sciacovelli, M. et. al. (2021) *Molecular Systems Biology*. **17**, e9730.

Examples

```
data(meta_network)
```

```
prepare_metab_inputs    add metabolic compartment and metab__ prefix to metabolite IDs
```

Description

This function adds metabolic compartments to the metabolic identifiers provided by the user.

Usage

```
prepare_metab_inputs(metab_input, compartment_codes)
```

Arguments

metab_input a named vector with metabolic statistics as inputs and metabolite identifiers as names

compartment_codes a character vector, the desired compartment codes to be added. Possible values are "r", "c", "e", "x", "m", "l", "n" and "g"

Value

a named vector with the compartment code and prefixed added to the names

```
preprocess_COSMOS_metabolism_to_signaling
```

Preprocess COSMOS Inputs For Metabolism to Signaling

Description

Runs checks on the input data and simplifies the prior knowledge network. Simplification includes the removal of (1) nodes that are not reachable from signaling nodes and (2) interactions between transcription factors and target genes if the target gene does not respond or the response is contradictory with the change in the transcription factor activity. Optionally, further TF activities are estimated via network optimization via CARNIVAL and the interactions between TF and genes are filtered again.

Usage

```
preprocess_COSMOS_metabolism_to_signaling(
  meta_network = meta_network,
  tf_regulon = load_tf_regulon_dorothea(),
  signaling_data,
  metabolic_data,
  diff_expression_data = NULL,
  diff_exp_threshold = 1,
  maximum_network_depth = 8,
  expressed_genes = NULL,
  remove_unexpressed_nodes = TRUE,
  filter_tf_gene_interaction_by_optimization = TRUE,
  CARNIVAL_options = default_CARNIVAL_options("lpSolve")
)
```

Arguments

<code>meta_network</code>	prior knowledge network (PKN). A PKN released with COSMOS and derived from Omnipath, STITCHdb and Recon3D can be used. See details on the data meta_network .
<code>tf_regulon</code>	collection of transcription factor - target interactions. A default collection from dorothea can be obtained by the <code>load_tf_regulon_dorothea</code> function.
<code>signaling_data</code>	numerical vector, where names are signaling nodes in the PKN and values are from {1, 0, -1}. Continuous data will be discretized using the <code>sign</code> function.
<code>metabolic_data</code>	numerical vector, where names are metabolic nodes in the PKN and values are continuous values that represents log2 fold change or t-values from a differential analysis. These values are compared to the simulation results (simulated nodes can take value -1, 0 or 1)
<code>diff_expression_data</code>	(optional) numerical vector that represents the results of a differential gene expression analysis. Names are gene names using gene symbole and values are log fold change or t-values. We use the “diff_exp_threshold” parameter to

decide which genes changed significantly. Genes with NA values are considered none expressed and they will be removed from the TF-gene expression interactions.

`diff_exp_threshold` threshold parameter (default 1) used to binarize the values of “diff_expression_data”.

`maximum_network_depth` integer > 0 (default: 8). Nodes that are further than “maximum_network_depth” steps from the signaling nodes on the directed graph of the PKN are considered non-reachable and are removed.

`expressed_genes` character vector. Names of nodes that are expressed. By default we consider all the nodes that appear in `diff_expression_data` with a numeric value (i.e. nodes with NA are removed)

`remove_unexpressed_nodes` if TRUE (default) removes nodes from the PKN that are not expressed, see input “expressed_genes”.

`filter_tf_gene_interaction_by_optimization` (default:TRUE), if TRUE then runs a network optimization that estimates TF activity not included in the inputs and checks the consistency between the estimated activity and change in gene expression. Removes interactions where TF and gene expression are inconsistent

`CARNIVAL_options` list that controls the options of CARNIVAL. See details in [default_CARNIVAL_options](#).

Value

cosmos_data object with the following fields:

`meta_network` Filtered PKN

`tf_regulon` TF - target regulatory network

`signaling_data_bin` Binarised signaling data

`metabolic_data` Metabolomics data

`diff_expression_data_bin` Binarized gene expression data

`optimized_network` Initial optimized network if `filter_tf_gene_interaction_by_optimization` is TRUE

See Also

[meta_network](#) for meta PKN, [load_tf_regulon_dorothea](#) for tf regulon, [runCARNIVAL](#).

Examples

```
data(toy_network)
data(toy_signaling_input)
data(toy_metabolic_input)
data(toy_RNA)
test_back <- preprocess_COSMOS_metabolism_to_signaling(
  meta_network = toy_network,
```

```

signaling_data = toy_signaling_input,
metabolic_data = toy_metabolic_input,
diff_expression_data = toy_RNA,
maximum_network_depth = 15,
remove_unexpressed_nodes = TRUE,
CARNIVAL_options = default_CARNIVAL_options("lpSolve")
)

```

preprocess_COSMOS_signaling_to_metabolism

Preprocess COSMOS Inputs For Signaling to Metabolism

Description

Runs checks on the input data and simplifies the prior knowledge network. Simplification includes the removal of (1) nodes that are not reachable from signaling nodes and (2) interactions between transcription factors and target genes if the target gene does not respond or the response is contradictory with the change in the transcription factor activity. Optionally, further TF activities are estimated via network optimization via CARNIVAL and the interactions between TF and genes are filtered again.

Usage

```

preprocess_COSMOS_signaling_to_metabolism(
  meta_network = meta_network,
  tf_regulon = load_tf_regulon_dorothea(),
  signaling_data,
  metabolic_data,
  diff_expression_data = NULL,
  diff_exp_threshold = 1,
  maximum_network_depth = 8,
  expressed_genes = NULL,
  remove_unexpressed_nodes = TRUE,
  filter_tf_gene_interaction_by_optimization = TRUE,
  CARNIVAL_options = default_CARNIVAL_options("lpSolve")
)

```

Arguments

<code>meta_network</code>	prior knowledge network (PKN). A PKN released with COSMOS and derived from Omnipath, STITCHdb and Recon3D can be used. See details on the data meta_network .
<code>tf_regulon</code>	collection of transcription factor - target interactions. A default collection from dorothea can be obtained by the load_tf_regulon_dorothea function.
<code>signaling_data</code>	numerical vector, where names are signaling nodes in the PKN and values are from {1, 0, -1}. Continuous data will be discretized using the sign function.

metabolic_data	numerical vector, where names are metabolic nodes in the PKN and values are continuous values that represents log2 fold change or t-values from a differential analysis. These values are compared to the simulation results (simulated nodes can take value -1, 0 or 1)
diff_expression_data	(optional) numerical vector that represents the results of a differential gene expression analysis. Names are gene names using gene symbols and values are log fold change or t-values. We use the “diff_exp_threshold” parameter to decide which genes changed significantly. Genes with NA values are considered none expressed and they will be removed from the TF-gene expression interactions.
diff_exp_threshold	threshold parameter (default 1) used to binarize the values of “diff_expression_data”.
maximum_network_depth	integer > 0 (default: 8). Nodes that are further than “maximum_network_depth” steps from the signaling nodes on the directed graph of the PKN are considered non-reachable and are removed.
expressed_genes	character vector. Names of nodes that are expressed. By default we consider all the nodes that appear in diff_expression_data with a numeric value (i.e. nodes with NA are removed)
remove_unexpressed_nodes	if TRUE (default) removes nodes from the PKN that are not expressed, see input “expressed_genes”.
filter_tf_gene_interaction_by_optimization	(default:TRUE), if TRUE then runs a network optimization that estimates TF activity not included in the inputs and checks the consistency between the estimated activity and change in gene expression. Removes interactions where TF and gene expression are inconsistent
CARNIVAL_options	list that controls the options of CARNIVAL. See details in default_CARNIVAL_options .

Value

cosmos_data object with the following fields:

meta_network Filtered PKN

tf_regulon TF - target regulatory network

signaling_data_bin Binarised signaling data

metabolic_data Metabolomics data

diff_expression_data_bin Binarized gene expression data

optimized_network Initial optimized network if filter_tf_gene_interaction_by_optimization is TRUE

See Also

[meta_network](#) for meta PKN, [load_tf_regulon_dorothea](#) for tf regulon, [runCARNIVAL](#).

Examples

```
data(toy_network)
data(toy_signaling_input)
data(toy_metabolic_input)
data(toy_RNA)
test_for <- preprocess_COSMOS_signaling_to_metabolism(meta_network = toy_network,
  signaling_data = toy_signaling_input,
  metabolic_data = toy_metabolic_input,
  diff_expression_data = toy_RNA,
  maximum_network_depth = 15,
  remove_unexpressed_nodes = TRUE,
  CARNIVAL_options = default_CARNIVAL_options("lpSolve"))
```

print.cosmos_data	<i>Print Cosmos Data Summary Print a summary of cosmos data.</i>
-------------------	--

Description

Print Cosmos Data Summary Print a summary of cosmos data.

Usage

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

Arguments

x [cosmos_data](#) object. Use the [preprocess_COSMOS_signaling_to_metabolism](#) or [preprocess_COSMOS_metabolism_to_signaling](#) functions to create one.

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

Value

input (invisible)

See Also

[print, cosmos_data](#)

```
run_COSMOS_metabolism_to_signaling
  run COSMOS metabolism to signaling
```

Description

Runs COSMOS from metabolism to signaling. This function uses CARNIVAL to find a subset of the prior knowledge network based on optimization that (1) includes the most measured and input nodes and (2) which is in agreement with the data. Use [preprocess_COSMOS_metabolism_to_signaling](#) to prepare the the inputs, measurements and the prior knowledge network.

Usage

```
run_COSMOS_metabolism_to_signaling(  
  data,  
  CARNIVAL_options = default_CARNIVAL_options("lpSolve")  
)
```

Arguments

data [cosmos_data](#) object. Use the [preprocess_COSMOS_metabolism_to_signaling](#) function to create an instance.

CARNIVAL_options List that controls the options of CARNIVAL. See details in [default_CARNIVAL_options](#).

Value

List with the following elements:

weightedSIF The averaged networks found by optimization in a format of a Simple Interaction network, i.e. each row codes an edge

N_networks Number of solutions found by the optimization

nodesAttributes Estimated node properties

individual_networks List of optimal networks found

individual_networks_node_attributes Node activity in each network

See Also

[preprocess_COSMOS_metabolism_to_signaling](#), [runCARNIVAL](#), [cosmos_data](#)

Examples

```
data(toy_network)  
data(toy_signaling_input)  
data(toy_metabolic_input)  
data(toy_RNA)  
test_back <- preprocess_COSMOS_metabolism_to_signaling(meta_network = toy_network,
```

```

    signaling_data = toy_signaling_input,
    metabolic_data = toy_metabolic_input,
    diff_expression_data = toy_RNA,
    maximum_network_depth = 15,
    remove_unexpressed_nodes = TRUE,
    CARNIVAL_options = default_CARNIVAL_options("lpSolve"))

test_result_back <- run_COSMOS_metabolism_to_signaling(data = test_back,
    CARNIVAL_options = default_CARNIVAL_options("lpSolve"))

```

```

run_COSMOS_signaling_to_metabolism
    run COSMOS signaling to metabolism

```

Description

Runs COSMOS from signaling to metabolism. This function uses CARNIVAL to find a subset of the prior knowledge network based on optimisation that (1) includes the most measured and input nodes and (2) which is in agreement with the data. Use [preprocess_COSMOS_signaling_to_metabolism](#) to prepare inputs, measurements and prior knowledge network.

Usage

```

run_COSMOS_signaling_to_metabolism(
  data,
  CARNIVAL_options = default_CARNIVAL_options("lpSolve")
)

```

Arguments

data [cosmos_data](#) object. Use the [preprocess_COSMOS_signaling_to_metabolism](#) function to create an instance.

CARNIVAL_options List that controls the options of CARNIVAL. See details in [default_CARNIVAL_options](#).

Value

List with the following elements:

weightedSIF The averaged networks found by optimization in a format of a Simple Interaction network, i.e. each row codes an edge

N_networks Number of solutions found by the optimization

nodesAttributes Estimated node properties

individual_networks List of optimal networks found

individual_networks_node_attributes Node activity in each network

See Also

[preprocess_COSMOS_metabolism_to_signaling](#), [runCARNIVAL](#), [cosmos_data](#)

Examples

```
data(toy_network)
data(toy_signaling_input)
data(toy_metabolic_input)
data(toy_RNA)
test_for <- preprocess_COSMOS_signaling_to_metabolism(meta_network = toy_network,
  signaling_data = toy_signaling_input,
  metabolic_data = toy_metabolic_input,
  diff_expression_data = toy_RNA,
  maximum_network_depth = 15,
  remove_unexpressed_nodes = TRUE,
  CARNIVAL_options = default_CARNIVAL_options("lpSolve"))

test_result_for <- run_COSMOS_signaling_to_metabolism(data = test_for,
  CARNIVAL_options = default_CARNIVAL_options("lpSolve"))
```

toy_metabolic_input *Toy Metabolic Input Data*

Description

This metabolic data are a subset from the metabolic measurements of the 786-O cell line from the NCI60 dataset.

Usage

```
data(toy_metabolic_input)
```

Format

An object of class “numeric” containing the t-values of 2 metabolites, which are named with metabolite HMDB Ids matching the toy network.

Source

Subset of: https://github.com/saezlab/COSMOS_MSB/blob/main/data/metab_input_COSMOS.csv

References

Dugourd, A., Kuppe, C. and Sciacovelli, M. et. al. (2021) *Molecular Systems Biology*. **17**, e9730.

Examples

```
data(toy_metabolic_input)
```

toy_network	<i>Toy Input Network</i>
-------------	--------------------------

Description

This signaling network is the reduced COSMOS network solution obtained in the cosmos test on 786-O NCI60 data. Here, this network solution is reused as an exemplary input prior knowledge network (PKN).

Usage

```
data(toy_network)
```

Format

An object of class “data.frame” with 19 rows (interactions) and three variables:

source Source node, either metabolite or protein

interaction Type of interaction, 1 = Activation, -1 = Inhibition

target Target node, either metabolite or protein A detailed description of the identifier formatting can be found under https://metapkn.omnipathdb.org/00__README.txt.

Source

The network data are available on github: https://github.com/saezlab/COSMOS_MSB/tree/main/results/COSMOS_result/COSMOS_res_session.RData. The toy_network is the combined network of the COSMOS network solutions CARNIVAL_Result2 and CARNIVAL_Result_rerun subsequently reduced to 19 exemplary nodes.

References

Dugourd, A., Kuppe, C. and Sciacovelli, M. et. al. (2021) *Molecular Systems Biology*. **17**, e9730.

Examples

```
data(toy_network)
```

toy_RNA	<i>Toy Input Transcription Data Set</i>
---------	---

Description

This exemplary transcription data are the specific deregulated gene expression of the 786-O cell line from the NCI60 dataset.

Usage

```
data(toy_RNA)
```

Format

An object of class “numeric” containing the t-values of 9300 genes, which are named with gene symbols matching the toy network.

Source

https://github.com/saezlab/COSMOS_MSB/blob/main/data/RNA_ttop_tumorvshealthy.csv

References

Dugourd, A., Kuppe, C. and Sciacovelli, M. et. al. (2021) *Molecular Systems Biology*. **17**, e9730.

Examples

```
data(toy_RNA)
```

toy_signaling_input	<i>Toy Signaling Input</i>
---------------------	----------------------------

Description

This signaling data are a subset of the footprint-based signaling activity estimates of transcription factors of the 786-O cell line from the NCI60 dataset.

Usage

```
data(toy_signaling_input)
```

Format

An object of class “data.frame” containing the normalised enrichment scores (NES) of 2 signaling proteins, which are named with their respective gene Entrez ID matching the toy network.

Source

Subset of: https://github.com/saezlab/COSMOS_MSB/blob/main/data/signaling_input_COSMOS.csv

References

Dugourd, A., Kuppe, C. and Sciacovelli, M. et. al. (2021) *Molecular Systems Biology*. **17**, e9730.

Examples

```
data(toy_signaling_input)
```

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