

Package ‘hca’

June 28, 2022

Title Exploring the Human Cell Atlas Data Coordinating Platform

Version 1.4.0

Description This package provides users with the ability to query the Human Cell Atlas data repository for single-cell experiment data. The `projects()`, `files()`, `samples()` and `bundles()` functions retrieve summary information on each of these indexes; corresponding `*_details()` are available for individual entries of each index. File-based resources can be downloaded using `files_download()`. Advanced use of the package allows the user to page through large result sets, and to flexibly query the 'list-of-lists' structure representing query responses.

License MIT + file LICENSE

Encoding UTF-8

Roxygen list(markdown = TRUE)

RoxygenNote 7.1.2

Depends R (>= 4.1)

Imports httr, jsonlite, dplyr, tibble, tidyr, readr, BiocFileCache, tools, utils, digest

Suggests futile.logger, LoomExperiment, SummarizedExperiment, SingleCellExperiment, S4Vectors, methods, testthat (>= 3.0.0), knitr, rmarkdown, BiocStyle

Config/testthat/edition 3

VignetteBuilder knitr

biocViews Software, SingleCell

git_url <https://git.bioconductor.org/packages/hca>

git_branch RELEASE_3_15

git_last_commit 1756088

git_last_commit_date 2022-04-26

Date/Publication 2022-06-28

Author Maya McDaniel [aut],
Martin Morgan [aut, cre] (<<https://orcid.org/0000-0002-5874-8148>>)

Maintainer Martin Morgan <martin.morgan@roswellpark.org>

R topics documented:

.details	2
bundles	3
catalogs	4
files	5
filters	7
hca_next	8
hca_next.tbl_hca	9
lol	10
manifest	12
optimus_loom_annotation	13
projects	14
samples	16
summary	18
Index	19

.details	<i>Single Entity Details</i>
----------	------------------------------

Description

Single Entity Details

Usage

```
.details(
  uuid = character(),
  catalog = NULL,
  view = c("projects", "files", "samples", "bundles")
)
```

Arguments

uuid	character() unique *_id
catalog	character(1) source of data. Use catalogs() for possible values.
view	character() type of entity i.e. project, file, sample, or bundle

Value

list-of-lists containing relevant details about the project, file, sample, or bundle

Description

`bundles()` takes a list of user provided project titles to be used to query the HCA API for information about available bundles.

`bundles_detail()` takes a unique `bundle_id` and `catalog` for the bundle, and returns details about the specified bundle as a list-of-lists

Usage

```
bundles(
  filters = NULL,
  size = 1000L,
  sort = "projectTitle",
  order = c("asc", "desc"),
  catalog = NULL,
  as = c("tibble", "lol", "list", "tibble_expanded"),
  columns = bundles_default_columns("character")
)
```

```
bundles_facets(facet = character(), catalog = NULL)
```

```
bundles_default_columns(as = c("tibble", "character"))
```

```
bundles_detail(uuid, catalog = NULL)
```

Arguments

<code>filters</code>	filter object created by <code>filters()</code> , or <code>NULL</code> (default; all projects).
<code>size</code>	<code>integer(1)</code> maximum number of results to return; default: all projects matching filter. The default (10000) is meant to be large enough to return all results.
<code>sort</code>	<code>character(1)</code> project facet (see <code>facet_options()</code>) to sort result; default: "projectTitle".
<code>order</code>	<code>character(1)</code> sort order. One of "asc" (ascending) or "desc" (descending).
<code>catalog</code>	<code>character(1)</code> source of data. Use <code>catalogs()</code> for possible values.
<code>as</code>	<code>character(1)</code> return format. One of "tibble" (default), "lol", "list", or "tibble_expanded", as described in the Details and Value sections of <code>?projects</code> .
<code>columns</code>	named <code>character()</code> indicating the paths to be used for parsing the 'lol' returned from the HCA to a tibble. The names of columns are used as column names in the returned tibble. If the columns are unnamed, a name is derived from the elements of path by removing <code>hits[*]</code> and all <code>[*]</code> , e.g., a path <code>hits[*].donorOrganisms[*].biologicalSex</code> is given the name <code>donorOrganisms.biologicalSex</code> .

facet	character() of valid facet names. Summary results (see 'Value', below) are returned when missing or length greater than 1; details are returned when a single facet is specified.
uuid	character() unique identifier (e.g., projectId) of the object.

Value

bundles_detail() returns a list-of-lists containing relevant details about the bundle

Examples

```

title <- paste(
  "Tabula Muris: Transcriptomic characterization of 20 organs and",
  "tissues from Mus musculus at single cell resolution"
)
filters <- filters( projectTitle = list(is = title) )
bundles(filters = filters)

bundles_facets()

bundle <- bundles(size = 1, as = "list")
bundle_uuid <- bundle[["hits"]][[1]][["entryId"]]
bundles_detail(uuid = bundle_uuid) |> lol() |>
lol_filter(is_leaf) |> print(n = Inf)

```

catalogs

Catalogs Available in the HCA

Description

catalogs() queries the API for all available project catalogs

Usage

```
catalogs()
```

Value

character() vector of available catalogs

Examples

```
catalogs()
```

Description

`files()` takes a list of user provided project titles to be used to query the HCA API for information about available files.

`files_download()` takes a tibble of files and a directory location as arguments to download the files of the tibble into the specified directory.

`files_detail()` takes a unique `file_id` and catalog for the file, and returns details about the specified file as a list-of-lists

`files_cache()` is the default location of the cache of downloaded files.

Usage

```
files(
  filters = NULL,
  size = 1000L,
  sort = "projectTitle",
  order = c("asc", "desc"),
  catalog = NULL,
  as = c("tibble", "lol", "list", "tibble_expanded"),
  columns = files_default_columns("character")
)
```

```
files_default_columns(as = c("tibble", "character"))
```

```
files_download(tbl, destination = NULL)
```

```
files_facets(facet = character(), catalog = NULL)
```

```
files_detail(uuid, catalog = NULL)
```

```
files_cache(create = FALSE)
```

Arguments

<code>filters</code>	filter object created by <code>filters()</code> , or <code>NULL</code> (default; all projects).
<code>size</code>	<code>integer(1)</code> maximum number of results to return; default: all projects matching filter. The default (10000) is meant to be large enough to return all results.
<code>sort</code>	<code>character(1)</code> project facet (see <code>facet_options()</code>) to sort result; default: "projectTitle".
<code>order</code>	<code>character(1)</code> sort order. One of "asc" (ascending) or "desc" (descending).
<code>catalog</code>	<code>character(1)</code> source of data. Use <code>catalogs()</code> for possible values.
<code>as</code>	<code>character(1)</code> return format. One of "tibble" (default), "lol", "list", or "tibble_expanded", as described in the Details and Value sections of ?projects.

columns	named character() indicating the paths to be used for parsing the 'lol' returned from the HCA to a tibble. The names of columns are used as column names in the returned tibble. If the columns are unnamed, a name is derived from the elements of path by removing hits[*] and all [*], e.g., a path hits[*].donorOrganisms[*].biologicalSex is given the name donorOrganisms.biologicalSex.
tbl	tibble of files (result of files())
destination	character() vector name of temporary directory to use for file downloads, or NULL
facet	character() of valid facet names. Summary results (see 'Value', below) are returned when missing or length greater than 1; details are returned when a single facet is specified.
uuid	character() unique identifier (e.g., projectId) of the object.
create	logical(1) create the default cache location, if it does not yet exist.

Details

files_cache() can be useful when it is necessary to 'clean up' the cache, e.g., BiocFileCache::cleanbfc() or more dramatically unlink(files_cache(), recursive = TRUE).

Value

files_download() returns a character() vector of file destinations

files_detail() returns a list-of-lists containing relevant details about the file.

files_cache() returns the path to the default cache. Use this as the cache= argument to BiocFileCache().

Examples

```
title <- paste(
  "Tabula Muris: Transcriptomic characterization of 20 organs and",
  "tissues from Mus musculus at single cell resolution"
)
filters <- filters( projectId = list(is = title) )
files(filters = filters)

files_filter <- filters(
  projectId = list(is = "cddab57b-6868-4be4-806f-395ed9dd635a"),
  fileFormat = list(is = "loom")
)
files_tbl <- files(filter = files_filter)
## Not run: files_download(files_tbl, destination = tempdir())
files_facets()
files_facets("fileFormat")

file <- files(size = 1, as = "list")
file_uuid <- file[["hits"]][[1]][["entryId"]]
files_detail(uuid = file_uuid)

files_cache(create = FALSE)
```

Description

`filters()` takes user input to be used as query filters. Each named argument is a list with a name specifying a verb (e.g., "is") and a character vector of allowed values, as in the examples. This input is then validated, reformatted to JSON, and encoded into a properly formatted URL.

Usage

```
facet_options()

filters(...)

## S3 method for class 'filters'
length(x)

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

Arguments

... named arguments, each of which is a `list()` specifying a query facet and its corresponding value to be used in the query

x for `length()` and `print()`, an object of class `filters`.

Value

`facet_options()` returns a vector of all permissible query facets for the HCA api.

`filters()` returns a `filters` object representing validated filters in a format suitable for use in `projects()` and related functions.

Examples

```
filters()

filters(
  organ = list(is = "pancreas")
)

filters(
  organ = list(is = "pancreas"),
  genusSpecies = list(is = "Homo sapiens")
)

filters(
  fileFormat = list(is = c("fastq", "fastq.gz"))
)
```

)

`hca_next`*Page through HCA results*

Description

`hca_next()` retrieves the next 'page' of results from a query of `projects()`, `samples()`, `files()`, or `bundles()`.

`hca_prev()` returns the previous 'page' of results.

Usage`hca_next(x)``hca_prev(x)`**Arguments**

`x` a 'tibble' or 'lol' object returned by `projects()`, `samples()`, `files()`, or `bundles()`.

Value

`hca_next()` returns the next page of results as a 'tibble' or 'lol'

`hcl_prev()` returns the previous page of results.

Examples

```
files <- files(size = 5)      # results 1-5, as a tibble
next_files <- hca_next(files) # results 6-10
next_files
hca_prev(next_files)        # previous results, i.e., files 1-5
```

hca_next.tbl_hca	<i>'tibble' representation of HCA query results</i>
------------------	---

Description

projects(), samples(), files(), and bundles() return, by default, a 'tibble' representation of the query.

hca_next() returns the next 'page' of results, if available.

hca_prev() returns the previous 'page' of results.

Usage

```
## S3 method for class 'tbl_hca'  
hca_next(x)
```

```
## S3 method for class 'tbl_hca'  
hca_prev(x)
```

Arguments

x a 'tibble' returned by projects(), samples(), files(), or bundles().

Value

hca_next() returns a tibble, with the same columns as x, containing the next 'page' of results.

hca_prev() returns a tibble with the same columns as x, containing the previous 'page' of results.

Examples

```
projects <- projects(size = 5)      # projects 1-5  
next_projects <- hca_next(projects) # projects 6-10  
  
hca_prev(next_projects)           # projects 1-5
```

Description

`lol()` constructs an indexed representation of an R 'list-of-lists', typically from JSON queries. The object is conveniently manipulated by other functions on this page to filter and select subsets of the structure, and to pull individual paths from across the list-of-lists.

`lol_filter()` filters available paths based on selections in `...`, e.g., `n` (number of matching elements) or `is_leaf` (is the element a 'leaf' in the list-of-lists representation?).

`lol_lpull()` returns a list containing elements corresponding to a single path.

`lol_pull()` tries to simplify the list-of-lists structure returned by `lol_lpull()` to a vector.

`lol_path()` returns a tibble representing the paths through the list-of-lists, without the underlying list-of-list data.

`as.list()` returns a list-of-lists representation of the data returned by `projects()`, etc.

`hca_next()` returns the next 'page' of results, if available.

`hca_prev()` returns the previous 'page' of results.

`lol_hits_lpull()` and `lol_hits_pull()` are variants of `lol_lpull()` and `lol_pull()` that retain the original geometry of `hits[*]`, even when the mapping between `hits[*]` and `path` is not 1:1.

Usage

```
lol(x = list())

lol_select(x, path = character())

lol_filter(x, ...)

lol_lpull(x, path)

lol_pull(x, path)

lol_path(x)

## S3 method for class 'lol'
as.list(x, ...)

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

## S3 method for class 'lol_hca'
hca_next(x)
```

```
## S3 method for class 'lol_hca'
hca_prev(x)

lol_hits_lpull(x, path)

lol_hits_pull(x, path)
```

Arguments

x	a 'list-of-lists' returned by <code>projects()</code> , <code>samples()</code> , <code>files()</code> , or <code>bundles()</code>
path	character(1) from the tibble returned by <code>lol_path(x)</code> .
...	for <code>lol_filter()</code> , named filter expressions evaluating to a logical vector with length equal to the number of rows in <code>lol_path()</code> .

Value

`lol()` returns a representation of the list-of-lists. The list has been processed to a dictionary with entries to all paths through the list, as well as a tibble summarizing the path, number of occurrences, and leaf status of each unique path.

`lol_select()` returns an object of class "lol" subset to contain just the elements matching path as 'top-level' elements of the list-of-lists.

`lol_filter()` returns an object of class lol, filtered to contain elements consistent with the filter criteria.

`lol_lpull()` returns a list, where each element corresponds to an element found at path in the list-of-lists structure x.

`lol_pull()` returns an unnamed vector of elements matching key.

`hca_next()` returns a list-of-lists containing the next 'page' of results.

`hca_prev()` returns a tibble with the same columns as x, containing the previous 'page' of results.

Examples

```
p1ol <- projects(as = "lol")
p1ol

p1ol |> lol_select("hits[*].projects[*]")

p1ol |>
  lol_select("hits[*].projects[*]") |>
  lol_filter(n == 44, is_leaf)

p1ol |>
  lol_pull("hits[*].entryId") |>
  head()

p1ol |> lol_path()

projects <- projects(size = 5, as = "lol")      # projects 1-5
next_projects <- hca_next(projects)            # projects 6-10
```

```
hca_prev(next_projects)          # projects 1-5
```

manifest *HCA File Querying*

Description

manifest() takes a list of user provided project titles to be used to query the HCA API for information about available manifest files.

manifest_cache() is the default location of the cache of downloaded manifest.

Usage

```
manifest(filters = NULL, catalog = NULL, update_cache = FALSE)
```

```
manifest_cache(create = FALSE)
```

Arguments

filters	hca filter object
catalog	character() name of catalog
update_cache	logical(1) when TRUE, update an existing cached resource by querying the HCA data server.
create	logical(1) create the default cache location, if it does not yet exist.

Details

manifest_cache() can be useful when it is necessary to 'clean up' the cache, e.g., BiocFileCache::cleanbfc() or more dramatically unlink(manifest_cache(), recursive = TRUE).

Value

manifest_cache() returns the path to the default cache. Use this as the cache= argument to BiocFileCache().

Examples

```
manifest_filter <- hca::filters(
  projectId = list(is = "4a95101c-9ffc-4f30-a809-f04518a23803"),
  fileFormat = list(is = "loom"),
  workflow = list(is = c("optimus_v4.2.2", "optimus_v4.2.3"))
)
## Not run:
result <- manifest(manifest_filter)
result
```

```
## End(Not run)
manifest_cache(create = FALSE)
```

```
optimus_loom_annotation
      HCA loom file annotation
```

Description

optimus_loom_annotation() takes the file path location of a .loom file generated by the Optimus pipeline, for which additional data will be extracted from the appropriate manifest. The .loom file will be imported as a LoomExperiment object, and the additional manifest information will be added to the object for return.

Usage

```
optimus_loom_annotation(loom, catalog = NULL)

## S3 method for class 'character'
optimus_loom_annotation(loom, catalog = NULL)

## S3 method for class 'LoomExperiment'
optimus_loom_annotation(loom, catalog = NULL)
```

Arguments

loom	Either a character(1) file path to a loom file on user's system, or a loom file obtained from the HCA and imported into R using LoomExperiment::import().
catalog	character() HCA catalog from which the .loom file originated.

Value

A 'LoomExperiment' object annotated with additional metadata() and colData() derived from the manifest file describing samples in the object.

See Also

manifest() and related functions for working with data returned from the */manifest/* HCA API endpoints.

Description

`projects()` takes user input to be used to query the HCA API for information about available projects.

`projects_facets()` summarizes facets and terms used by all records in the projects index.

`*_columns()` returns a tibble or named character vector describing the content of the tibble returned by `projects()`, `files()`, `samples()`, or `bundles()`.

`projects_detail()` takes a unique `project_id` and `catalog` for the project, and returns details about the specified project as a list-of-lists

Usage

```
projects(
  filters = NULL,
  size = 1000L,
  sort = "projectTitle",
  order = c("asc", "desc"),
  catalog = NULL,
  as = c("tibble", "lol", "list", "tibble_expanded"),
  columns = projects_default_columns("character")
)

projects_facets(facet = character(), catalog = NULL)

projects_default_columns(as = c("tibble", "character"))

projects_detail(uuid, catalog = NULL)
```

Arguments

<code>filters</code>	filter object created by <code>filters()</code> , or <code>NULL</code> (default; all projects).
<code>size</code>	<code>integer(1)</code> maximum number of results to return; default: all projects matching filter. The default (10000) is meant to be large enough to return all results.
<code>sort</code>	<code>character(1)</code> project facet (see <code>facet_options()</code>) to sort result; default: "projectTitle".
<code>order</code>	<code>character(1)</code> sort order. One of "asc" (ascending) or "desc" (descending).
<code>catalog</code>	<code>character(1)</code> source of data. Use <code>catalogs()</code> for possible values.
<code>as</code>	<code>character(1)</code> return format. One of "tibble" (default), "lol", "list", or "tibble_expanded", as described in the Details and Value sections of <code>?projects</code> .
<code>columns</code>	<code>named character()</code> indicating the paths to be used for parsing the 'lol' returned from the HCA to a tibble. The names of columns are used as column names in the returned tibble. If the columns are unnamed, a name is derived from the elements of path by removing <code>hits[*]</code> and all <code>[*]</code> , e.g., a path <code>hits[*].donorOrganisms[*].biological</code> is given the name <code>donorOrganisms.biologicalSex</code> .

facet	character() of valid facet names. Summary results (see 'Value', below) are returned when missing or length greater than 1; details are returned when a single facet is specified.
uuid	character() unique identifier (e.g., projectId) of the object.

Details

The `as` argument determines the object returned by the function. Possible values are:

- "tibble" (default) A tibble (data.frame) summarizing essential elements of projects, samples, bundles, or files.
- "lol" A 'list-of-lists' representation of the JSON returned by the query as a 'list-of-lists' data structure, indexed and presented to enable convenient filtering, selection, and extraction. See `?lol`.
- "list" An R list (typically, highly recursive) containing detailed project information, constructed from the JSON response to the original query.
- "tibble_expanded" A tibble (data.frame) containing (almost) all information for each project, sample, bundle, or file. The exception is user-contributed matrices present in `projects()` records; these must be accessed using the "lol" format to extract specific paths as a standard "tibble".

Value

When `as = "tibble"` or `as = "tibble_expanded"`, a tibble with each row representing an HCA object (project, sample, bundle, or file, depending on the function invoked), and columns summarizing the object. "tibble_expanded" columns contains almost all information about the object, except as noted in the Details section.

When `as = "lol"`, a list-of-lists data structure representing detailed information on each object.

When `as = "list"`, `projects()` returns an R list, typically containing other lists or atomic vectors, representing detailed information on each project.

`projects_facets()` invoked with no `facet=` argument returns a tibble summarizing terms available as `projects()` return values, and for use in filters. The tibble contains columns

- `facet`: the name of the facet.
- `n_terms`: the number of distinct values the facet can take.
- `n_values`: the number of occurrences of the facet term in the entire catalog.

`projects_facets()` invoked with a scalar value for `facet=` returns a tibble summarizing terms used in the facet, and the number of occurrences of the term in the entire catalog.

*_columns() returns a tibble with column name containing the column name used in the tibble returned by projects(), files(), samples(), or bundles(), and path the path (see lol_hits()) to the data in the list-of-lists by the same functions when as = "lol". When as = "character", the return value is a named list with paths as elements and abbreviations as names.

list-of-lists containing relevant details about the project.

See Also

lol() and other lol_*() functions for working with the list-of-list data structure returned when as = "lol".

Examples

```
projects(filters())

projects_facets()
projects_facets("genusSpecies")

projects_default_columns()

project <- projects(size = 1, as = "list")
project_uuid <- project[["hits"]][[1]][["entryId"]]
projects_detail(uuid = project_uuid)
```

samples

HCA Sample Querying

Description

samples() takes a list of user provided project titles to be used to query the HCA API for information about available samples.

samples_detail() takes a unique sample_id and catalog for the sample, and returns details about the specified sample as a list-of-lists

Usage

```
samples(
  filters = NULL,
  size = 1000L,
  sort = "projectTitle",
  order = c("asc", "desc"),
  catalog = NULL,
  as = c("tibble", "lol", "list", "tibble_expanded"),
  columns = samples_default_columns("character")
)

samples_facets(facet = character(), catalog = NULL)
```



```

samples_default_columns(as = c("tibble", "character"))

samples_detail(uuid, catalog = NULL)

```

Arguments

filters	filter object created by filters(), or NULL (default; all projects).
size	integer(1) maximum number of results to return; default: all projects matching filter. The default (10000) is meant to be large enough to return all results.
sort	character(1) project facet (see facet_options()) to sort result; default: "projectTitle".
order	character(1) sort order. One of "asc" (ascending) or "desc" (descending).
catalog	character(1) source of data. Use catalogs() for possible values.
as	character(1) return format. One of "tibble" (default), "lol", "list", or "tibble_expanded", as described in the Details and Value sections of ?projects.
columns	named character() indicating the paths to be used for parsing the 'lol' returned from the HCA to a tibble. The names of columns are used as column names in the returned tibble. If the columns are unnamed, a name is derived from the elements of path by removing hits[*] and all [*], e.g., a path hits[*].donorOrganisms[*].biologicalSex is given the name donorOrganisms.biologicalSex.
facet	character() of valid facet names. Summary results (see 'Value', below) are returned when missing or length greater than 1; details are returned when a single facet is specified.
uuid	character() unique identifier (e.g., projectId) of the object.

Value

samples_detail() returns a list-of-lists containing relevant details about the sample

Examples

```

title <- paste(
  "Tabula Muris: Transcriptomic characterization of 20 organs and",
  "tissues from Mus musculus at single cell resolution"
)
filters <- filters( projectTitle = list(is = title) )
samples(filters = filters)

samples_facets()

sample <- samples(size = 1, as = "list")
sample_uuid <- sample[["hits"]][[1]][["entryId"]]
samples_detail(uuid = sample_uuid)

```

summary

Repository summary statistics

Description

summary() provides numerical summaries of catalog content

Usage

```
summary(  
  filters = NULL,  
  type = c("overview", "fileTypeSummaries", "cellCountSummaries", "organTypes", "list"),  
  catalog = NULL  
)
```

Arguments

filters filter object created by filters(), or NULL (default; all projects).

type character(1) type of summary to return. Possible values include "overview", "fileTypeSummaries", "cellCountSummaries", "organType", and a "list" off all summary statistics.

catalog character(1) source of data. Use catalogs() for possible values.

Value

summary() returns a tibble or (for type = "list") a list-of-lists of summary statistics.

Examples

```
summary()  
  
filter <- filters(  
  organ = list(is = c("brain", "heart")),  
  genusSpecies = list(is = "Homo sapiens")  
)  
summary(filter)  
summary(filter, "fileTypeSummaries")  
summary(filter, "cellCountSummaries")
```

Index

.details, 2

as.list.lol (lol), 10

bundles, 3

bundles_default_columns (bundles), 3

bundles_detail (bundles), 3

bundles_facets (bundles), 3

catalogs, 4

facet_options (filters), 7

files, 5

files_cache (files), 5

files_default_columns (files), 5

files_detail (files), 5

files_download (files), 5

files_facets (files), 5

filters, 7

hca_next, 8

hca_next.lol_hca (lol), 10

hca_next.tbl_hca, 9

hca_prev (hca_next), 8

hca_prev.lol_hca (lol), 10

hca_prev.tbl_hca (hca_next.tbl_hca), 9

length.filters (filters), 7

lol, 10

lol_filter (lol), 10

lol_hits_lpull (lol), 10

lol_hits_pull (lol), 10

lol_lpull (lol), 10

lol_path (lol), 10

lol_pull (lol), 10

lol_select (lol), 10

manifest, 12

manifest_cache (manifest), 12

optimus_loom_annotation, 13

print.filters (filters), 7

print.lol (lol), 10

projects, 14

projects_default_columns (projects), 14

projects_detail (projects), 14

projects_facets (projects), 14

samples, 16

samples_default_columns (samples), 16

samples_detail (samples), 16

samples_facets (samples), 16

summary, 18