
BIOM Documentation

Release 1.2.0

The BIOM Project

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Contents

The **BIOM file format** (canonically pronounced *biome*) is designed to be a general-use format for representing biological sample by observation contingency tables. BIOM is a recognized standard for the [Earth Microbiome Project](#) and is a [Genomics Standards Consortium](#) candidate project.

The **BIOM format** is designed for general use in broad areas of comparative -omics. For example, in marker-gene surveys, the primary use of this format is to represent OTU tables: the observations in this case are OTUs and the matrix contains counts corresponding to the number of times each OTU is observed in each sample. With respect to metagenome data, this format would be used to represent metagenome tables: the observations in this case might correspond to SEED subsystems, and the matrix would contain counts corresponding to the number of times each subsystem is observed in each metagenome. Similarly, with respect to genome data, this format may be used to represent a set of genomes: the observations in this case again might correspond to SEED subsystems, and the counts would correspond to the number of times each subsystem is observed in each genome.

There are two components to the BIOM project: first is definition of the BIOM format, and second is development of support objects in multiple programming languages to support the use of BIOM in diverse bioinformatics applications. The version of the BIOM file format is independent of the version of the *biom-format* software.

There are official implementations of BIOM format support objects (APIs) in the Python and R programming languages. The rest of this site contains details about the BIOM file format (which is independent of the API) and the Python `biom-format` API. For more details about the R API, please see the [CRAN biom package](#).

Contents

1.1 BIOM Documentation

These pages provide format specifications and API information for the BIOM table objects.

1.1.1 The biom file format

The BIOM project consists of two independent tools: the *biom-format* software package, which contains software tools for working with BIOM-formatted files and the tables they represent; and the BIOM file format. As of the 1.0.0 software version and the 1.0 file format version, the version of the software and the file format are independent of one another. Version specific documentation of the file formats can be found on the following pages.

The biom file format: Version 1.0

The *biom* format is based on [JSON](#) to provide the overall structure for the format. JSON is a widely supported format with native parsers available within many programming languages.

Required top-level fields:

```

id           : <string or null> a field that can be used to id a table (or null)
format       : <string> The name and version of the current biom format
format_url   : <url> A string with a static URL providing format details
type         : <string> Table type (a controlled vocabulary)
               Acceptable values:
                 "OTU table"
                 "Pathway table"
                 "Function table"
                 "Ortholog table"
                 "Gene table"
                 "Metabolite table"
                 "Taxon table"
generated_by : <string> Package and revision that built the table
date         : <datetime> Date the table was built (ISO 8601 format)
rows         : <list of objects> An ORDERED list of obj describing the rows
               (explained in detail below)
columns      : <list of objects> An ORDERED list of obj describing the columns
               (explained in detail below)

```

```

matrix_type      : <string> Type of matrix data representation (a controlled vocabulary)
                  Acceptable values:
                    "sparse" : only non-zero values are specified
                    "dense"  : every element must be specified
matrix_element_type : Value type in matrix (a controlled vocabulary)
                  Acceptable values:
                    "int"    : integer
                    "float"  : floating point
                    "unicode": unicode string
shape            : <list of ints>, the number of rows and number of columns in data
data             : <list of lists>, counts of observations by sample
                  if matrix_type is "sparse", [[row, column, value],
                                                [row, column, value],
                                                ...]
                  if matrix_type is "dense",  [[value, value, value, ...],
                                                [value, value, value, ...],
                                                ...]

```

Optional top-level fields:

```

comment          : <string> A free text field containing any information that you
                  feel is relevant (or just feel like sharing)

```

The rows value is an **ORDERED** list of objects where each object corresponds to a single row in the matrix. Each object can currently store arbitrary keys, although this might become restricted based on table type. Each object must provide, at the minimum:

```

id               : <string> an arbitrary UNIQUE identifier
metadata         : <an object or null> A object containing key, value metadata pairs

```

The columns value is an **ORDERED** list of objects where each object corresponds to a single column in the matrix. Each object can currently store arbitrary keys, although this might become restricted based on table type. Each object must provide, at the minimum:

```

id               : <string> an arbitrary UNIQUE identifier
metadata         : <an object or null> A object containing key, value metadata pairs

```

Example biom files

Below are examples of minimal and rich biom files in both sparse and dense formats. To decide which of these you should generate for new data types, see the section on *Tips and FAQs regarding the BIOM file format*.

Minimal sparse OTU table

```

{
  "id":null,
  "format": "Biological Observation Matrix 0.9.1-dev",
  "format_url": "http://biom-format.org/documentation/format_versions/biom-1.0.html",
  "type": "OTU table",
  "generated_by": "QIIME revision 1.4.0-dev",
  "date": "2011-12-19T19:00:00",
  "rows":[
    {"id":"GG_OTU_1", "metadata":null},
    {"id":"GG_OTU_2", "metadata":null},
    {"id":"GG_OTU_3", "metadata":null},
    {"id":"GG_OTU_4", "metadata":null},
    {"id":"GG_OTU_5", "metadata":null}
  ]
}

```



```

    ],
    "columns": [
        {"id": "Sample1", "metadata": null},
        {"id": "Sample2", "metadata": null},
        {"id": "Sample3", "metadata": null},
        {"id": "Sample4", "metadata": null},
        {"id": "Sample5", "metadata": null},
        {"id": "Sample6", "metadata": null}
    ],
    "matrix_type": "sparse",
    "matrix_element_type": "int",
    "shape": [5, 6],
    "data": [[0, 2, 1],
              [1, 0, 5],
              [1, 1, 1],
              [1, 3, 2],
              [1, 4, 3],
              [1, 5, 1],
              [2, 2, 1],
              [2, 3, 4],
              [2, 4, 2],
              [3, 0, 2],
              [3, 1, 1],
              [3, 2, 1],
              [3, 5, 1],
              [4, 1, 1],
              [4, 2, 1]
    ]
}

```

Minimal dense OTU table

```

{
    "id": null,
    "format": "Biological Observation Matrix 0.9.1-dev",
    "format_url": "http://biom-format.org/documentation/format_versions/biom-1.0.html",
    "type": "OTU table",
    "generated_by": "QIIME revision 1.4.0-dev",
    "date": "2011-12-19T19:00:00",
    "rows": [
        {"id": "GG_OTU_1", "metadata": null},
        {"id": "GG_OTU_2", "metadata": null},
        {"id": "GG_OTU_3", "metadata": null},
        {"id": "GG_OTU_4", "metadata": null},
        {"id": "GG_OTU_5", "metadata": null}
    ],
    "columns": [
        {"id": "Sample1", "metadata": null},
        {"id": "Sample2", "metadata": null},
        {"id": "Sample3", "metadata": null},
        {"id": "Sample4", "metadata": null},
        {"id": "Sample5", "metadata": null},
        {"id": "Sample6", "metadata": null}
    ],
    "matrix_type": "dense",
    "matrix_element_type": "int",
    "shape": [5, 6],
    "data": [[0, 0, 1, 0, 0, 0],

```

```
        [5,1,0,2,3,1],
        [0,0,1,4,2,0],
        [2,1,1,0,0,1],
        [0,1,1,0,0,0]]
}
```

Rich sparse OTU table

```
{
  "id": null,
  "format": "Biological Observation Matrix 0.9.1-dev",
  "format_url": "http://biom-format.org/documentation/format_versions/biom-1.0.html",
  "type": "OTU table",
  "generated_by": "QIIME revision 1.4.0-dev",
  "date": "2011-12-19T19:00:00",
  "rows": [
    { "id": "GG_OTU_1", "metadata": { "taxonomy": [ "k__Bacteria", "p__Proteobacteria", "c__Gammaproteobact",
    { "id": "GG_OTU_2", "metadata": { "taxonomy": [ "k__Bacteria", "p__Cyanobacteria", "c__Nostocophycidae",
    { "id": "GG_OTU_3", "metadata": { "taxonomy": [ "k__Archaea", "p__Euryarchaeota", "c__Methanomicrobia",
    { "id": "GG_OTU_4", "metadata": { "taxonomy": [ "k__Bacteria", "p__Firmicutes", "c__Clostridia", "o__Ha",
    { "id": "GG_OTU_5", "metadata": { "taxonomy": [ "k__Bacteria", "p__Proteobacteria", "c__Gammaproteobact",
    ],
  "columns": [
    { "id": "Sample1", "metadata": {
      "BarcodeSequence": "CGCTTATCGAGA",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "gut",
      "Description": "human gut" } },
    { "id": "Sample2", "metadata": {
      "BarcodeSequence": "CATAACAGTAGC",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "gut",
      "Description": "human gut" } },
    { "id": "Sample3", "metadata": {
      "BarcodeSequence": "CTCTCTACCTGT",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "gut",
      "Description": "human gut" } },
    { "id": "Sample4", "metadata": {
      "BarcodeSequence": "CTCTCGGCCTGT",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "skin",
      "Description": "human skin" } },
    { "id": "Sample5", "metadata": {
      "BarcodeSequence": "CTCTCTACCAAT",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "skin",
      "Description": "human skin" } },
    { "id": "Sample6", "metadata": {
      "BarcodeSequence": "CTAACTACCAAT",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "skin",
      "Description": "human skin" } }
    ],
  "matrix_type": "sparse",
  "matrix_element_type": "int",
  "shape": [5, 6],
  "data": [[0,2,1],
```

```

    [1,0,5],
    [1,1,1],
    [1,3,2],
    [1,4,3],
    [1,5,1],
    [2,2,1],
    [2,3,4],
    [2,5,2],
    [3,0,2],
    [3,1,1],
    [3,2,1],
    [3,5,1],
    [4,1,1],
    [4,2,1]
  ]
}

```

Rich dense OTU table

```

{
  "id":null,
  "format": "Biological Observation Matrix 0.9.1-dev",
  "format_url": "http://biom-format.org/documentation/format_versions/biom-1.0.html",
  "type": "OTU table",
  "generated_by": "QIIME revision 1.4.0-dev",
  "date": "2011-12-19T19:00:00",
  "rows": [
    { "id": "GG_OTU_1", "metadata": { "taxonomy": [ "k__Bacteria", "p__Proteobacteria", "c__Gammaproteobact" ],
    { "id": "GG_OTU_2", "metadata": { "taxonomy": [ "k__Bacteria", "p__Cyanobacteria", "c__Nostocophycideae" ],
    { "id": "GG_OTU_3", "metadata": { "taxonomy": [ "k__Archaea", "p__Euryarchaeota", "c__Methanomicrobia",
    { "id": "GG_OTU_4", "metadata": { "taxonomy": [ "k__Bacteria", "p__Firmicutes", "c__Clostridia", "o__Ha
    { "id": "GG_OTU_5", "metadata": { "taxonomy": [ "k__Bacteria", "p__Proteobacteria", "c__Gammaproteobact
    ],
  "columns": [
    { "id": "Sample1", "metadata": {
      "BarcodeSequence": "CGCTTATCGAGA",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "gut",
      "Description": "human gut" } },
    { "id": "Sample2", "metadata": {
      "BarcodeSequence": "CATACCAGTAGC",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "gut",
      "Description": "human gut" } },
    { "id": "Sample3", "metadata": {
      "BarcodeSequence": "CTCTCTACCTGT",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "gut",
      "Description": "human gut" } },
    { "id": "Sample4", "metadata": {
      "BarcodeSequence": "CTCTCGGCCTGT",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "skin",
      "Description": "human skin" } },
    { "id": "Sample5", "metadata": {
      "BarcodeSequence": "CTCTCTACCAAT",
      "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
      "BODY_SITE": "skin",

```

```
        "Description": "human skin"}},
{"id": "Sample6", "metadata": {
    "BarcodeSequence": "CTAACTACCAAT",
    "LinkerPrimerSequence": "CATGCTGCCTCCCGTAGGAGT",
    "BODY_SITE": "skin",
    "Description": "human skin"}}
],
"matrix_type": "dense",
"matrix_element_type": "int",
"shape": [5, 6],
"data": [[0, 0, 1, 0, 0, 0],
         [5, 1, 0, 2, 3, 1],
         [0, 0, 1, 4, 2, 0],
         [2, 1, 1, 0, 0, 1],
         [0, 1, 1, 0, 0, 0]]
}
```

Release versions contain three integers in the following format: `major-version.incremental-version.minor-version`. When `-dev` is appended to the end of a version string that indicates a development (or between-release version). For example, `1.0.0-dev` would refer to the development version following the 1.0.0 release.

1.1.2 Tips and FAQs regarding the BIOM file format

Should I generate sparse or dense biom files?

In general, we recommend using the sparse format for your biom files. These will be a lot smaller than the dense format biom files when your data is sparse (i.e., more than 85% of your counts are zero). This is common for OTU tables and metagenome tables, and you'll want to investigate whether it's true for your data. If you currently format your data in tab-separated tables where observations are rows and samples are columns, you can format that file to be convertible to biom format with the `biom convert` command. Here you can create dense and sparse formats, and see which file size is smaller. See the section on *Converting between file formats*.

Motivation for the BIOM format

The BIOM format was motivated by several goals. First, to facilitate efficient handling and storage of large, sparse biological contingency tables; second, to support encapsulation of core study data (contingency table data and sample/observation metadata) in a single file; and third, to facilitate the use of these tables between tools that support this format (e.g., passing of data between [QIIME](#), [MG-RAST](#), and [VAMPS](#)).

Efficient handling and storage of very large tables

In QIIME, we began hitting limitations with OTU table objects when working with thousands of samples and hundreds of thousands of OTUs. In the near future we expect that we'll be dealing with hundreds of thousands of samples in single analyses.

The OTU table format up to QIIME 1.4.0 involved a dense matrix: if an OTU was not observed in a given sample, that would be indicated with a zero. We now primarily represent OTU tables in a sparse format: if an OTU is not observed in a sample, there is no count for that OTU. The two ways of representing this data are exemplified here.

A dense representation of an OTU table:

OTU ID	PC.354	PC.355	PC.356
OTU0	0	0	4
OTU1	6	0	0

```
OTU2    1    0    7
OTU3    0    0    3
```

A sparse representation of an OTU table:

```
PC.354 OTU1 6
PC.354 OTU2 1
PC.356 OTU0 4
PC.356 OTU2 7
PC.356 OTU3 3
```

OTU table data tends to be sparse (e.g., greater than 90% of counts are zero, and frequently as many as 99% of counts are zero) in which case the latter format is more convenient to work with as it has a smaller memory footprint. Both of these representations are supported in the biom-format project via dense and sparse Table types. Generally if less than 85% of your counts are zero, a dense representation will be more efficient.

Encapsulation of core study data (OTU table data and sample/OTU metadata) in a single file

The JSON-format OTU table allow for storage of arbitrary amounts of sample and OTU metadata in a single file. Sample metadata corresponds to what is generally found in QIIME mapping files. At this stage inclusion of this information in the OTU table file is optional, but it may be useful for sharing these files with other QIIME users and for publishing or archiving results of analyses. OTU metadata (generally a taxonomic assignment for an OTU) is also optional. In contrast to the previous OTU table format, you can now store more than one OTU metadata value in this field, so for example you can score taxonomic assignments based on two different taxonomic assignment approaches.

Facilitating the use of tables between tools that support this format

Different tools, such as QIIME, MG-RAST, and VAMPS work with similar data structures that represent different types of data. An example of this is a *metagenome* table that could be generated by MG-RAST (where for example, columns are metagenomes and rows are functional categories). Exporting this data from MG-RAST in a suitable format will allow for the application of many of the QIIME tools to this data (such as generation of alpha rarefaction plots or beta diversity ordination plots). This new format is far more general than previous formats, so will support adoption by groups working with different data types and is already being integrated to support transfer of data between QIIME, MG-RAST, and VAMPS.

File extension

We recommend that BIOM files use the `.biom` extension.

1.1.3 biom-format Table objects

The biom-format project provides rich Table objects to support use of the BIOM file format. The objects encapsulate matrix data (such as OTU counts) and abstract the interaction away from the programmer. This provides the immediate benefit of the programmer not having to worry about what the underlying data object is, and in turn allows for different data representations to be supported. Currently, biom-format supports a dense object built off of `numpy.array` (NumPy) and a sparse object built off of Python dictionaries.

biom-format table_factory method

Generally, construction of a Table subclass will be through the `table_factory` method. This method facilitates any necessary data conversions and supports a wide variety of input data types.

Description of available `Table` objects

There are multiple objects available but some of them are unofficial abstract base classes (does not use the `abc` module for historical reasons). In practice, the objects used should be the derived Tables such as `SparseOTUTable` or `DenseGeneTable`.

Abstract base classes

Abstract base classes establish standard interfaces for subclassed types and provide common functionality for derived types.

Table `Table` is a container object and an abstract base class that provides a common and required API for subclassed objects. Through the use of private interfaces, it is possible to create public methods that operate on the underlying datatype without having to implement each method in each subclass. For instance, `Table.iterSamplesData` will return a generator that always yields `numpy.array` vectors for each sample regardless of how the table data is actually stored. This functionality results from derived classes implementing private interfaces, such as `Table._conv_to_np`.

OTUTable The `OTUTable` base class provides functionality specific for OTU tables. Currently, it only provides a static private member variable that describes its BIOM type. This object was stubbed out incase future methods are developed that do not make sense with the context of, say, an MG-RAST metagenomic abundance table. It is advised to always use an object that subclasses `OTUTable` if the analysis is on OTU data.

PathwayTable A table type to represent gene pathways.

FunctionTable A table type to represent gene functions.

OrthologTable A table type to represent gene orthologs.

GeneTable A table type to represent genes.

MetaboliteTable A table type to represent metabolite profiles.

TaxonTable A table type to represent taxonomies.

Container classes

The container classes implement required private member variable interfaces as defined by the `Table` abstract base class. Specifically, these objects define the ways in which data is moved into and out of the contained data object. These are fully functional and usable objects, however they do not implement table type specific functionality.

SparseTable The subclass `SparseTable` can be derived for use with table data. This object implemented all of the required private interfaces specified by the `Table` base class. The object contains a `_data` private member variable that is an instance of `biom.table.SparseDict`. It is advised to used derived objects of `SparseTable` if the data being operated on is sparse.

DenseTable The `DenseTable` object fulfills all private member methods stubbed out by the `Table` base class. The dense table contains a private member variable that is an instance of `numpy.array`. The `array` object is a matrix that contains all values including zeros. It is advised to use this table only if the number of samples and observations is reasonable. Unfortunately, it isn't reasonable to define reasonable in this context. However, if either the number of observations or the number of samples is > 1000 , it would probably be a good idea to rely on a `SparseTable`.

Table type objects

The table type objects define variables and methods specific to a table type. These inherit from a `Container Class` and a table type base class, and are therefore instantiable. Generally you'll instantiate tables with `biom.table.table_factory`, and one of these will be passed as the `constructor` argument.

DenseOTUTable

SparseOTUTable

DensePathwayTable

SparsePathwayTable

DenseFunctionTable

SparseFunctionable

DenseOrthologTable

SparseOrthologTable

DenseGeneTable

SparseGeneTable

DenseMetaboliteTable

SparseMetaboliteTable

1.1.4 Converting between file formats

The `convert` command in the `biom-format` project can be used to convert between `biom` and `tab-delimited` table formats. This

- converting `biom` format tables to `tab-delimited` tables for easy viewing in programs such as Excel
- converting between `sparse` and `dense` `biom` formats

Note: The `tab-delimited` tables are commonly referred to as the *classic format* tables, while `BIOM` formatted tables are referred to as *biom tables*.

General usage examples

Convert a `tab-delimited` table to `sparse biom` format. Note that you *must* specify the type of table here:

```
biom convert -i table.txt -o table.from_txt.biom --table-type="otu table"
```

Convert a `tab-delimited` table to `dense biom` format:

```
biom convert -i table.txt -o table.dense.biom --table-type="otu table" --matrix-type=dense
```

Convert `biom` format to `tab-delimited` table format:

```
biom convert -i table.biom -o table.from_biom.txt -b
```

Convert `dense biom` format to `sparse biom` format:

```
biom convert -i table.dense.biom -o table.sparse.biom --dense-biom-to-sparse-biom
```

Convert `sparse biom` format to `dense biom` format:

```
biom convert -i table.sparse.biom -o table.dense.biom --sparse-biom-to-dense-biom
```

Convert `biom` format to `classic` format, including the `taxonomy` observation metadata as the last column of the `classic` format table. Because the `BIOM` format can support an arbitrary number of observation (or sample) metadata entries, and the `classic` format can support only a single observation metadata entry, you must specify which of the observation metadata entries you want to include in the output table:

```
biom convert -i table.biom -o table.from_biom_w_taxonomy.txt -b --header-key taxonomy
```

Convert `biom` format to `classic` format, including the `taxonomy` observation metadata as the last column of the `classic` format table, but renaming that column as `ConsensusLineage`. This is useful when using legacy tools that require a specific name for the observation metadata column.:

```
biom convert -i table.biom -o table.from_biom_w_consensuslineage.txt -b --header-key taxonomy --output
```

Special case usage examples

Converting QIIME 1.4.0 and earlier OTU tables to BIOM format

If you are converting a `QIIME 1.4.0` or earlier `OTU` table to `BIOM` format, there are a few steps to go through. First, for convenience, you might want to rename the `ConsensusLineage` column `taxonomy`. You can do this with the following command:


```
sed 's/Consensus Lineage/ConsensusLineage/' < otu_table.txt | sed 's/ConsensusLineage/taxonomy/' > ot
```

Then, you'll want to perform the conversion including a step to convert the taxonomy *string* from the classic OTU table to a taxonomy *list*, as it's represented in QIIME 1.4.0-dev and later:

```
biom convert -i otu_table.taxonomy.txt -o otu_table.from_txt.biom --table-type="otu table" --process
```

1.1.5 Adding sample and observation metadata to biom files

Frequently you'll have an existing BIOM file and want to add sample and/or observation metadata to it. For samples, metadata is frequently environmental or technical details about your samples: the subject that a sample was collected from, the pH of the sample, the PCR primers used to amplify DNA from the samples, etc. For observations, metadata is frequently a categorization of the observation: the taxonomy of an OTU, or the EC hierarchy of a gene. You can use the `biom add-metadata` command to add this information to an existing BIOM file.

To get help with `add-metadata` you can call:

```
biom add-metadata -h
```

This command takes a BIOM file, and corresponding sample and/or observation mapping files. The following examples are used in the commands below. You can find these files in the `biom-format/examples` directory.

Your BIOM file might look like the following:

```
{
  "id":null,
  "format": "Biological Observation Matrix 1.0.0-dev",
  "format_url": "http://biom-format.org",
  "type": "OTU table",
  "generated_by": "some software package",
  "date": "2011-12-19T19:00:00",
  "rows":[
    {"id":"GG_OTU_1", "metadata":null},
    {"id":"GG_OTU_2", "metadata":null},
    {"id":"GG_OTU_3", "metadata":null},
    {"id":"GG_OTU_4", "metadata":null},
    {"id":"GG_OTU_5", "metadata":null}
  ],
  "columns": [
    {"id":"Sample1", "metadata":null},
    {"id":"Sample2", "metadata":null},
    {"id":"Sample3", "metadata":null},
    {"id":"Sample4", "metadata":null},
    {"id":"Sample5", "metadata":null},
    {"id":"Sample6", "metadata":null}
  ],
  "matrix_type": "sparse",
  "matrix_element_type": "int",
  "shape": [5, 6],
  "data": [[0,2,1],
           [1,0,5],
           [1,1,1],
           [1,3,2],
           [1,4,3],
           [1,5,1],
           [2,2,1],
           [2,3,4],
           [2,5,2],
```

```
[3,0,2],
[3,1,1],
[3,2,1],
[3,5,1],
[4,1,1],
[4,2,1]
]
}
```

A sample metadata mapping file could then look like the following. Notice that there is an extra sample in here with respect to the above BIOM table. Any samples in the mapping file that are not in the BIOM file are ignored.

```
#SampleID      BarcodeSequence DOB
# Some optional
# comment lines...
Sample1 AGCACGAGCCTA      20060805
Sample2 AACTCGTCGATG      20060216
Sample3 ACAGACCACTCA      20060109
Sample4 ACCAGCGACTAG      20070530
Sample5 AGCAGCACTTGT      20070101
Sample6 AGCAGCACAAC      20070716
```

An observation metadata mapping file might look like the following. Notice that there is an extra observation in here with respect to the above BIOM table. Any observations in the mapping file that are not in the BIOM file are ignored.

```
#OTUID taxonomy      confidence
# Some optional
# comment lines
GG_OTU_0      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__      0.980
GG_OTU_1      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnospiraceae
GG_OTU_2      Root;k__Bacteria      0.980
GG_OTU_3      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnospiraceae
GG_OTU_4      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnospiraceae
GG_OTU_5      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnospiraceae
```

Adding metadata

To add sample metadata to a BIOM file, you can run the following:

```
biom add-metadata -i min_sparse_otu_table.biom -o table.w_smd.biom --sample-metadata-fp sam_md.txt
```

To add observation metadata to a BIOM file, you can run the following:

```
biom add-metadata -i min_sparse_otu_table.biom -o table.w_omd.biom --observation-metadata-fp obs_md.txt
```

You can also combine these in a single command to add both observation and sample metadata:

```
biom add-metadata -i min_sparse_otu_table.biom -o table.w_md.biom --observation-metadata-fp obs_md.txt
```

In the last case, the resulting BIOM file will look like the following:

```
{
  "columns": [
    {
      "id": "Sample1",
      "metadata": {
        "BarcodeSequence": "AGCACGAGCCTA",
        "DOB": "20060805"
      }
    }
  ]
}
```

```

    }
  },
  {
    "id": "Sample2",
    "metadata": {
      "BarcodeSequence": "AACTCGTCGATG",
      "DOB": "20060216"
    }
  },
  {
    "id": "Sample3",
    "metadata": {
      "BarcodeSequence": "ACAGACCACTCA",
      "DOB": "20060109"
    }
  },
  {
    "id": "Sample4",
    "metadata": {
      "BarcodeSequence": "ACCAGCGACTAG",
      "DOB": "20070530"
    }
  },
  {
    "id": "Sample5",
    "metadata": {
      "BarcodeSequence": "AGCAGCACTTGT",
      "DOB": "20070101"
    }
  },
  {
    "id": "Sample6",
    "metadata": {
      "BarcodeSequence": "AGCAGCACAAC",
      "DOB": "20070716"
    }
  }
],
"data": [
  [0, 2, 1.0],
  [1, 0, 5.0],
  [1, 1, 1.0],
  [1, 3, 2.0],
  [1, 4, 3.0],
  [1, 5, 1.0],
  [2, 2, 1.0],
  [2, 3, 4.0],
  [2, 5, 2.0],
  [3, 0, 2.0],
  [3, 1, 1.0],
  [3, 2, 1.0],
  [3, 5, 1.0],
  [4, 1, 1.0],
  [4, 2, 1.0]
],
"date": "2012-12-11T07:36:15.467843",
"format": "Biological Observation Matrix 1.0.0",
"format_url": "http://biom-format.org",

```

```
"generated_by": "some software package",
"id": null,
"matrix_element_type": "float",
"matrix_type": "sparse",
"rows": [
  {
    "id": "GG_OTU_1",
    "metadata": {
      "confidence": "0.665",
      "taxonomy": "Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnos"
    }
  },
  {
    "id": "GG_OTU_2",
    "metadata": {
      "confidence": "0.980",
      "taxonomy": "Root;k__Bacteria"
    }
  },
  {
    "id": "GG_OTU_3",
    "metadata": {
      "confidence": "1.000",
      "taxonomy": "Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnos"
    }
  },
  {
    "id": "GG_OTU_4",
    "metadata": {
      "confidence": "0.842",
      "taxonomy": "Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnos"
    }
  },
  {
    "id": "GG_OTU_5",
    "metadata": {
      "confidence": "1.000",
      "taxonomy": "Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnos"
    }
  }
],
"shape": [5, 6],
"type": "OTU table"
}
```

Processing metadata while adding

There are some additional parameters you can pass to this command for more complex processing.

You can tell the command to process certain metadata column values as integers (`--int-fields`), floating point (i.e., decimal or real) numbers (`--float-fields`), or as hierarchical semicolon-delimited data (`--sc-separated`).

```
biom add-metadata -i min_sparse_otu_table.biom -o table.w_md.biom --observation-metadata-fp obs_md.t
```

Here your resulting BIOM file will look like the following, where DOB values are now integers (compare to the above: they're not quoted now), confidence values are now floating point numbers (again, not quoted now), and

taxonomy values are now lists where each entry is a taxonomy level, opposed to above where they appear as a single semi-colon-separated string.

```
{
  "columns": [
    {
      "id": "Sample1",
      "metadata": {
        "BarcodeSequence": "AGCACGAGCCTA",
        "DOB": 20060805
      }
    },
    {
      "id": "Sample2",
      "metadata": {
        "BarcodeSequence": "AACTCGTCGATG",
        "DOB": 20060216
      }
    },
    {
      "id": "Sample3",
      "metadata": {
        "BarcodeSequence": "ACAGACCACTCA",
        "DOB": 20060109
      }
    },
    {
      "id": "Sample4",
      "metadata": {
        "BarcodeSequence": "ACCAGCGACTAG",
        "DOB": 20070530
      }
    },
    {
      "id": "Sample5",
      "metadata": {
        "BarcodeSequence": "AGCAGCACTTGT",
        "DOB": 20070101
      }
    },
    {
      "id": "Sample6",
      "metadata": {
        "BarcodeSequence": "AGCAGCACAACT",
        "DOB": 20070716
      }
    }
  ],
  "data": [
    [0, 2, 1.0],
    [1, 0, 5.0],
    [1, 1, 1.0],
    [1, 3, 2.0],
    [1, 4, 3.0],
    [1, 5, 1.0],
    [2, 2, 1.0],
    [2, 3, 4.0],
    [2, 5, 2.0],
    [3, 0, 2.0],
  ]
}
```

```
[3, 1, 1.0],
[3, 2, 1.0],
[3, 5, 1.0],
[4, 1, 1.0],
[4, 2, 1.0]
],
"date": "2012-12-11T07:30:29.870689",
"format": "Biological Observation Matrix 1.0.0",
"format_url": "http://biom-format.org",
"generated_by": "some software package",
"id": null,
"matrix_element_type": "float",
"matrix_type": "sparse",
"rows": [
  {
    "id": "GG_OTU_1",
    "metadata": {
      "confidence": 0.665,
      "taxonomy": ["Root", "k__Bacteria", "p__Firmicutes", "c__Clostridia", "o__Clostridia"]
    }
  },
  {
    "id": "GG_OTU_2",
    "metadata": {
      "confidence": 0.98,
      "taxonomy": ["Root", "k__Bacteria"]
    }
  },
  {
    "id": "GG_OTU_3",
    "metadata": {
      "confidence": 1.0,
      "taxonomy": ["Root", "k__Bacteria", "p__Firmicutes", "c__Clostridia", "o__Clostridia"]
    }
  },
  {
    "id": "GG_OTU_4",
    "metadata": {
      "confidence": 0.842,
      "taxonomy": ["Root", "k__Bacteria", "p__Firmicutes", "c__Clostridia", "o__Clostridia"]
    }
  },
  {
    "id": "GG_OTU_5",
    "metadata": {
      "confidence": 1.0,
      "taxonomy": ["Root", "k__Bacteria", "p__Firmicutes", "c__Clostridia", "o__Clostridia"]
    }
  }
],
"shape": [5, 6],
"type": "OTU table"
}
```

If you have multiple fields that you'd like processed in one of these ways, you can pass a comma-separated list of field names (e.g., `--float-fields confidence,pH`).

Renaming (or naming) metadata columns while adding

You can also override the names of the metadata fields provided in the mapping files with the `--observation-header` and `--sample-header` parameters. This is useful if you want to rename metadata columns, or if metadata column headers aren't present in your metadata mapping file. If you pass either of these parameters, you must name all columns in order. If there are more columns in the metadata mapping file than there are headers, extra columns will be ignored (so this is also a useful way to select only the first *n* columns from your mapping file). For example, if you want to rename the `DOB` column in the sample metadata mapping you could do the following:

```
biom add-metadata -i min_sparse_otu_table.biom -o table.w_smd.biom --sample-metadata-fp sam_md.txt --
```

If you have a mapping file without headers such as the following:

```
GG_OTU_0      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__          0.980
GG_OTU_1      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnospiraceae
GG_OTU_2      Root;k__Bacteria          0.980
GG_OTU_3      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnospiraceae
GG_OTU_4      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnospiraceae
GG_OTU_5      Root;k__Bacteria;p__Firmicutes;c__Clostridia;o__Clostridiales;f__Lachnospiraceae
```

you could name these while adding them as follows:

```
biom add-metadata -i min_sparse_otu_table.biom -o table.w_omd.biom --observation-metadata-fp obs_md.txt
```

As a variation on the last command, if you only want to include the taxonomy column and exclude the confidence column, you could run:

```
biom add-metadata -i min_sparse_otu_table.biom -o table.w_omd.biom --observation-metadata-fp obs_md.txt
```

1.1.6 Sparse matrix backends

As the BIOM project evolves, so do the underlying data structures, leading to potential runtime trade offs between implementations. Currently, there are three distinct sparse matrix backends to BIOM: the `CSMat` (default as of BIOM v1.1), the `SparseMat` and the `SparseDict`. Specific differences are discussed below.

How to check what sparse backend is in use

To check what sparse backend is in use, simply execute `biom show-install-info`. The last line shows the `SparseObj` type. For instance:

```
$ biom show-install-info
```

```
System information
```

```
=====
```

```
Platform:      darwin
Python/GCC version: 2.7.1 (r271:86832, Aug 30 2012, 10:07:33) [GCC 4.2.1 (Based on Apple Inc. bu
Python executable: /Users/caporaso/.virtualenvs/biom/bin/python
```

```
Dependency versions
```

```
=====
```

```
pyqi version:      0.2.0
NumPy version:      1.7.1
dateutil version:   1.5
```

```
biom-format package information
```

```
=====
biom-format version:    1.2.0
    SparseObj type:     biom.csmat.CSMat
```

The last line indicates that the CSMat object is in use.

Changing the sparse backend

There are two methods to change the backend that is used. The first method is by copying the `biom_config` file located under `support_files/` and placing it in your home directory as `~/.biom_config`. Then, edit `~/.biom_config` and replace the current backend type with the desired type.

The second method is to set the environment variable `$BIOM_CONFIG_FP` to a file path of your choice, and place the following into that file:

```
python_code_sparse_backend    <BACKEND TYPE>
```

Where `<BACKEND TYPE>` is replaced by the specific backend implementation to use.

Sparse matrix backend descriptions

Different sparse matrix backends have different performance characteristics. As BIOM changes over time, additional methods may be added that address specific runtime concerns.

CSMat

The default sparse backend is the CSMat. CSMat implements coordinate list, compressed sparse row and compressed sparse column formats and facilitates interaction with these representations. This backend will have the lowest memory footprint. In general, this backend should be the fastest. However, it has been observed that under certain circumstances, this backend may not perform the best.

SparseMat

The `SparseMat` is built using a combination of Python objects, a Cython wrapper and C++. It implements the dictionary of keys sparse matrix representation. This method performs pretty well, but has an increasing memory footprint as the number of nonzero values increases. Under some situations, specifically those that require a large number of `Table` creations, this backend has about a 15-20% reduced runtime over CSMat.

SparseDict

The `SparseDict` is the naive pure Python implementation. This was first implemented as a test backend, and it is not advised to use this object.

1.1.7 Summarizing BIOM tables

If you have an existing BIOM file and want to compile a summary of the information in that table, you can use the `biom summarize-table` command.

To get help with `biom summarize-table` you can call:


```
biom summarize-table -h
```

This command takes a BIOM file or gzipped BIOM file as input, and will print a summary of the count information on a per-sample basis to the new file specified by the `-o` parameter. The example file used in the commands below can be found in the `biom-format/examples` directory.

Summarizing sample data

To summarize the per-sample data in a BIOM file, you can run:

```
biom summarize-table -i rich_sparse_otu_table.biom -o rich_sparse_otu_table_summary.txt
```

The following information will be written to `rich_sparse_otu_table_summary.txt`:

```
Num samples: 6
Num observations: 5
Total count: 27
Table density (fraction of non-zero values): 0.5000
Table md5 (unzipped): e0d1194d2d94ea81994c93b8f0db7f51

Counts/sample summary:
  Min: 3
  Max: 7
  Median: 4.0
  Mean: 4.5
  Std. dev.: 1.5
  Sample Metadata Categories: LinkerPrimerSequence; BarcodeSequence; Description; BODY_SITE
  Observation Metadata Categories: taxonomy

Counts/sample detail:
  Sample2: 3
  Sample5: 3
  Sample3: 4
  Sample6: 4
  Sample4: 6
  Sample1: 7
```

As you can see, general summary information about the table is provided, including the number of samples, the number of observations, the total count (i.e., the sum of all values in the table), and so on, followed by the per-sample counts.

Summarizing sample data qualitatively

To summarize the per-sample data in a BIOM file qualitatively, where the number of unique observations per sample (rather than the total count of observations per sample) are provided, you can run:

```
biom summarize-table -i rich_sparse_otu_table.biom --qualitative -o rich_sparse_otu_table_qual_summary.txt
```

The following information will be written to `rich_sparse_otu_table_qual_summary.txt`:

```
Num samples: 6
Num observations: 5
Table md5 (unzipped): e0d1194d2d94ea81994c93b8f0db7f51

Observations/sample summary:
  Min: 1
  Max: 4
  Median: 2.5
```

Mean: 2.5

Std. dev.: 0.957427107756

Sample Metadata Categories: LinkerPrimerSequence; BarcodeSequence; Description; BODY_SITE

Observation Metadata Categories: taxonomy

Observations/sample detail:

Sample5: 1

Sample1: 2

Sample4: 2

Sample2: 3

Sample6: 3

Sample3: 4

1.2 BIOM License

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Version 2, June 1991

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How to Apply These Terms to Your New Programs

If you develop a new program, and you want it to be of the greatest possible use to the public, the best way to achieve this is to make it free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest to attach them to the start of each source file to most effectively convey the exclusion of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

```
<one line to give the program's name and a brief idea of what it does.>
Copyright 2007-2009 (C) <year> <name of author>
```

```
This program is free software; you can redistribute it and/or modify
it under the terms of the GNU General Public License as published by
the Free Software Foundation; either version 2 of the License, or
(at your option) any later version.
```

```
This program is distributed in the hope that it will be useful,
but WITHOUT ANY WARRANTY; without even the implied warranty of
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You should have received a copy of the GNU General Public License
along with this program; if not, write to the Free Software
Foundation, Inc., 59 Temple Place, Suite 330, Boston, MA 02111-1307 USA
```

Also add information on how to contact you by electronic and paper mail.

If the program is interactive, make it output a short notice like this when it starts in an interactive mode:

```
Gnomovision version 69, Copyright 2007-2009 (C) year name of author
Gnomovision comes with ABSOLUTELY NO WARRANTY; for details type `show w'.
This is free software, and you are welcome to redistribute it
under certain conditions; type `show c' for details.
```

The hypothetical commands `show w' and `show c' should show the appropriate parts of the General Public License. Of course, the commands you use may be called something other than `show w' and `show c'; they could even be mouse-clicks or menu items--whatever suits your program.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the program, if necessary. Here is a sample; alter the names:

```
Yoyodyne, Inc., hereby disclaims all copyright interest in the program
`Gnomovision' (which makes passes at compilers) written by James Hacker.
```

<signature of Ty Coon>, 1 April 1989
Ty Coon, President of Vice

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BIOM version

The latest official version of the biom-format project is 1.2.0 and of the BIOM file format is 1.0. Details on the file format can be found [here](#).

Installing the biom-format project

To install the `biom-format` project, you can download the release version `biom-format-1.2.0`, or work with the development version. Generally we recommend working with the release version as it will be more stable, but if you want access to the latest features (and can tolerate some instability) you should work with the development version.

The biom-format project has the following dependencies:

- Python ≥ 2.7 and < 3.0
- numpy $\geq 1.3.0$
- `pyqi` 0.2.0
- gcc $\geq 4.1.2$ (optional; used for more efficient sparse table representations)
- cython $\geq 0.14.1$ (optional; used for more efficient sparse table representations)
- dateutil (optional; must be installed if using the `biom validate-table` command)

We'll illustrate the install process in the `$HOME/code` directory. You can either work in this directory on your system (creating it, if necessary, by running `mkdir $HOME/code`) or replace all occurrences of `$HOME/code` in the following instructions with your working directory. Change to this directory to start the install process:

```
cd $HOME/code
```

To install the release version, download from `biom-format-1.2.0`, uncompress the file, and change to the resulting directory:

```
wget ftp://thebeast.colorado.edu/pub/biom-format-releases/biom-format-1.2.0.tar.gz
tar -xvzf biom-format-1.2.0.tar.gz
cd $HOME/code/biom-format-1.2.0
```

Alternatively, to install the development version, pull it from github, and change to the resulting directory:

```
git clone git://github.com/biom-format/biom-format.git
cd $HOME/code/biom-format
```

To install (either the development or release version), follow these steps:

```
sudo python setup.py install
```

If you do not have `sudo` access on your system (or don't want to install the `biom-format` project in the default location) you'll need to install the library code and scripts in specified directories, and then tell your system where to look for those files. You can do this as follows:

```
echo "export PATH=$HOME/bin/:$PATH" >> $HOME/.bashrc
echo "export PYTHONPATH=$HOME/lib/:$PYTHONPATH" >> $HOME/.bashrc
mkdir -p $HOME/bin $HOME/lib/
source $HOME/.bashrc
python setup.py install --install-scripts=$HOME/bin/ --install-purelib=$HOME/lib/ --install-lib=$HOME/lib/
```

You should then have access to the biom-format project. You can test this by running the following command:

```
python -c "from biom import __version__; print __version__"
```

You should see the current version of the biom-format project.

Next you can run:

```
which biom
```

You should get a file path ending with `biom` printed to your screen if it is installed correctly. Finally, to see a list of all `biom` commands, run:

```
biom
```

3.1 Enabling tab completion of biom commands

The `biom` command referenced in the previous section is a driver for commands in biom-format, powered by [pyqi](#). You can enable tab completion of biom command names and command options (meaning that when you begin typing the name of a command or option you can auto-complete it by hitting the *tab* key) by following a few simple steps from the [pyqi](#) documentation. While this step is optional, tab completion is very convenient so it's worth enabling.

To enable tab completion, follow the steps outlined under [Configuring bash completion](#) in the [pyqi](#) install documentation, substituting `biom` for `my-project` and `my_project` in all commands. After completing those steps and closing and re-opening your terminal, auto-completion should be enabled.

Citing the BIOM project

You can cite the BIOM format as follows:

The Biological Observation Matrix (BIOM) format or: how I learned to stop worrying and love the ome-ome.
Daniel McDonald, Jose C. Clemente, Justin Kuczynski, Jai Ram Rideout, Jesse Stombaugh, Doug Wendel, Andreas Wilke, Susan Huse, John Hufnagle, Folker Meyer, Rob Knight, and J. Gregory Caporaso.
GigaScience, June 2012.

Development team

The biom-format project was conceived of and developed by the [QIIME](#), [MG-RAST](#), and [VAMPS](#) development groups to support interoperability of our software packages. If you have questions about the biom-format project you can contact gregcaporaso@gmail.com.