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# **cooler Documentation**

***Release 0.9.3***

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# CONTENTS

<b>1</b>	<b>Quickstart</b>	<b>3</b>
1.1	Installation . . . . .	3
1.2	Command line interface . . . . .	3
1.3	Python API . . . . .	4
<b>2</b>	<b>What is cooler?</b>	<b>5</b>
2.1	Genomically-labeled arrays . . . . .	5
2.2	Data model . . . . .	6
2.3	Container . . . . .	7
<b>3</b>	<b>Concepts</b>	<b>9</b>
3.1	Resource String . . . . .	9
3.2	Data selection . . . . .	9
3.3	Create a scool file . . . . .	13
<b>4</b>	<b>Schema</b>	<b>15</b>
4.1	Data collection . . . . .	15
4.2	URI syntax . . . . .	16
4.3	Tables . . . . .	16
4.4	Indexes . . . . .	18
4.5	Storage mode . . . . .	18
4.6	Metadata . . . . .	18
4.7	File flavors . . . . .	19
4.8	Previous schema versions . . . . .	22
<b>5</b>	<b>API Reference</b>	<b>23</b>
5.1	Quick reference . . . . .	23
5.2	cooler . . . . .	24
5.3	cooler.create . . . . .	35
5.4	cooler.fileops . . . . .	36
5.5	cooler.util . . . . .	37
<b>6</b>	<b>CLI Reference</b>	<b>41</b>
6.1	Quick reference . . . . .	41
6.2	cooler cload . . . . .	42
6.3	cooler cload pairs . . . . .	42
6.4	cooler cload pairix . . . . .	44
6.5	cooler cload tabix . . . . .	45
6.6	cooler cload hiclib . . . . .	46
6.7	cooler load . . . . .	47
6.8	cooler merge . . . . .	49

6.9	cooler coarsen	49
6.10	cooler zoomify	50
6.11	cooler balance	51
6.12	cooler info	53
6.13	cooler dump	53
6.14	cooler show	55
6.15	cooler tree	56
6.16	cooler attrs	56
6.17	cooler ls	57
6.18	cooler cp	57
6.19	cooler mv	58
6.20	cooler ln	58
6.21	cooler makebins	59
6.22	cooler digest	60
6.23	cooler csort	60
<b>7</b>	<b>Release notes</b>	<b>63</b>
7.1	v0.9.3	63
7.2	v0.9.2	63
7.3	v0.9.1	63
7.4	v0.9.0	64
7.5	v0.8.11	64
7.6	v0.8.10	65
7.7	v0.8.9	65
7.8	v0.8.8	65
7.9	v0.8.7	66
7.10	v0.8.6	66
7.11	v0.8.5	66
7.12	v0.8.4	66
7.13	v0.8.3	67
7.14	v0.8.2	67
7.15	v0.8.1	68
7.16	v0.8.0	68
7.17	v0.7.11	69
7.18	v0.7.10	70
7.19	v0.7.9	70
7.20	v0.7.8	70
7.21	v0.7.7	70
7.22	v0.7.6	71
7.23	v0.7.5	71
7.24	v0.7.4	72
7.25	v0.7.3	72
7.26	v0.7.2	72
7.27	v0.7.1	72
7.28	v0.7.0	72
7.29	v0.6.6	73
7.30	v0.6.5	73
7.31	v0.6.4	73
7.32	v0.6.3	74
7.33	v0.6.2	74
7.34	v0.6.1	74
7.35	v0.6.0	74
7.36	v0.5.3	75
7.37	v0.5.2	75

7.38	v0.5.1 . . . . .	75
7.39	v0.5.0 . . . . .	76
7.40	v0.4.0 . . . . .	76
7.41	v0.3.0 . . . . .	76
7.42	v0.2.1 . . . . .	77
7.43	v0.2 . . . . .	77
7.44	v0.1 . . . . .	77
<b>Index</b>		<b>79</b>



Cooler is a Python support library for .cool/.mcool files: an efficient storage format for high resolution genomic interaction matrices.

The cooler package aims to facilitate:

- Creation, aggregation and manipulation of genomically-labeled sparse matrices.
- Querying: sequential and range query patterns and tabular and sparse/dense array retrieval.
- Scalable out-of-core operations on the data.
- Data export and visualization.

Follow cooler development on [GitHub](#).

Contents:





## QUICKSTART

### 1.1 Installation

Install **cooler** from [PyPI](#) using **pip**.

```
$ pip install cooler
```

Requirements:

- Python 2.7 or 3.4 and higher
- libhdf5
- Python packages **numpy**, **scipy**, **pandas**, **h5py**.

We highly recommend using the **conda** package manager to install scientific packages like these. To get **conda**, you can download either the full [Anaconda](#) Python distribution which comes with lots of data science software or the minimal [Miniconda](#) distribution which is just the standalone package manager plus Python. In the latter case, you can install the packages as follows:

```
$ conda install numpy scipy pandas h5py
```

If you are using **conda**, you can alternatively install **cooler** from the [bioconda channel](#).


```
$ conda install -c conda-forge -c bioconda cooler
```

### 1.2 Command line interface

See:

- Jupyter Notebook [CLI walkthrough](#).
- The [CLI Reference](#) for more information.

The **cooler** package includes command line tools for creating, querying and manipulating cooler files.

```
$ cooler cload pairs hg19.chrom.sizes:10000 $PAIRS_FILE out.10000.cool
$ cooler balance -p 10 out.10000.cool
$ cooler dump -b -t pixels --header --join -r chr3:10M-12M -r2 chr17 out.10000.cool |  head
```

Output:

chrom1	start1	end1	chrom2	start2	end2	count	balanced	
chr3	100000000		100100000		chr17	0	100000	1 0.810766
chr3	100000000		100100000		chr17	5200000	5300000	1 1.2055
chr3	100000000		100100000		chr17	6400000	6500000	1 0.587372
chr3	100000000		100100000		chr17	9000000	9100000	1 1.02558
chr3	100000000		100100000		chr17	10300000	10400000	1 0.718195
chr3	100000000		100100000		chr17	13200000	13300000	1 0.803212
chr3	100000000		100100000		chr17	15000000	15100000	1 0.925146
chr3	100000000		100100000		chr17	17500000	17600000	1 0.950326
chr3	100000000		100100000		chr17	18000000	18100000	1 0.745982

## 1.3 Python API

See:

- Jupyter Notebook [API walkthrough](#).
- The [API Reference](#) for more information.

The cooler library provides a thin wrapper over the excellent NumPy-aware [h5py](#) Python interface to HDF5. It supports creation of cooler files and the following types of **range queries** on the data:

- Tabular selections are retrieved as Pandas DataFrames and Series.
- Matrix selections are retrieved as NumPy arrays, DataFrames, or SciPy sparse matrices.
- Metadata is retrieved as a json-serializable Python dictionary.
- Range queries can be supplied using either integer bin indexes or genomic coordinate intervals.

```
>>> import cooler
>>> import matplotlib.pyplot as plt
>>> c = cooler.Cooler('bigDataset.cool')
>>> resolution = c.binsize
>>> mat = c.matrix(balance=True).fetch('chr5:10,000,000-15,000,000')
>>> plt.matshow(np.log10(mat), cmap='YlOrRd')
```

```
>>> import multiprocessing as mp
>>> import h5py
>>> pool = mp.Pool(8)
>>> c = cooler.Cooler('bigDataset.cool')
>>> weights, stats = cooler.balance_cooler(c, map=pool.map, ignore_diags=3, min_nnz=10)
```

## WHAT IS COOLER?

Cooler is the *implementation* of a data model for genomically-labeled sparse 2D arrays (matrices) with identical axes in HDF5. It is also the name of the *Python package* that supports the format.

We use the term genomically-labeled array to refer to a data structure that assigns unique quantitative values to tuples of *genomic bins* obtained from an interval partition of a reference genome assembly. The tuples of bins make up the coordinates of the array's elements. By omitting elements possessing zero or no value, the representation becomes sparse.

Cooler was designed for the storage and manipulation of extremely large Hi-C datasets at any resolution, but is not limited to Hi-C data in any way.

### 2.1 Genomically-labeled arrays

We can describe two tabular representations of such data.

#### BG2

By extending the *bedGraph* format, we can encode a 2D array with the following header.

chrom1	start1	end1	chrom2	start2	end2	value
--------	--------	------	--------	--------	------	-------

Other bin-related attributes (e.g. X and Y) can be appended as columns X1, X2, Y1, Y2, and so on. One problem with this representation is that each bin-related attribute can be repeated many times throughout the table, leading to great redundancy.

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**Note:** *bedGraph* is technically different from *BED*: the former describes a quantitative track supported by **non-overlapping** intervals (a step function), while the latter describes genomic intervals with no such restrictions. BG2 is different from *BEDPE* in the same way: intervals on the same axis are non-overlapping and interval pairs are not repeated (describing a heatmap).

---

#### COO

A simple solution is to decompose or “normalize” the single table into two files. The first is a bin table that describes the genomic bin segmentation on both axes of the matrix (in the one-dimensional *bedGraph* style). The second table contains single columns that reference the rows of the bin table, providing a condensed representation of the nonzero elements of the array. Conveniently, this corresponds to the classic coordinate list (COO) sparse matrix representation. This two-table representation is used as a text format by *HiC-Pro*.

bins		
chrom	start	end

elements		
bin1_id	bin2_id	value

The table of elements (non-zero pixels) is often too large to hold in memory, but for any small selection of elements we can reconstitute the bin-related attributes by “joining” the bin IDs against the bin table. We refer to this process as element *annotation*.

## 2.2 Data model

We model a genomically-labeled sparse matrix using three tables. It corresponds to the bin and element (pixel) tables above. We include a third chromosome description table for completeness, and indexes to support random access.

### 2.2.1 Tables

#### chroms

- Required columns: `name[, length]`
- Order: *enumeration*

An semantic ordering of the chromosomes, scaffolds or contigs of the assembly that the data is mapped to. This information can be extracted from the bin table below, but is included separately for convenience. This enumeration is the intended ordering of the chromosomes as they would appear in a global genomic matrix. Additional columns can provide metadata on the chromosomes, such as their length.

#### bins

- Required columns: `chrom, start, end [, weight]`
- Order: `chrom (enum), start`

An enumeration of the concatenated genomic bins that make up a single dimension or axis of the global genomic matrix. Genomic bins can be of fixed size or variable sizes (e.g. restriction fragments). A genomic bin is defined by the triple (`chrom, start, end`), where `start` is zero-based and `end` is 1-based. The order is significant: the bins are sorted by chromosome (based on the chromosome enumeration) then by `start`, and each genomic bin is implicitly endowed with a 0-based bin ID from this ordering (i.e., its row number in the table). A reserved but optional column called `weight` can store weights for normalization or matrix balancing. Additional columns can be added to describe other bin-associated properties such as additional normalization vectors or bin-level masks.

## pixels

- Required columns: `bin1_id`, `bin2_id`, `count`
- Order: `bin1_id`, `bin2_id`

The array is stored as a single table containing only the nonzero upper triangle elements, assuming the ordering of the bins given by the bin table. Each row defines a non-zero element of the genomic matrix. Additional columns can be appended to store pixel-associated properties such as pixel-level masks or filtered and transformed versions of the data. Currently, the pixels are sorted lexicographically by the bin ID of the 1st axis (matrix row) then the bin ID of the 2nd axis (matrix column).

### 2.2.2 Indexes

The sort order on the pixels and types of indexing strategies that can be used are strongly related. We stipulate that the records of the pixel table must be sorted lexicographically by the bin ID along the first axis, then by the bin ID along the second axis. This way, the `bin1_id` column can be substituted with its run length encoding, which serves as a lookup index for the rows of the matrix. With this index, we obtain a compressed sparse row (CSR) sparse matrix representation.

Given an enumeration of chromosomes, the bin table must also be lexicographically sorted by chromosome then by start coordinate. Then similarly, the chrom column of the bin table will reference the rows of the chrom table, and can also be substituted with a run length encoding.

## 2.3 Container

The reference implementation of this data model uses [HDF5](#) as the container format. HDF5 is a hierarchical data format for homogeneously typed multidimensional arrays, which supports chunking, compression, and random access. The HDF5 file specification and open source standard library is maintained by the nonprofit HDF Group.

HDF5 files consist of three fundamental entities: groups, datasets, and attributes. The hierarchical organization of an HDF5 file is conceptually analogous to a file system: *groups* are akin to directories and *datasets* (arrays) are akin to files. Additionally, key-value metadata can be attached to groups and datasets using *attributes*. The standard library provides the ability to access and manipulate these entities. There are bindings for virtually every platform and programming environment. To learn more in detail about HDF5, I recommend the book [HDF5 and Python](#) by Andrew Collette, the author of `h5py`.

To implement the data model in HDF5, data tables are stored in a columnar representation as HDF5 groups of 1D array datasets of equal length. Metadata is stored using top-level attributes. See the [schema](#).

### 2.3.1 HDF5 bindings in other languages

- canonical C-library [libhdf5](#)
- C++: [C++ API](#)
- IDL: [bindings](#)
- Java: [Java HDF5 Interface](#)
- Julia: [HDF5.jl](#)
- Mathematica: [API](#)
- MATLAB: [high and low level API](#)

- node.js: [hdf5.node](#)
- Perl: [PDL::IO::HDF5](#)
- R: [rhdf5](#), [h5](#)
- Apache [Spark](#)

### 2.3.2 Caveats

HDF5 is not a database system and is not journalled. It supports concurrent read access but not simultaneous reads and writes (with upcoming support for the [SWMR](#) access pattern). One must be careful using multi-process concurrency based on Unix `fork()`: if a file is already open before the fork, the child processes will inherit state such that they won't play well with each other on that file. HDF5 will work fine with Python's `multiprocessing` as long as you make sure to close file handles before creating a process pool. Otherwise, you'll need to use locks or avoid opening the file in worker processes completely (see this [blog post](#) for a simple workaround). For more information on using `multiprocessing` safely, see this [discussion](#).

## CONCEPTS

### 3.1 Resource String

The default location for a single-cooler .cool file is the root group / of the HDF5 file. It does not need to be explicitly specified.

```
>>> import cooler
>>> c = cooler.Cooler('data/WT.DpnII.10kb.cool')
>>> c = cooler.Cooler('data/WT.DpnII.10kb.cool::/') # same as above
```

However, coolers can be stored at any level of the HDF5 hierarchy and qualified using a URI string of the form /path/to/cool/file::/path/to/cooler/group.

```
>>> c1 = cooler.Cooler('data/WT.DpnII.mcool::resolutions/10000')
>>> c2 = cooler.Cooler('data/WT.DpnII.mcool::resolutions/1000')
```

The current standard for Hi-C coolers is to name multi-resolution coolers under .mcool extension, and store different resolutions in an HDF5 group resolutions, as shown above.

### 3.2 Data selection

Several `cooler.Cooler` methods return data selectors. Those include selecting tables and matrices (see below). Data selectors don't retrieve any data from disk until queried. There are several ways to query using selectors. Genomic range strings may be provided as 3-tuples (`chrom: str, start: int, end: int`) or in UCSC-style strings of the style `{chrom}:{start}-{end}`. Unit prefixes `k`, `M`, `G` are supported in range strings. For regions with start and end that are not multiples of the resolution, selectors return the range of shortest range bins that fully contains the open interval `[start, end)`.

#### 3.2.1 Table selectors (chroms, bins, pixels)

There are data selectors for the three tables: `cooler.Cooler.chroms()`, `cooler.Cooler.bins()`, `cooler.Cooler.pixels()`. They support the following:

- lazily select columns or lists of columns, returning new selectors
- query table rows using integer/slice indexing syntax

```
>>> c.bins()
<cooler.core.RangeSelector1D at 0xfdb2e4f0710>
```

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```
>>> c.bins()[10]
chrom    start      end    weight
0  chr1      0    1000000    NaN
1  chr1 1000000    2000000  1.243141
2  chr1 2000000    3000000  1.313995
3  chr1 3000000    4000000  1.291705
4  chr1 4000000    5000000  1.413288
5  chr1 5000000    6000000  1.165382
6  chr1 6000000    7000000  0.811824
7  chr1 7000000    8000000  1.056107
8  chr1 8000000    9000000  1.058915
9  chr1 9000000   10000000  1.035910

>>> c.pixels()[10]
   bin1_id  bin2_id  count
0         0         0  18578
1         0         1  11582
2         0         2   446
3         0         3   196
4         0         4    83
5         0         5   112
6         0         6   341
7         0         7   255
8         0         8   387
9         0         9   354

>>> c.bins()['weight']
<cooler.core.RangeSelector1D at 0x7fdb2e509240>

>>> weights = c.bins()['weight'].fetch('chr3')
>>> weights.head()
494    1.144698
495    1.549848
496    1.212580
497    1.097539
498    0.871931
Name: weight, dtype: float64

>>> mybins1 = c.bins().fetch('chr3:10,000,000-20,000,000')
>>> mybins2 = c.bins().fetch( ('chr3', 10000000, 20000000) )
>>> mybins2.head()
   chrom    start      end    weight
504  chr3 10000000  11000000  0.783160
505  chr3 11000000  12000000  0.783806
506  chr3 12000000  13000000  0.791204
507  chr3 13000000  14000000  0.821171
508  chr3 14000000  15000000  0.813079
```



### 3.2.2 Matrix selector

The `cooler.Cooler.matrix()` selector supports two types of queries:

- 2D bin range queries using slice indexing syntax
- 2D genomic range range queries using the `fetch` method

The matrix selector's `fetch` method is intended to represent a **2D range query** (rectangular window), similar to the slice semantics of a 2D array. Given a matrix selector `sel`, when calling `sel.fetch(region1, region2)` the `region1` and `region2` are single contiguous genomic ranges along the first and second axes of the contact matrix. This mirrors the global slice indexing interface of the matrix selector `sel[a:b, c:d]`, where the only difference is that the genomic range syntax cannot cross chromosome boundaries. If `region2` is not provided, it is taken to be the same as `region1`. That means that `sel.fetch('chr2:10M-20M')` returns the same result as `sel.fetch('chr2:10M-20M', 'chr2:10M-20M')`. As a single rectangular window, queries like `sel.fetch('chr2', 'chr3')` will return *inter*-chromosomal values and not *intra*-chromosomal ones.

```
>>> c.matrix(balance=False)[1000:1005, 1000:1005]
array([[120022, 34107, 17335, 14053, 4137],
       [ 34107, 73396, 47427, 16125, 3642],
       [ 17335, 47427, 80458, 25105, 5394],
       [ 14053, 16125, 25105, 104536, 27214],
       [ 4137, 3642, 5394, 27214, 114135]])

>>> matrix = c.matrix(sparse=True, balance=False)
>>> matrix
<cooler.core.RangeSelector2D at 0x7fdb2e245908>

>>> matrix[:]
<3114x3114 sparse matrix of type '<class 'numpy.int64'>'
  with 8220942 stored elements in COOrdinate format>

>>> c.matrix(balance=False, as_pixels=True, join=True)[1000:1005, 1000:1005]
  chrom1    start1    end1 chrom2    start2    end2    count
0   chr5  115000000  116000000   chr5  115000000  116000000  120022
1   chr5  115000000  116000000   chr5  116000000  117000000   34107
2   chr5  115000000  116000000   chr5  117000000  118000000   17335
3   chr5  115000000  116000000   chr5  118000000  119000000   14053
4   chr5  115000000  116000000   chr5  119000000  120000000    4137
5   chr5  116000000  117000000   chr5  116000000  117000000   73396
6   chr5  116000000  117000000   chr5  117000000  118000000   47427
7   chr5  116000000  117000000   chr5  118000000  119000000   16125
8   chr5  116000000  117000000   chr5  119000000  120000000    3642
9   chr5  117000000  118000000   chr5  117000000  118000000   80458
10  chr5  117000000  118000000   chr5  118000000  119000000   25105
11  chr5  117000000  118000000   chr5  119000000  120000000    5394
12  chr5  118000000  119000000   chr5  118000000  119000000  104536
13  chr5  118000000  119000000   chr5  119000000  120000000   27214
14  chr5  119000000  120000000   chr5  119000000  120000000  114135

>>> A1 = c.matrix().fetch('chr1')
>>> A2 = c.matrix().fetch('chr3:10,000,000-20,000,000')
>>> A3 = c.matrix().fetch( ('chr3', 10000000, 20000000) )
>>> A4 = c.matrix().fetch('chr2', 'chr3')
```

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```
>>> A5 = c.matrix().fetch('chr3:10M-20M', 'chr3:35M-40M')
```

### 3.2.3 Dask

Dask data structures provide a way to manipulate and distribute computations on larger-than-memory data using familiar APIs. The experimental `read_table` function can be used to generate a dask dataframe backed by the pixel table of a cooler as follows:

```
>>> from cooler.sandbox.dask import read_table
>>> df = daskify(c.filename, 'pixels')

>>> df
Dask DataFrame Structure:
              bin1_id bin2_id  count
npartitions=223
0              int64   int64  int64
9999999          ...     ...    ...
...              ...     ...    ...
2219999999       ...     ...    ...
2220472929       ...     ...    ...
Dask Name: daskify, 223 tasks

>>> df = cooler.annotate(df, c.bins(), replace=False)
>>> df
Dask DataFrame Structure:
              chrom1 start1  end1  weight1  chrom2 start2  end2  weight2 bin1_id_
↳bin2_id count
npartitions=31
None          object  int64  int64  float64  object  int64  int64  float64  int64  _
↳int64  int64
None          ...     ...    ...    ...    ...    ...    ...    ...    ...    _
↳...     ...
...          ...     ...    ...    ...    ...    ...    ...    ...    ...    _
↳...     ...
None          ...     ...    ...    ...    ...    ...    ...    ...    ...    _
↳...     ...
None          ...     ...    ...    ...    ...    ...    ...    ...    ...    _
↳...     ...
Dask Name: getitem, 125 tasks

>>> df = df[df.chrom1 == df.chrom2]
>>> grouped = df.groupby(df.bin2_id - df.bin1_id)
>>> x = grouped['count'].sum()
>>> x
Dask Series Structure:
npartitions=1
None      int64
None      ...
Name: count, dtype: int64
Dask Name: series-groupby-sum-agg, 378 tasks
```

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```
>>> x.compute()
0      476155231
1      284724453
2      139952477
3       96520218
4      71962080
5      56085850
6      45176881
7      37274367
8      31328555
9      26781986
10     23212616
11     20366934
12     18066135
13     16159826
14     14584058
15     13249443
16     12117854
17     11149845
...
```

Learn more about the [Dask](#) project.

### 3.3 Create a scool file

The creation of a single-cell cooler file is similar to a regular cooler file. Each cell needs to have a name, bin table and a pixel table. All cells must have the same dimensions, and the bins and pixels needs to be provided as two dicts with the cell names as keys.

```
>>> name_pixel_dict = {'cell1': pixels_cell1, 'cell2': pixels_cell2, 'cell3': pixels_
↳ cell3}
>>> name_bins_dict = {'cell1': bins_cell1, 'cell2': bins_cell2, 'cell3': bins_cell3}
>>> cooler.create_scool('single_cell_cool.scool', name_bins_dict, name_pixel_dict)
```

To read the content, each individual cell must be handled as a regular cool file.

```
>> content_of_scool = cooler.fileops.list_coolers('single_cell_cool.scool')
['/', '/cells/cell1', '/cells/cell2', '/cells/cell3']
>>> c1 = cooler.Cooler('single_cell_cool.scool::cells/cell1')
>>> c2 = cooler.Cooler('single_cell_cool.scool::cells/cell2')
>>> c3 = cooler.Cooler('single_cell_cool.scool::cells/cell3')
```



## SCHEMA

Schema Version 3
------------------

The following document describes a [compressed sparse row \(CSR\)](#) storage scheme for a matrix (i.e., a quantitative heatmap) with genomically labeled dimensions/axes.

HDF5 does not natively implement sparse arrays or relational data structures: its datasets are dense multidimensional arrays. We implement tables and sparse array indexes in HDF5 using groups of 1D arrays. The descriptions of tables and indexes in this document specify required groups and arrays, conventional column orders, and default data types.

---

### Summary of changes

- Version 3 introduces the `storage-mode` metadata attribute to accomodate square matrices that are non-symmetric. Version 2 files which lack the `storage-mode` attribute should be interpreted as using the “symmetric-upper” storage mode. See [Storage mode](#).
  - The multi-resolution cooler file layout has been standardized. See [File flavors](#).
- 

## 4.1 Data collection

We refer to the object hierarchy describing a single matrix as a cooler *data collection*. A cooler data collection consists of **tables**, **indexes** and **metadata** describing a genomically-labelled sparse matrix.

A typical data collection has the following structure. At the top level, there are four [HDF5 Groups](#), each containing 1D arrays ([HDF5 Datasets](#)). The depiction below shows an example group hierarchy as a tree, with arrays at the leaves, printed with their shapes in parentheses and their data type symbols.

```
/
├── chroms
│   ├── length (24,) int32
│   └── name (24,) |S64
├── bins
│   ├── chrom (3088281,) int32
│   ├── start (3088281,) int32
│   ├── end (3088281,) int32
│   └── weight (3088281,) float64
├── pixels
│   ├── bin1_id (271958554,) int64
│   └── bin2_id (271958554,) int64
```

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```
└─ count (271958554,) int32
└─ indexes
    └─ bin1_offset (3088282,) int64
    └─ chrom_offset (25,) int64
```

## 4.2 URI syntax

We identify a cooler data collection using a **URI string** to its top-level group, separating the system path to the container file from the **group path** within the container file by a double colon `::`.

```
path/to/container.cool::/path/to/cooler/group
```

For any URI, the leading slash after the `::` may be omitted. To reference the root group `/`, the entire `::/` suffix may be omitted (i.e., just a file path).

## 4.3 Tables

A **table** is a group of equal-length 1D arrays representing **columns**.

Additional groups and tables may be added to a data collection as long as they are not nested under the group of another table.

This storage mode does not enforce specific **column orders**, but conventional orders for *required* columns is provided in the listings below.

This storage mode does not set limits on the **number or length of columns**. Additional arrays may be inserted into a table to form new columns, but they must conform to the common length of the table.

The table descriptions below are given in the [datashape](#) layout language. The column **data types** are given as numpy equivalents. They are only defaults and may be altered as desired.

GZIP is chosen as the default **compression** filter for all columns. This is for portability reasons, since all versions of the HDF5 library ship with it.

### 4.3.1 chroms

```
chroms: {
  # REQUIRED
  name:    typevar['Nchroms'] * string['ascii'],
  length:  typevar['Nchroms'] * int32
}
```

In HDF5, `name` is a null-padded, fixed-length ASCII array, which maps to numpy's `S` dtype.

### 4.3.2 bins

```
bins: {
  # REQUIRED
  chrom:    typevar['Nbins'] * categorical[typevar['name'], type=string, ordered=True],
  start:    typevar['Nbins'] * int32,
  end:      typevar['Nbins'] * int32,

  # RESERVED
  weight:   typevar['Nbins'] * float64
}
```

In HDF5, we use the integer-backed ENUM type to encode the `chrom` column. For data collections with a very large number of scaffolds, the ENUM type information may be too large to fit in the object's metadata header. In that case, the `chrom` column is stored using raw integers and the enumeration is inferred from the `chrom` table.

Genomic intervals are stored using a 0-start, half-open representation. The first interval in a scaffold should have `start` = 0 and the last interval should have `end` = the chromosome length. Intervals are sorted by `chrom`, then by `start`.

Because they measure the same quantity in the same units, the coordinate columns `chroms/length`, `bins/start` and `bins/end` should be encoded using the same data type.

The **cooler balance** command stores balancing weights in a column called `weight` by default. NaN values indicate genomic bins that were blacklisted during the balancing procedure.

### 4.3.3 pixels

```
pixels: {
  # REQUIRED
  bin1_id:  typevar['Nnz'] * int64,
  bin2_id:  typevar['Nnz'] * int64,

  # RESERVED
  count:    typevar['Nnz'] * int32
}
```

In the matrix coordinate system, `bin1_id` refers to the *i*th axis and `bin2_id` refers to the *j*th. Bin IDs are zero-based, i.e. we start counting at 0. Pixels are sorted by `bin1_id` then by `bin2_id`.

The `count` column is integer by default, but floating point types can be substituted. Additional columns are to be interpreted as supplementary value columns.

**Warning:** `float16` has limited support from 3rd party libraries and is not recommended. For floating point value columns consider using either single- (float32) or double-precision (float64).

## 4.4 Indexes

Indexes are stored as 1D arrays in a separate group called `indexes`. They can be thought of as run-length encodings of the `bins/chrom` and `pixels/bin1_id` columns, respectively. Both arrays are required.

```
indexes: {  
  chrom_offset: (typevar['Nchroms'] + 1) * int64,  
  bin1_offset:  (typevar['Nbins'] + 1) * int64  
}
```

- `chrom_offset`: indicates which row in the bin table each chromosome first appears. The last element stores the length of the bin table.
- `bin1_offset`: indicates which row in the pixel table each bin1 ID first appears. The last element stores the length of the pixel table. This index is usually called *indptr* in CSR data structures.

## 4.5 Storage mode

Storing a symmetric matrix requires only the *upper triangular part, including the diagonal*, since the remaining elements can be reconstructed from the former ones. To indicate the use of this **mode of matrix storage** to client software, the value of the metadata attribute `storage-mode` must be set to `"symmetric-upper"` (see [Metadata](#)).

New in version 3: To indicate the absence of a special storage mode, e.g. for **non-symmetric** matrices, `storage-mode` must be set to `"square"`. This storage mode indicates to client software that 2D range queries should not be symmetrized.

**Warning:** In schema v2 and earlier, the symmetric-upper storage mode is always assumed.

## 4.6 Metadata

Essential key-value properties are stored as [HDF5 attributes](#) at the top-level group of the data collection. Note that depending on where the data collection is located in the file, this can be different from the root group of the entire file `/`.

### Required attributes

**format : string (constant)**

“HDF5::Cooler”

**format-version : int**

The schema version used.

**bin-type : { "fixed", "variable" }**

Indicates whether the resolution is constant along both axes.

**bin-size : int or "null"**

Size of genomic bins in base pairs if bin-type is “fixed”. Otherwise, “null”.



**storage-mode** : { "symmetric-upper", "square" }

Indicates whether ordinary sparse matrix encoding is used ("square") or whether a symmetric matrix is encoded by storing only the upper triangular elements ("symmetric-upper").

### Reserved, but optional

**assembly** : string

Name of the genome assembly, e.g. "hg19".

**generated-by** : string

Agent that created the file, e.g. "cooler-x.y.z".

**creation-date** : datetime string

The moment the collection was created.

**metadata** : JSON

Arbitrary JSON-compatible **user metadata** about the experiment.

All scalar string attributes, including serialized JSON, must be stored as **variable-length UTF-8 encoded strings**.

**Warning:** When assigning scalar string attributes in Python 2, always store values having `unicode` type. In `h5py`, assigning a Python text string (Python 3 `str` or Python 2 `unicode`) to an HDF5 attribute results in variable-length UTF-8 storage.

Additional metadata may be stored in other top-level attributes and the attributes of table groups and columns.

## 4.7 File flavors

Many cooler data collections can be stored in a single file. We recognize two conventional **layouts**:

### 4.7.1 Single-resolution

- A single-resolution cooler file that contains a single data collection under the `/` group. Conventional file extension: `.cool`.

```
XYZ.1000.cool
/
├── bins
├── chroms
├── pixels
└── indexes
```

### 4.7.2 Multi-resolution

- A multi-resolution cooler file that contains multiple “coarsened” resolutions or “zoom-levels” derived from the same dataset. Multires cooler files should store each data collection underneath a group called `/resolutions` within a sub-group whose name is the bin size (e.g. `XYZ.1000.mcool::resolutions/10000`). If the base cooler has variable-length bins, then use 1 to designate the base resolution, and the use coarsening multiplier (e.g. 2, 4, 8, etc.) to name the lower resolutions. Conventional file extension: `.mcool`.

```
XYZ.1000.mcool
/
├── resolutions
│   ├── 1000
│   │   ├── bins
│   │   ├── chroms
│   │   ├── pixels
│   │   └── indexes
│   ├── 2000
│   │   ├── bins
│   │   ├── chroms
│   │   ├── pixels
│   │   └── indexes
│   ├── 5000
│   │   ├── bins
│   │   ├── chroms
│   │   ├── pixels
│   │   └── indexes
│   └── 10000
│       ├── bins
│       ├── chroms
│       ├── pixels
│       └── indexes
├── .
├── .
└── .
```

In addition, a multi-resolution cooler file may indicate to clients that it is using this layout with the following `/-level` attributes:

**format : string (constant)**

“HDF5::MCOOL”

**format-version : int**

2

**bin-type : { "fixed", "variable" }**

Indicates whether the resolution is constant along both axes.

**Note:** The old multi-resolution layout used resolutions strictly in increments of *powers of 2*. In this layout (MCOOL version 2), the data collections are named by zoom level, starting with `XYZ.1000.mcool::0` being the coarsest resolution up until the finest or “base” resolution (e.g., `XYZ.1000.mcool::14` for 14 levels of coarsening).

Changed in version 0.8: Both the legacy layout and the new mcool layout are supported by [HiGlass](#). Prior to cooler 0.8, the new layout was produced only when requesting a specific list of resolutions. As of cooler 0.8, the new layout is

always produced by the **cooler zoomify** command unless the `--legacy` option is given. Files produced by `cooler.zoomify_cooler()`, `hic2cool`, and the mcools from the [4DN data portal](#) also follow the new layout.

### 4.7.3 Single-cell (single-resolution)

A single-cell cooler file contains all the matrices of a single-cell Hi-C data set. All cells are stored under a group called `/cells`, and all cells share the primary bin table columns i.e. `bins['chrom']`, `bins['start']` and `bins['end']` which are [hardlinked](#) to the root-level bin table. Any individual cell can be accessed using the regular `cooler.Cooler` interface. Conventional file extension: `.scool`.

```
XYZ.scool
/
├── bins
├── chroms
└── cells
    ├── cell_id1
    │   ├── bins
    │   ├── chroms
    │   ├── pixels
    │   └── indexes
    ├── cell_id2
    │   ├── bins
    │   ├── chroms
    │   ├── pixels
    │   └── indexes
    ├── cell_id3
    │   ├── bins
    │   ├── chroms
    │   ├── pixels
    │   └── indexes
    └── cell_id4
        ├── bins
        ├── chroms
        ├── pixels
        └── indexes
    .
    .
    .
```

In addition, a single-cell single-resolution cooler file may indicate to clients that it is using this layout with the following `/-`level attributes:

**format : string (constant)**

“HDF5::SCOOL”

**format-version : int**

1

**bin-type : { "fixed", "variable" }**

Indicates whether the resolution is constant along both axes.

**bin-size : int**

The bin resolution

**nbins : int**

The number of bins

**nchroms : int**

The number of chromosomes of the cells

**ncells : int**

The number of stored cells

## 4.8 Previous schema versions

- v1
- v2

## API REFERENCE

### 5.1 Quick reference

#### 5.1.1 Cooler class

<code>cooler.Cooler</code>	A convenient interface to a cooler data collection.
<code>cooler.Cooler.binsize</code>	Resolution in base pairs if uniform else None
<code>cooler.Cooler.chromnames</code>	List of reference sequence names
<code>cooler.Cooler.chromsizes</code>	Ordered mapping of reference sequences to their lengths in bp
<code>cooler.Cooler.bins(**kwargs)</code>	Bin table selector
<code>cooler.Cooler.pixels([join])</code>	Pixel table selector
<code>cooler.Cooler.matrix([field, balance, ...])</code>	Contact matrix selector
<code>cooler.Cooler.open([mode])</code>	Open the HDF5 group containing the Cooler with h5py
<code>cooler.Cooler.info</code>	File information and metadata
<code>cooler.Cooler.offset(region)</code>	Bin ID containing the left end of a genomic region
<code>cooler.Cooler.extent(region)</code>	Bin IDs containing the left and right ends of a genomic region

#### 5.1.2 Creation/reduction

<code>cooler.create_cooler(cool_uri, bins, pixels)</code>	Create a cooler from bins and pixels at the specified URI.
<code>cooler.merge_coolers(output_uri, input_uris, ...)</code>	Merge multiple coolers with identical axes.
<code>cooler.coarsen_cooler(base_uri, output_uri, ...)</code>	Coarsen a cooler to a lower resolution by an integer factor $k$ .
<code>cooler.zoomify_cooler(base_uris, outfile, ...)</code>	Generate multiple cooler resolutions by recursive coarsening.
<code>cooler.create_scool(cool_uri, bins, ...[, ...])</code>	Create a single-cell (scool) file.

### 5.1.3 Manipulation

<code>cooler.annotate(pixels, bins[, replace])</code>	Add bin annotations to a data frame of pixels.
<code>cooler.balance_cooler(clr, *[, cis_only, ...])</code>	Iterative correction or matrix balancing of a sparse Hi-C contact map in Cooler HDF5 format.
<code>cooler.rename_chroms(clr, rename_dict[, h5opts])</code>	Substitute existing chromosome/contig names for new ones.

### 5.1.4 File operations

<code>cooler.fileops.is_cooler(uri)</code>	Determine if a URI string references a cooler data collection.
<code>cooler.fileops.is_multires_file(filepath[, ...])</code>	Determine if a file is a multi-res cooler file.
<code>cooler.fileops.list_coolers(filepath)</code>	List group paths to all cooler data collections in a file.
<code>cooler.fileops.cp(src_uri, dst_uri[, overwrite])</code>	Copy a group or dataset from one file to another or within the same file.
<code>cooler.fileops.mv(src_uri, dst_uri[, overwrite])</code>	Rename a group or dataset within the same file.
<code>cooler.fileops.ln(src_uri, dst_uri[, soft, ...])</code>	Create a hard link to a group or dataset in the same file.

## 5.2 cooler

### class cooler.Cooler

A convenient interface to a cooler data collection.

#### Parameters

- **store** (str, `h5py.File` or `h5py.Group`) – Path to a cooler file, URI string, or open handle to the root HDF5 group of a cooler data collection.
- **root** (str, optional [*deprecated*]) – HDF5 Group path to root of cooler group if store is a file. This option is deprecated. Instead, use a URI string of the form <file\_path>::<group\_path>.
- **kwargs** (optional) – Options to be passed to `h5py.File()` upon every access. By default, the file is opened with the default driver and mode='r'.

#### Notes

If store is a file path, the file will be opened temporarily in when performing operations. This allows *Cooler* objects to be serialized for multiprocessing and distributed computations.

Metadata is accessible as a dictionary through the *info* property.

Table selectors, created using *chroms()*, *bins()*, and *pixels()*, perform range queries over table rows, returning `pd.DataFrame` and `pd.Series`.

A matrix selector, created using *matrix()*, performs 2D matrix range queries, returning `numpy.ndarray` or `scipy.sparse.coo_matrix`.

**\_\_init\_\_**(*store*, *root=None*, *\*\*kwargs*)

**Parameters**

- **store** (*str* | *Group*) –
- **root** (*str* | *None*) –

**bins**(*\*\*kwargs*)

Bin table selector

**Returns**

*Table selector*

**Return type**

*RangeSelectorID*

**property binsize:** *int* | *None*

Resolution in base pairs if uniform else None

**property chromnames:** *list[str]*

List of reference sequence names

**chroms**(*\*\*kwargs*)

Chromosome table selector

**Returns**

*Table selector*

**Return type**

*RangeSelectorID*

**property chromsizes:** *Series*

Ordered mapping of reference sequences to their lengths in bp

**extent**(*region*)

Bin IDs containing the left and right ends of a genomic region

**Parameters**

**region** (*str* or *tuple*) – Genomic range

**Returns**

*2-tuple of ints*

**Return type**

*tuple[int, int]*

## Examples

```
>>> c.extent('chr3')
(1311, 2131)
```

**property info:** *dict*

File information and metadata

**Returns**

*dict*

**matrix**(*field=None, balance=True, sparse=False, as\_pixels=False, join=False, ignore\_index=True, divisive\_weights=None, chunksize=10000000*)

Contact matrix selector

#### Parameters

- **field** (*str, optional*) – Which column of the pixel table to fill the matrix with. By default, the ‘count’ column is used.
- **balance** (*bool, optional*) – Whether to apply pre-calculated matrix balancing weights to the selection. Default is True and uses a column named ‘weight’. Alternatively, pass the name of the bin table column containing the desired balancing weights. Set to False to return untransformed counts.
- **sparse** (*bool, optional*) – Return a `scipy.sparse.coo_matrix` instead of a dense 2D numpy array.
- **as\_pixels** (*bool, optional*) – Return a DataFrame of the corresponding rows from the pixel table instead of a rectangular sparse matrix. False by default.
- **join** (*bool, optional*) – If requesting pixels, specifies whether to expand the bin ID columns into (chrom, start, end). Has no effect when requesting a rectangular matrix. Default is True.
- **ignore\_index** (*bool, optional*) – If requesting pixels, don’t populate the index column with the pixel IDs to improve performance. Default is True.
- **divisive\_weights** (*bool, optional*) – Force balancing weights to be interpreted as divisive (True) or multiplicative (False). Weights are always assumed to be multiplicative by default unless named KR, VC or SQRT\_VC, in which case they are assumed to be divisive by default.
- **chunksize** (*int*) –

#### Returns

*Matrix selector*

#### Return type

*RangeSelector2D*

#### Notes

If `as_pixels=True`, only data explicitly stored in the pixel table will be returned: if the cooler’s storage mode is symmetric-upper, lower triangular elements will not be generated. If `as_pixels=False`, those missing non-zero elements will automatically be filled in.

**offset**(*region*)

Bin ID containing the left end of a genomic region

#### Parameters

**region** (*str or tuple*) – Genomic range

#### Returns

*int*

#### Return type

*int*



## Examples

```
>>> c.offset('chr3')
1311
```

**open**(*mode='r', \*\*kwargs*)

Open the HDF5 group containing the Cooler with h5py

Functions as a context manager. Any `open_kws` passed during construction are ignored.

### Parameters

**mode** (*str*, *optional* [*default: 'r'*]) –

- 'r' (readonly)
- 'r+' or 'a' (read/write)

### Return type

*Group*

## Notes

For other parameters, see `h5py.File`.

**pixels**(*join=False, \*\*kwargs*)

Pixel table selector

### Parameters

**join** (*bool*, *optional*) – Whether to expand bin ID columns into chrom, start, and end columns. Default is `False`.

### Returns

*Table selector*

### Return type

*RangeSelector1D*

**property storage\_mode: str**

Indicates whether ordinary sparse matrix encoding is used ("`square`") or whether a symmetric matrix is encoded by storing only the upper triangular elements ("`symmetric-upper`").

**cooler.annotate**(*pixels, bins, replace=False*)

Add bin annotations to a data frame of pixels.

This is done by performing a relational “join” against the bin IDs of a table that describes properties of the genomic bins. New columns will be appended on the left of the output data frame.

Changed in version 0.8.0: The default value of `replace` changed to `False`.

### Parameters

- **pixels** (*DataFrame*) – A data frame containing columns named `bin1_id` and/or `bin2_id`. If columns `bin1_id` and `bin2_id` are both present in `pixels`, the adjoined columns will be suffixed with ‘1’ and ‘2’ accordingly.
- **bins** (*DataFrame* or *DataFrame selector*) – Data structure that contains a full description of the genomic bins of the contact matrix, where the index corresponds to bin IDs.
- **replace** (*bool*, *optional*) – Remove the original `bin1_id` and `bin2_id` columns from the output. Default is `False`.

**Returns**

DataFrame

**Return type**

DataFrame

```
cooler.create_cooler(cool_uri, bins, pixels, columns=None, dtypes=None, metadata=None, assembly=None,
                    ordered=False, symmetric_upper=True, mode='w', mergebuf=20000000,
                    delete_temp=True, temp_dir=None, max_merge=200, boundscheck=True,
                    dupcheck=True, triucheck=True, ensure_sorted=False, h5opts=None, lock=None)
```

Create a cooler from bins and pixels at the specified URI.

Because the number of pixels is often very large, the input pixels are normally provided as an iterable (e.g., an iterator or generator) of DataFrame **chunks** that fit in memory.

New in version 0.8.0.

**Parameters**

- **cool\_uri** (*str*) – Path to cooler file or URI string. If the file does not exist, it will be created.
- **bins** (*pandas.DataFrame*) – Segmentation of the chromosomes into genomic bins as a BED-like DataFrame with columns **chrom**, **start** and **end**. May contain additional columns.
- **pixels** (*DataFrame, dictionary, or iterable of either*) – A table, given as a dataframe or a column-oriented dict, containing columns labeled **bin1\_id**, **bin2\_id** and **count**, sorted by (**bin1\_id**, **bin2\_id**). If additional columns are included in the pixel table, their names and dtypes must be specified using the **columns** and **dtypes** arguments. For larger input data, an **iterable** can be provided that yields the pixel data as a sequence of chunks. If the input is a dask DataFrame, it will also be processed one chunk at a time.
- **columns** (*sequence of str, optional*) – Customize which value columns from the input pixels to store in the cooler. Non-standard value columns will be given dtype **float64** unless overridden using the **dtypes** argument. If **None**, we only attempt to store a value column named "count".
- **dtypes** (*dict, optional*) – Dictionary mapping column names to dtypes. Can be used to override the default dtypes of **bin1\_id**, **bin2\_id** or **count** or assign dtypes to custom value columns. Non-standard value columns given in **dtypes** must also be provided in the **columns** argument or they will be ignored.
- **metadata** (*dict, optional*) – Experiment metadata to store in the file. Must be JSON compatible.
- **assembly** (*str, optional*) – Name of genome assembly.
- **ordered** (*bool, optional [default: False]*) – If the input chunks of pixels are provided with correct triangularity and in ascending order of (**bin1\_id**, **bin2\_id**), set this to **True** to write the cooler in one step. If **False** (default), we create the cooler in two steps using an external sort mechanism. See Notes for more details.
- **symmetric\_upper** (*bool, optional [default: True]*) – If **True**, sets the file's storage-mode property to **symmetric-upper**: use this only if the input data references the upper triangle of a symmetric matrix! For all other cases, set this option to **False**.
- **mode** (*{'w', 'a'}, optional [default: 'w']*) – Write mode for the output file. 'a': if the output file exists, append the new cooler to it. 'w': if the output file exists, it will be truncated. Default is 'w'.

- **mergebuf** (*int, optional*) – Maximum number of records to buffer in memory at any give time during the merge step.
- **delete\_temp** (*bool, optional*) – Whether to delete temporary files when finished. Useful for debugging. Default is False.
- **temp\_dir** (*str, optional*) – Create temporary files in a specified directory instead of the same directory as the output file. Pass - to use the system default.
- **max\_merge** (*int, optional*) – If merging more than max\_merge chunks, do the merge recursively in two passes.
- **h5opts** (*dict, optional*) – HDF5 dataset filter options to use (compression, shuffling, checksumming, etc.). Default is to use autochunking and GZIP compression, level 6.
- **lock** (*multiprocessing.Lock, optional*) – Optional lock to control concurrent access to the output file.
- **ensure\_sorted** (*bool, optional*) – Ensure that each input chunk is properly sorted.
- **boundscheck** (*bool, optional*) – Input validation: Check that all bin IDs lie in the expected range.
- **dupcheck** (*bool, optional*) – Input validation: Check that no duplicate pixels exist within any chunk.
- **triucheck** (*bool, optional*) – Input validation: Check that bin1\_id <= bin2\_id when creating coolers in symmetric-upper mode.

**Return type**

None

**See also:**[\*cooler.create\\_scool\*](#), [\*cooler.create.sanitize\\_records\*](#), [\*cooler.create.sanitize\\_pixels\*](#)**Notes**

If the pixel chunks are provided in the correct order required for the output to be properly sorted, then the cooler can be created in a single step by setting `ordered=True`.

If not, the cooler is created in two steps via an external sort mechanism. In the first pass, the sequence of pixel chunks are processed and sorted in memory and saved to temporary coolers. In the second pass, the temporary coolers are merged into the output file. This way the individual chunks do not need to be provided in any particular order. When `ordered=False`, the following options for the merge step are available: `mergebuf`, `delete_temp`, `temp_dir`, `max_merge`.

Each chunk of pixels will go through a validation pipeline, which can be customized with the following options: `boundscheck`, `triucheck`, `dupcheck`, `ensure_sorted`.

`cooler.merge_coolers(output_uri, input_uris, mergebuf, columns=None, dtypes=None, agg=None, **kwargs)`

Merge multiple coolers with identical axes.

The merged cooler is stored at `output_uri`.

New in version 0.8.0.

**Parameters**

- **output\_uri** (*str*) – Output cooler file path or URI.
- **input\_uris** (*list of str*) – List of input file path or URIs of coolers to combine.

- **mergebuf** (*int*) – Maximum number of pixels processed at a time.
- **columns** (*list of str, optional*) – Specify which pixel value columns to include in the aggregation. Default is to use all available value columns.
- **dtypes** (*dict, optional*) – Specific dtypes to use for value columns. Default is to propagate the current dtypes of the value columns.
- **agg** (*dict, optional*) – Functions to use for aggregating each value column. Pass the same kind of dict accepted by `pandas.DataFrame.groupby.agg`. Default is to apply ‘sum’ to every value column.
- **kwargs** – Passed to `cooler.create`.

**Return type**

None

**Notes**

The default output file mode is ‘w’. If appending output to an existing file, pass *mode*='a'.

**See also:**

[`cooler.coarsen\_cooler`](#), [`cooler.zoomify\_cooler`](#)

`cooler.coarsen_cooler`(*base\_uri, output\_uri, factor, chunksize, nproc=1, columns=None, dtypes=None, agg=None, \*\*kwargs*)

Coarsen a cooler to a lower resolution by an integer factor *k*.

This is done by pooling *k*-by-*k* neighborhoods of pixels and aggregating. Each chromosomal block is coarsened individually. Result is a coarsened cooler stored at *output\_uri*.

New in version 0.8.0.

**Parameters**

- **base\_uri** (*str*) – Input cooler file path or URI.
- **output\_uri** (*str*) – Input cooler file path or URI.
- **factor** (*int*) – Coarsening factor.
- **chunksize** (*int*) – Number of pixels processed at a time per worker.
- **nproc** (*int, optional*) – Number of workers for batch processing of pixels. Default is 1, i.e. no process pool.
- **columns** (*list of str, optional*) – Specify which pixel value columns to include in the aggregation. Default is to use all available value columns.
- **dtypes** (*dict, optional*) – Specific dtypes to use for value columns. Default is to propagate the current dtypes of the value columns.
- **agg** (*dict, optional*) – Functions to use for aggregating each value column. Pass the same kind of dict accepted by `pandas.DataFrame.groupby.agg`. Default is to apply ‘sum’ to every value column.
- **kwargs** – Passed to `cooler.create`.

**Return type**

None

See also:

[`cooler.zoomify\_cooler`](#), [`cooler.merge\_coolers`](#)

`cooler.zoomify_cooler`(*base\_uris*, *outfile*, *resolutions*, *chunksize*, *nproc*=1, *columns*=None, *dtypes*=None, *agg*=None, *\*\*kwargs*)

Generate multiple cooler resolutions by recursive coarsening.

Result is a “zoomified” or “multires” cool file stored at *outfile* using the MCOOL v2 layout, where coolers are stored under a hierarchy of the form *resolutions*/*r* for each resolution *r*.

New in version 0.8.0.

#### Parameters

- **base\_uris** (*str* or *sequence of str*) – One or more cooler URIs to use as “base resolutions” for aggregation.
- **outfile** (*str*) – Output multires cooler (mcool) file path.
- **resolutions** (*list of int*) – A list of target resolutions to generate.
- **chunksize** (*int*) – Number of pixels processed at a time per worker.
- **nproc** (*int*, *optional*) – Number of workers for batch processing of pixels. Default is 1, i.e. no process pool.
- **columns** (*list of str*, *optional*) – Specify which pixel value columns to include in the aggregation. Default is to use only the column named ‘count’ if it exists.
- **dtypes** (*dict*, *optional*) – Specific dtypes to use for value columns. Default is to propagate the current dtypes of the value columns.
- **agg** (*dict*, *optional*) – Functions to use for aggregating each value column. Pass the same kind of dict accepted by `pandas.DataFrame.groupby.agg`. Default is to apply ‘sum’ to every value column.
- **kwargs** – Passed to `cooler.create`.

#### Return type

None

See also:

[`cooler.coarsen\_cooler`](#), [`cooler.merge\_coolers`](#)

`cooler.balance_cooler`(*clr*, *\**, *cis\_only*=False, *trans\_only*=False, *ignore\_diags*=2, *mad\_max*=5, *min\_nnz*=10, *min\_count*=0, *blacklist*=None, *rescale\_marginals*=True, *x0*=None, *tol*=1e-05, *max\_iters*=200, *chunksize*=10000000, *map*=<class ‘map’>, *use\_lock*=False, *store*=False, *store\_name*=‘weight’)

Iterative correction or matrix balancing of a sparse Hi-C contact map in Cooler HDF5 format.

#### Parameters

- **clr** (`cooler.Cooler`) – Cooler object
- **cis\_only** (*bool*, *optional*) – Do iterative correction on intra-chromosomal data only. Inter-chromosomal data is ignored.
- **trans\_only** (*bool*, *optional*) – Do iterative correction on inter-chromosomal data only. Intra-chromosomal data is ignored.
- **ignore\_diags** (*int* or *False*, *optional*) – Drop elements occurring on the first *ignore\_diags* diagonals of the matrix (including the main diagonal).

- **chunksize** (*int or None, optional*) – Split the contact matrix pixel records into equally sized chunks to save memory and/or parallelize. Set to *None* to use all the pixels at once.
- **mad\_max** (*int, optional*) – Pre-processing bin-level filter. Drop bins whose log marginal sum is less than **mad\_max** median absolute deviations below the median log marginal sum.
- **min\_nnz** (*int, optional*) – Pre-processing bin-level filter. Drop bins with fewer nonzero elements than this value.
- **min\_count** (*int, optional*) – Pre-processing bin-level filter. Drop bins with lower marginal sum than this value.
- **blacklist** (*list or 1D array, optional*) – An explicit list of IDs of bad bins to filter out when performing balancing.
- **rescale\_marginals** (*bool, optional*) – Normalize the balancing weights such that the balanced matrix has rows / columns that sum to 1.0. The scale factor is stored in the **stats** output dictionary.
- **map** (*callable, optional*) – Map function to dispatch the matrix chunks to workers. Default is the builtin **map**, but alternatives include parallel map implementations from a multi-processing pool.
- **x0** (*1D array, optional*) – Initial weight vector to use. Default is to start with **ones(n\_bins)**.
- **tol** (*float, optional*) – Convergence criterion is the variance of the marginal (row/col) sum vector.
- **max\_iters** (*int, optional*) – Iteration limit.
- **store** (*bool, optional*) – Whether to store the results in the file when finished. Default is *False*.
- **store\_name** (*str, optional*) – Name of the column of the bin table to save to. Default name is ‘weight’.
- **use\_lock** (*bool*) –

#### Returns

- **bias** (1D array, whose shape is the number of bins in **h5**.) – Vector of bin bias weights to normalize the observed contact map. Dropped bins will be assigned the value **NaN**.  $N[i, j] = O[i, j] * bias[i] * bias[j]$
- **stats** (*dict*) – Summary of parameters used to perform balancing and the average magnitude of the corrected matrix’s marginal sum at convergence.

#### Return type

tuple[ndarray, dict]

**cooler.rename\_chroms**(*clr, rename\_dict, h5opts=None*)

Substitute existing chromosome/contig names for new ones. They will be written to the file and the Cooler object will be refreshed.

#### Parameters

- **clr** (**Cooler**) – Cooler object that can be opened with write permissions.
- **rename\_dict** (*dict*) – Dictionary of old -> new chromosome names. Any names omitted from the dictionary will be kept as is.
- **h5opts** (*dict, optional*) – HDF5 filter options.

**Return type**

None

`cooler.create_scool(cool_uri, bins, cell_name_pixels_dict, columns=None, dtypes=None, metadata=None, assembly=None, ordered=False, symmetric_upper=True, mode='w', mergebuf=20000000, delete_temp=True, temp_dir=None, max_merge=200, boundscheck=True, dupcheck=True, triucheck=True, ensure_sorted=False, h5opts=None, lock=None, **kwargs)`

Create a single-cell (scool) file.

For each cell store a cooler matrix under `/cells`, where all matrices have the same dimensions.

Each cell is a regular cooler data collection, so the input must be a bin table and pixel table for each cell. The pixel tables are provided as a dictionary where the key is a unique cell name. The bin tables can be provided as a dict with the same keys or a single common bin table can be given.

New in version 0.8.9.

**Parameters**

- **cool\_uri** (*str*) – Path to scool file or URI string. If the file does not exist, it will be created.
- **bins** (*pandas.DataFrame* or *Dict[str, DataFrame]*) – A single bin table or dictionary of cell names to bins tables. A bin table is a dataframe with columns `chrom`, `start` and `end`. May contain additional columns.
- **cell\_name\_pixels\_dict** (*Dict[str, DataFrame]*) – Cell name as key and pixel table *DataFrame* as value. A table, given as a dataframe or a column-oriented dict, containing columns labeled `bin1_id`, `bin2_id` and `count`, sorted by (`bin1_id`, `bin2_id`). If additional columns are included in the pixel table, their names and dtypes must be specified using the `columns` and `dtypes` arguments. For larger input data, an **iterable** can be provided that yields the pixel data as a sequence of chunks. If the input is a dask *DataFrame*, it will also be processed one chunk at a time.
- **columns** (*sequence of str, optional*) – Customize which value columns from the input pixels to store in the cooler. Non-standard value columns will be given dtype `float64` unless overridden using the `dtypes` argument. If `None`, we only attempt to store a value column named "count".
- **dtypes** (*dict, optional*) – Dictionary mapping column names to dtypes. Can be used to override the default dtypes of `bin1_id`, `bin2_id` or `count` or assign dtypes to custom value columns. Non-standard value columns given in `dtypes` must also be provided in the `columns` argument or they will be ignored.
- **metadata** (*dict, optional*) – Experiment metadata to store in the file. Must be JSON compatible.
- **assembly** (*str, optional*) – Name of genome assembly.
- **ordered** (*bool, optional [default: False]*) – If the input chunks of pixels are provided with correct triangularity and in ascending order of (`bin1_id`, `bin2_id`), set this to `True` to write the cooler in one step. If `False` (default), we create the cooler in two steps using an external sort mechanism. See Notes for more details.
- **symmetric\_upper** (*bool, optional [default: True]*) – If `True`, sets the file's storage-mode property to `symmetric-upper`: use this only if the input data references the upper triangle of a symmetric matrix! For all other cases, set this option to `False`.
- **mode** (*{'w', 'a'}, optional [default: 'w']*) – Write mode for the output file. 'a': if the output file exists, append the new cooler to it. 'w': if the output file exists, it will be truncated. Default is 'w'.

- **mergebuf** (*int*, *optional*) – Maximum number of records to buffer in memory at any give time during the merge step.
- **delete\_temp** (*bool*, *optional*) – Whether to delete temporary files when finished. Useful for debugging. Default is False.
- **temp\_dir** (*str*, *optional*) – Create temporary files in a specified directory instead of the same directory as the output file. Pass - to use the system default.
- **max\_merge** (*int*, *optional*) – If merging more than `max_merge` chunks, do the merge recursively in two passes.
- **h5opts** (*dict*, *optional*) – HDF5 dataset filter options to use (compression, shuffling, checksumming, etc.). Default is to use autochunking and GZIP compression, level 6.
- **lock** (*multiprocessing.Lock*, *optional*) – Optional lock to control concurrent access to the output file.
- **ensure\_sorted** (*bool*, *optional*) – Ensure that each input chunk is properly sorted.
- **boundscheck** (*bool*, *optional*) – Input validation: Check that all bin IDs lie in the expected range.
- **dupcheck** (*bool*, *optional*) – Input validation: Check that no duplicate pixels exist within any chunk.
- **triucheck** (*bool*, *optional*) – Input validation: Check that `bin1_id <= bin2_id` when creating coolers in symmetric-upper mode.

**Return type**

None

**See also:**[`cooler.create\_cooler`](#), [`cooler.zoomify\_cooler`](#)**Notes**

If the pixel chunks are provided in the correct order required for the output to be properly sorted, then the cooler can be created in a single step by setting `ordered=True`.

If not, the cooler is created in two steps via an external sort mechanism. In the first pass, the sequence of pixel chunks are processed and sorted in memory and saved to temporary coolers. In the second pass, the temporary coolers are merged into the output file. This way the individual chunks do not need to be provided in any particular order. When `ordered=False`, the following options for the merge step are available: `mergebuf`, `delete_temp`, `temp_dir`, `max_merge`.

Each chunk of pixels will go through a validation pipeline, which can be customized with the following options: `boundscheck`, `triucheck`, `dupcheck`, `ensure_sorted`.



## 5.3 cooler.create

`cooler.create.sanitize_pixels(bins, **kwargs)`

Builds a function to sanitize an already-binned genomic data with genomic bin assignments.

### Parameters

- **bins** (*DataFrame*) – Bin table to compare pixel records against.
- **is\_one\_based** (*bool*, *optional*) – Whether the input bin IDs are one-based, rather than zero-based. They will be converted to zero-based.
- **tril\_action** (*'reflect'*, *'drop'*, *'raise'* or *None*) – How to handle lower triangle (“tril”) pixels. If set to ‘reflect’ [default], tril pixels will be flipped or “reflected” to their mirror image: “sided” column pairs will have their values swapped. If set to ‘drop’, tril pixels will be discarded. This is useful if your input data is duplexed, i.e. contains mirror duplicates of every record. If set to ‘raise’, an exception will be raised if any tril record is encountered.
- **bin1\_field** (*str*) – Name of the column representing ith (row) axis of the matrix. Default is ‘bin1\_id’.
- **bin2\_field** (*str*) – Name of the column representing jth (col) axis of the matrix. Default is ‘bin2\_id’.
- **sided\_fields** (*sequence of str*) – Base names of column pairs to swap values between when mirror-reflecting pixels.
- **suffixes** (*pair of str*) – Suffixes used to identify pairs of sided columns. e.g.: (‘1’, ‘2’), (‘\_x’, ‘\_y’), etc.
- **sort** (*bool*) – Whether to sort the output dataframe by bin\_id and bin2\_id.

### Returns

*callable* – Function of one argument that takes a raw dataframe and returns a sanitized dataframe.

### Return type

*Callable[[Dataframe], DataFrame]*

`cooler.create.sanitize_records(bins, schema=None, **kwargs)`

Builds a function to sanitize and assign bin IDs to a data frame of paired genomic positions based on a provided genomic bin segmentation.

### Parameters

- **bins** (*DataFrame*) – Bin table to compare records against.
- **schema** (*str*, *optional*) – Use pre-defined parameters for a particular format. Any options can be overridden via kwargs. If not provided, values for all the options below must be given.
- **decode\_chroms** (*bool*) – Convert string chromosome names to integer IDs based on the order given in the bin table. Set to False if the chromosomes are already given as an enumeration, starting at 0. Records with either chrom ID < 0 are dropped.
- **is\_one\_based** (*bool*) – Whether the input anchor coordinates are one-based, rather than zero-based. They will be converted to zero-based.
- **tril\_action** (*'reflect'*, *'drop'*, *'raise'* or *None*) – How to handle lower triangle (“tril”) records. If set to ‘reflect’, tril records will be flipped or “reflected” to their mirror image: “sided” column pairs will have their values swapped. If set to ‘drop’, tril records will

be discarded. This is useful if your input data is symmetric, i.e. contains mirror duplicates of every record. If set to 'raise', an exception will be raised if any tril record is encountered.

- **chrom\_field** (*str*) – Base name of the two chromosome/scaffold/contig columns.
- **anchor\_field** (*str*) – Base name of the positional anchor columns.
- **sided\_fields** (*sequence of str*) – Base names of column pairs to swap values between when mirror-reflecting records.
- **suffixes** (*pair of str*) – Suffixes used to identify pairs of sided columns. e.g.: ('1', '2'), ('\_x', '\_y'), etc.
- **sort** (*bool*) – Whether to sort the output dataframe by bin\_id and bin2\_id.
- **validate** (*bool*) – Whether to do type- and bounds-checking on the anchor position columns. Raises `BadInputError`.

**Returns**

*callable* – Function of one argument that takes a raw dataframe and returns a sanitized dataframe with bin IDs assigned.

**Return type**

*Callable[[DataFrame], DataFrame]*

## 5.4 cooler.fileops

`cooler.fileops.is_cooler(uri)`

Determine if a URI string references a cooler data collection. Returns False if the file or group path doesn't exist.

**Parameters**

**uri** (*str*) –

**Return type**

*bool*

`cooler.fileops.is_multires_file(filepath, min_version=1)`

Determine if a file is a multi-res cooler file. Returns False if the file doesn't exist.

**Parameters**

- **filepath** (*str*) –
- **min\_version** (*int*) –

**Return type**

*bool*

`cooler.fileops.list_coolers(filepath)`

List group paths to all cooler data collections in a file.

**Parameters**

**filepath** (*str*) –

**Returns**

*list* – Cooler group paths in the file.

**Return type**

*list[str]*

`cooler.fileops.cp(src_uri, dst_uri, overwrite=False)`

Copy a group or dataset from one file to another or within the same file.

**Parameters**

- **src\_uri** (*str*) –
- **dst\_uri** (*str*) –
- **overwrite** (*bool*) –

**Return type**

None

`cooler.fileops.mv(src_uri, dst_uri, overwrite=False)`

Rename a group or dataset within the same file.

**Parameters**

- **src\_uri** (*str*) –
- **dst\_uri** (*str*) –
- **overwrite** (*bool*) –

**Return type**

None

`cooler.fileops.ln(src_uri, dst_uri, soft=False, overwrite=False)`

Create a hard link to a group or dataset in the same file. Also supports soft links (in the same file) or external links (different files).

**Parameters**

- **src\_uri** (*str*) –
- **dst\_uri** (*str*) –
- **soft** (*bool*) –
- **overwrite** (*bool*) –

**Return type**

None

## 5.5 cooler.util

`cooler.util.partition(start, stop, step)`

Partition an integer interval into equally-sized subintervals. Like builtin `range()`, but yields pairs of end points.

## Examples

```
>>> for lo, hi in partition(0, 9, 2):
    print(lo, hi)
0 2
2 4
4 6
6 8
8 9
```

### Parameters

- **start** (*int*) –
- **stop** (*int*) –
- **step** (*int*) –

### Return type

*Iterator[tuple[int, int]]*

`cooler.util.fetch_chromsizes(db, **kwargs)`

Download chromosome sizes from UCSC as a `pandas.Series`, indexed by chromosome label.

### Parameters

**db** (*str*) –

### Return type

*Series*

`cooler.util.read_chromsizes(filepath_or, name_patterns=('^chr[0-9]+$' , '^chr[XY]$', '^chrM$'),  
all_names=False, **kwargs)`

Parse a `<db>.chrom.sizes` or `<db>.chromInfo.txt` file from the UCSC database, where `db` is a genome assembly name.

### Parameters

- **filepath\_or** (*str* or *file-like*) – Path or url to text file, or buffer.
- **name\_patterns** (*sequence*, *optional*) – Sequence of regular expressions to capture desired sequence names. Each corresponding set of records will be sorted in natural order.
- **all\_names** (*bool*, *optional*) – Whether to return all contigs listed in the file. Default is `False`.

### Returns

`pandas.Series` – Series of integer bp lengths indexed by sequence name.

### Return type

*Series*

## References

- [UCSC assembly terminology](#)
- [GRC assembly terminology](#)

`cooler.util.binnify(chromsizes, binsize)`

Divide a genome into evenly sized bins.

### Parameters

- **chromsizes** (*Series*) – pandas Series indexed by chromosome name with chromosome lengths in bp.
- **binsize** (*int*) – size of bins in bp

### Returns

**bins** (`pandas.DataFrame`) – Dataframe with columns: chrom, start, end.

### Return type

*DataFrame*

`cooler.util.digest(fasta_records, enzyme)`

Divide a genome into restriction fragments.

### Parameters

- **fasta\_records** (*OrderedDict*) – Dictionary of chromosome names to sequence records.
- **enzyme** (*str*) – Name of restriction enzyme (e.g., ‘DpnII’).

### Returns

**frags** (`pandas.DataFrame`) – Dataframe with columns: chrom, start, end.

### Return type

*DataFrame*



## CLI REFERENCE

### 6.1 Quick reference

```
cooler [OPTIONS] COMMAND [ARGS]...
```

#### Data ingest

<i>cooler cload</i>	Create a cooler from genomic point pairs and bins.
<i>cooler load</i>	Create a cooler from a pre-binned matrix.

#### Reduction

<i>cooler merge</i>	Merge multiple coolers with identical axes.
<i>cooler coarsen</i>	Coarsen a cooler to a lower resolution.
<i>cooler zoomify</i>	Generate a multi-resolution cooler file by coarsening.

#### Normalization

<i>cooler balance</i>	Out-of-core matrix balancing.
-----------------------	-------------------------------

#### Ex- port/visualization

<i>cooler info</i>	Display a cooler's info and metadata.
<i>cooler dump</i>	Dump a cooler's data to a text stream.
<i>cooler show</i>	Display and browse a cooler with matplotlib.

#### File manipula- tion/info

<i>cooler tree</i>	Display a file's data hierarchy.
<i>cooler attrs</i>	Display a file's attribute hierarchy.
<i>cooler ls</i>	List all coolers inside a file.
<i>cooler cp</i>	Copy a cooler from one file to another or within the same file.
<i>cooler mv</i>	Rename a cooler within the same file.
<i>cooler ln</i>	Create a hard, soft or external link to a cooler.

Helper commands	
<i>cooler makebins</i>	Generate fixed-width genomic bins.
<i>cooler digest</i>	Generate fragment-delimited genomic bins.
<i>cooler csort</i>	Sort and index a contact list.

## Options

**-v, --verbose**

Verbose logging.

**-d, --debug**

On error, drop into the post-mortem debugger shell.

**-V, --version**

Show the version and exit.

See the cooler\_cli.ipynb Jupyter Notebook for specific examples on usage: (<https://github.com/open2c/cooler-binder>).

---

## 6.2 cooler cload

Create a cooler from genomic pairs and bins.

Choose a subcommand based on the format of the input contact list.

```
cooler cload [OPTIONS] COMMAND [ARGS]...
```

### Commands

• **hiclib**                      • **pairix**                      • **pairs**                      • **tabix**

---

## 6.3 cooler cload pairs

Bin any text file or stream of pairs.

Pairs data need not be sorted. Accepts compressed files. To pipe input from stdin, set PAIRS\_PATH to '-'.

BINS : One of the following

<TEXT:INTEGER> : 1. Path to a chromsizes file, 2. Bin size in bp

<TEXT> : Path to BED file defining the genomic bin segmentation.

PAIRS\_PATH : Path to contacts (i.e. read pairs) file.

COOL\_PATH : Output COOL file path or URI.



```
cooler cload pairs [OPTIONS] BINS PAIRS_PATH COOL_PATH
```

## Arguments

### BINS

Required argument

### PAIRS\_PATH

Required argument

### COOL\_PATH

Required argument

## Options

**--metadata** <metadata>

Path to JSON file containing user metadata.

**--assembly** <assembly>

Name of genome assembly (e.g. hg19, mm10)

**-c1, --chrom1** <chrom1>

chrom1 field number (one-based) [required]

**-p1, --pos1** <pos1>

pos1 field number (one-based) [required]

**-c2, --chrom2** <chrom2>

chrom2 field number (one-based) [required]

**-p2, --pos2** <pos2>

pos2 field number (one-based) [required]

**--chunksize** <chunksize>

Number of input lines to load at a time

**-0, --zero-based**

Positions are zero-based [default: False]

**--comment-char** <comment\_char>

Comment character that indicates lines to ignore. [default: #]

**-N, --no-symmetric-upper**

Create a complete square matrix without implicit symmetry. This allows for distinct upper- and lower-triangle values

**--input-copy-status** <input\_copy\_status>

Copy status of input data when using symmetric-upper storage. | *unique*: Incoming data comes from a unique half of a symmetric map, regardless of how the coordinates of a pair are ordered. *duplex*: Incoming data contains upper- and lower-triangle duplicates. All input records that map to the lower triangle will be discarded! | If you wish to treat lower- and upper-triangle input data as distinct, use the **--no-symmetric-upper** option. [default: unique]

**--field <field>**

Specify quantitative input fields to aggregate into value columns using the syntax `--field <field-name>=<field-number>`. Optionally, append `:` followed by `dtype=<dtype>` to specify the data type (e.g. float), and/or `agg=<agg>` to specify an aggregation function different from sum (e.g. mean). Field numbers are 1-based. Passing 'count' as the target name will override the default behavior of storing pair counts. Repeat the `--field` option for each additional field.

**--temp-dir <temp\_dir>**

Create temporary files in a specified directory. Pass `-` to use the platform default temp dir.

**--no-delete-temp**

Do not delete temporary files when finished.

**--max-merge <max\_merge>**

Maximum number of chunks to merge before invoking recursive merging [default: 200]

**--storage-options <storage\_options>**

Options to modify the data filter pipeline. Provide as a comma-separated list of key-value pairs of the form 'k1=v1,k2=v2,...'. See <http://docs.h5py.org/en/stable/high/dataset.html#filter-pipeline> for more details.

**-a, --append**

Pass this flag to append the output cooler to an existing file instead of overwriting the file.

---

## 6.4 cooler cload pairix

Bin a pairix-indexed contact list file.

BINS : One of the following

`<TEXT:INTEGER>` : 1. Path to a chromsizes file, 2. Bin size in bp

`<TEXT>` : Path to BED file defining the genomic bin segmentation.

PAIRS\_PATH : Path to contacts (i.e. read pairs) file.

COOL\_PATH : Output COOL file path or URI.

See also: 'cooler csort' to sort and index a contact list file

Pairix on GitHub: <https://github.com/4dn-dcic/pairix>.

`cooler cload pairix [OPTIONS] BINS PAIRS_PATH COOL_PATH`

### Arguments

**BINS**

Required argument

**PAIRS\_PATH**

Required argument

**COOL\_PATH**

Required argument

## Options

- metadata** <metadata>  
Path to JSON file containing user metadata.
- assembly** <assembly>  
Name of genome assembly (e.g. hg19, mm10)
- p, --nproc** <nproc>  
Number of processes to split the work between. [default: 8]
- 0, --zero-based**  
Positions are zero-based [default: False]
- s, --max-split** <max\_split>  
Divide the pairs from each chromosome into at most this many chunks. Smaller chromosomes will be split less frequently or not at all. Increase this value if large chromosomes dominate the workload on multiple processors. [default: 2]

## 6.5 cooler cload tabix

Bin a tabix-indexed contact list file.

**BINS** : One of the following

<TEXT:INTEGER> : 1. Path to a chromsizes file, 2. Bin size in bp

<TEXT> : Path to BED file defining the genomic bin segmentation.

**PAIRS\_PATH** : Path to contacts (i.e. read pairs) file.

**COOL\_PATH** : Output COOL file path or URI.

See also: ‘cooler csort’ to sort and index a contact list file

Tabix manpage: <<http://www.htslib.org/doc/tabix.html>>.

```
cooler cload tabix [OPTIONS] BINS PAIRS_PATH COOL_PATH
```

## Arguments

### **BINS**

Required argument

### **PAIRS\_PATH**

Required argument

### **COOL\_PATH**

Required argument

## Options

- metadata** <metadata>  
Path to JSON file containing user metadata.
- assembly** <assembly>  
Name of genome assembly (e.g. hg19, mm10)
- p, --nproc** <nproc>  
Number of processes to split the work between. [default: 8]
- c2, --chrom2** <chrom2>  
chrom2 field number (one-based)
- p2, --pos2** <pos2>  
pos2 field number (one-based)
- 0, --zero-based**  
Positions are zero-based [default: False]
- s, --max-split** <max\_split>  
Divide the pairs from each chromosome into at most this many chunks. Smaller chromosomes will be split less frequently or not at all. Increase this value if large chromosomes dominate the workload on multiple processors. [default: 2]
- 

## 6.6 cooler cload hiclib

Bin a hiclib HDF5 contact list (frag) file.

BINS : One of the following

<TEXT:INTEGER> : 1. Path to a chromsizes file, 2. Bin size in bp

<TEXT> : Path to BED file defining the genomic bin segmentation.

PAIRS\_PATH : Path to contacts (i.e. read pairs) file.

COOL\_PATH : Output COOL file path or URI.

hiclib on BitBucket: <<https://github.com/mirnylab/hiclib-legacy>>.

cooler cload hiclib [OPTIONS] BINS PAIRS\_PATH COOL\_PATH

## Arguments

### BINS

Required argument

### PAIRS\_PATH

Required argument

### COOL\_PATH

Required argument

## Options

- metadata** <metadata>  
Path to JSON file containing user metadata.
- assembly** <assembly>  
Name of genome assembly (e.g. hg19, mm10)
- c, --chunksize** <chunksize>  
Control the number of pixels handled by each worker process at a time. [default: 100000000]

## 6.7 cooler load

Create a cooler from a pre-binned matrix.

**BINS\_PATH** : One of the following

<TEXT:INTEGER> : 1. Path to a chromsizes file, 2. Bin size in bp

<TEXT> : Path to BED file defining the genomic bin segmentation.

**PIXELS\_PATH** : Text file containing nonzero pixel values. May be gzipped. Pass '-' to use stdin.

**COOL\_PATH** : Output COOL file path or URI.

### Notes

Two input format options (tab-delimited). Input pixel file may be compressed.

COO: COO-rdinate sparse matrix format (a.k.a. ijk triple). 3 columns: "bin1\_id, bin2\_id, count",

BG2: 2D version of the bedGraph format. 7 columns: "chrom1, start1, end1, chrom2, start2, end2, count"

### Examples

```
cooler load -f bg2 <chrom.sizes>:<binsize> in.bg2.gz out.cool
```

```
cooler load [OPTIONS] BINS_PATH PIXELS_PATH COOL_PATH
```

## Arguments

### **BINS\_PATH**

Required argument

### **PIXELS\_PATH**

Required argument

### **COOL\_PATH**

Required argument

## Options

**-f, --format** <format>

‘coo’ refers to a tab-delimited sparse triplet file (bin1, bin2, count). ‘bg2’ refers to a 2D bedGraph-like file (chrom1, start1, end1, chrom2, start2, end2, count). [required]

**--metadata** <metadata>

Path to JSON file containing user metadata.

**--assembly** <assembly>

Name of genome assembly (e.g. hg19, mm10)

**--field** <field>

Add supplemental value fields or override default field numbers for the specified format. Specify quantitative input fields to aggregate into value columns using the syntax **--field** <field-name>=<field-number>. Optionally, append **:** followed by **dtype=<dtype>** to specify the data type (e.g. float). Field numbers are 1-based. Repeat the **--field** option for each additional field.

**-c, --chunksize** <chunksize>

Size (in number of lines/records) of data chunks to read and process from the input file at a time. These chunks will be saved as temporary partial Coolers and merged at the end. Also specifies the size of the buffer during the merge step.

**--count-as-float**

Store the ‘count’ column as floating point values instead of as integers. Can also be specified using the *-field* option.

**--one-based**

Pass this flag if the bin IDs listed in a COO file are one-based instead of zero-based.

**--comment-char** <comment\_char>

Comment character that indicates lines to ignore. [default: #]

**-N, --no-symmetric-upper**

Create a complete square matrix without implicit symmetry. This allows for distinct upper- and lower-triangle values

**--input-copy-status** <input\_copy\_status>

Copy status of input data when using symmetric-upper storage. | *unique*: Incoming data comes from a unique half of a symmetric matrix, regardless of how element coordinates are ordered. Execution will be aborted if duplicates are detected. | *duplex*: Incoming data contains upper- and lower-triangle duplicates. All lower-triangle input elements will be discarded! | If you wish to treat lower- and upper-triangle input data as distinct, use the **--no-symmetric-upper** option instead. [default: unique]

**--temp-dir** <temp\_dir>

Create temporary files in a specified directory. Pass **-** to use the platform default temp dir.

**--no-delete-temp**

Do not delete temporary files when finished.

**--storage-options** <storage\_options>

Options to modify the data filter pipeline. Provide as a comma-separated list of key-value pairs of the form ‘k1=v1,k2=v2,...’. See <http://docs.h5py.org/en/stable/high/dataset.html#filter-pipeline> for more details.

**-a, --append**

Pass this flag to append the output cooler to an existing file instead of overwriting the file.

## 6.8 cooler merge

Merge multiple coolers with identical axes.

**OUT\_PATH** : Output file path or URI.

**IN\_PATHS** : Input file paths or URIs of coolers to merge.

### Notes

Data columns merged:

pixels/bin1\_id, pixels/bin2\_id, pixels/<value columns>

Data columns preserved:

chroms/name, chroms/length bins/chrom, bins/start, bins/end

Additional columns in the the input files are not transferred to the output.

```
cooler merge [OPTIONS] OUT_PATH [IN_PATHS]...
```

### Arguments

#### OUT\_PATH

Required argument

#### IN\_PATHS

Optional argument(s)

### Options

**-c, --chunksize <chunksize>**

Size of the merge buffer in number of pixel table rows. [default: 20000000]

**--field <field>**

Specify the names of value columns to merge as '<name>'. Repeat the *--field* option for each one. Use '<name>,dtype=<dtype>' to specify the dtype. Include 'agg=<agg>' to specify an aggregation function different from 'sum'.

**-a, --append**

Pass this flag to append the output cooler to an existing file instead of overwriting the file.

## 6.9 cooler coarsen

Coarsen a cooler to a lower resolution.

Works by pooling *k*-by-*k* neighborhoods of pixels and aggregating. Each chromosomal block is coarsened individually.

**COOL\_PATH** : Path to a COOL file or Cooler URI.

```
cooler coarsen [OPTIONS] COOL_PATH
```

## Arguments

### COOL\_PATH

Required argument

## Options

**-k, --factor <factor>**

Gridding factor. The contact matrix is coarsegrained by grouping each chromosomal contact block into k-by-k element tiles [default: 2]

**-n, -p, --nproc <nproc>**

Number of processes to use for batch processing chunks of pixels [default: 1, i.e. no process pool]

**-c, --chunksize <chunksize>**

Number of pixels allocated to each process [default: 10000000]

**--field <field>**

Specify the names of value columns to merge as '*<name>*'. Repeat the *--field* option for each one. Use '*<name>*,dtype=*<dtype>*' to specify the dtype. Include '*,agg=<agg>*' to specify an aggregation function different from 'sum'.

**-o, --out <out>**

Output file or URI [required]

**-a, --append**

Pass this flag to append the output cooler to an existing file instead of overwriting the file.

---

## 6.10 cooler zoomify

Generate a multi-resolution cooler file by coarsening.

COOL\_PATH : Path to a COOL file or Cooler URI.

```
cooler zoomify [OPTIONS] COOL_PATH
```

## Arguments

### COOL\_PATH

Required argument



## Options

**-n, -p, --nproc <nproc>**

Number of processes to use for batch processing chunks of pixels [default: 1, i.e. no process pool]

**-c, --chunksize <chunksize>**

Number of pixels allocated to each process [default: 10000000]

**-r, --resolutions <resolutions>**

Comma-separated list of target resolutions. Use suffixes B or N to specify a progression: B for binary (geometric steps of factor 2), N for nice (geometric steps of factor 10 interleaved with steps of 2 and 5). Examples: 1000B=1000,2000,4000,8000,... 1000N=1000,2000,5000,10000,... 5000N=5000,10000,25000,50000,... 4DN is an alias for 1000,2000,5000N [default: B]

**--balance**

Apply balancing to each zoom level. Off by default.

**--balance-args <balance\_args>**

Additional arguments to pass to cooler balance. To deal with space ambiguity, use quotes to pass multiple arguments, e.g. `--balance-args '--nproc 8 --ignore-diags 3'`. Note that nproc for balancing must be specified independently of zoomify arguments.

**-i, --base-uri <base\_uri>**

One or more additional base coolers to aggregate from, if needed.

**-o, --out <out>**

Output file or URI

**--field <field>**

Specify the names of value columns to merge as '`<name>`'. Repeat the `--field` option for each one. Use '`<name>:dtype=<dtype>`' to specify the dtype. Include '`,agg=<agg>`' to specify an aggregation function different from 'sum'.

**--legacy**

Use the legacy layout of integer-labeled zoom levels.

## 6.11 cooler balance

Out-of-core matrix balancing.

Matrix must be symmetric. See the help for various filtering options to mask out poorly mapped bins.

COOL\_PATH : Path to a COOL file.

```
cooler balance [OPTIONS] COOL_PATH
```

## Arguments

### COOL\_PATH

Required argument

## Options

### --cis-only

Calculate weights against intra-chromosomal data only instead of genome-wide.

### --trans-only

Calculate weights against inter-chromosomal data only instead of genome-wide.

### --ignore-diags <ignore\_diags>

Number of diagonals of the contact matrix to ignore, including the main diagonal. Examples: 0 ignores nothing, 1 ignores the main diagonal, 2 ignores diagonals (-1, 0, 1), etc. [default: 2]

### --ignore-dist <ignore\_dist>

Distance from the diagonal in bp to ignore. The maximum of the corresponding number of diagonals and *--ignore-diags* will be used.

### --mad-max <mad\_max>

Ignore bins from the contact matrix using the ‘MAD-max’ filter: bins whose log marginal sum is less than mad-max median absolute deviations below the median log marginal sum of all the bins in the same chromosome. [default: 5]

### --min-nnz <min\_nnz>

Ignore bins from the contact matrix whose marginal number of nonzeros is less than this number. [default: 10]

### --min-count <min\_count>

Ignore bins from the contact matrix whose marginal count is less than this number. [default: 0]

### --blacklist <blacklist>

Path to a 3-column BED file containing genomic regions to mask out during the balancing procedure, e.g. sequence gaps or regions of poor mappability.

### -p, --nproc <nproc>

Number of processes to split the work between. [default: 8]

### -c, --chunksize <chunksize>

Control the number of pixels handled by each worker process at a time. [default: 10000000]

### --tol <tol>

Threshold value of variance of the marginals for the algorithm to converge. [default: 1e-05]

### --max-iters <max\_iters>

Maximum number of iterations to perform if convergence is not achieved. [default: 200]

### --name <name>

Name of column to write to. [default: weight]

### -f, --force

Overwrite the target dataset, ‘weight’, if it already exists.

### --check

Check whether a data column ‘weight’ already exists.

**--stdout**

Print weight column to stdout instead of saving to file.

**--convergence-policy <convergence\_policy>**

What to do with weights when balancing doesn't converge in `max_iters`. 'store\_final': Store the final result, regardless of whether the iterations converge to the specified tolerance; 'store\_nan': Store a vector of NaN values to indicate that the matrix failed to converge; 'discard': Store nothing and exit gracefully; 'error': Abort with non-zero exit status. [default: store\_final]

---

## 6.12 cooler info

Display a cooler's info and metadata.

COOL\_PATH : Path to a COOL file or cooler URI.

```
cooler info [OPTIONS] COOL_PATH
```

### Arguments

**COOL\_PATH**

Required argument

### Options

**-f, --field <field>**

Print the value of a specific info field.

**-m, --metadata**

Print the user metadata in JSON format.

**-o, --out <out>**

Output file (defaults to stdout)

---

## 6.13 cooler dump

Dump a cooler's data to a text stream.

COOL\_PATH : Path to COOL file or cooler URI.

```
cooler dump [OPTIONS] COOL_PATH
```

## Arguments

### COOL\_PATH

Required argument

## Options

**-t, --table <table>**

Which table to dump. Choosing ‘chroms’ or ‘bins’ will cause all pixel-related options to be ignored. Note that for coolers stored in symmetric-upper mode, ‘pixels’ only holds the upper triangle values of the matrix. [default: pixels]

**-c, --columns <columns>**

Restrict output to a subset of columns, provided as a comma-separated list.

**-H, --header**

Print the header of column names as the first row. [default: False]

**--na-rep <na\_rep>**

Missing data representation. Default is empty ‘’.

**--float-format <float\_format>**

Format string for floating point numbers (e.g. ‘.12g’, ‘03.2f’). [default: g]

**-r, --range <range>**

The coordinates of a genomic region shown along the row dimension, in UCSC-style notation. (Example: chr1:10,000,000-11,000,000). If omitted, the entire contact matrix is printed.

**-r2, --range2 <range2>**

The coordinates of a genomic region shown along the column dimension. If omitted, the column range is the same as the row range.

**-f, --fill-lower**

For coolers using ‘symmetric-upper’ storage, populate implicit areas of the genomic query box by generating lower triangle pixels. If not specified, only upper triangle pixels are reported. This option has no effect on coolers stored in ‘square’ mode. [default: False]

**-b, --balanced, --no-balance**

Apply balancing weights to data. This will print an extra column called *balanced* [default: False]

**--join**

Print the full chromosome bin coordinates instead of bin IDs. This will replace the *bin1\_id* column with *chrom1*, *start1*, and *end1*, and the *bin2\_id* column with *chrom2*, *start2* and *end2*. [default: False]

**--annotate <annotate>**

Join additional columns from the bin table against the pixels. Provide a comma separated list of column names (no spaces). The merged columns will be suffixed by ‘1’ and ‘2’ accordingly.

**--one-based-ids**

Print bin IDs as one-based rather than zero-based.

**--one-based-starts**

Print start coordinates as one-based rather than zero-based.

**-k, --chunksize <chunksize>**

Sets the number of pixel records loaded from disk at one time. Can affect the performance of joins on high resolution datasets. [default: 1000000]

**-o, --out <out>**

Output text file If .gz extension is detected, file is written using zlib. Default behavior is to stream to stdout.

## 6.14 cooler show

Display and browse a cooler in matplotlib.

**COOL\_PATH** : Path to a COOL file or Cooler URI.

**RANGE** : The coordinates of the genomic region to display, in UCSC notation. Example: chr1:10,000,000-11,000,000

```
cooler show [OPTIONS] COOL_PATH RANGE
```

### Arguments

**COOL\_PATH**

Required argument

**RANGE**

Required argument

### Options

**-r2, --range2 <range2>**

The coordinates of a genomic region shown along the column dimension. If omitted, the column range is the same as the row range. Use to display asymmetric matrices or trans interactions.

**-b, --balanced**

Show the balanced contact matrix. If not provided, display the unbalanced counts.

**-o, --out <out>**

Save the image of the contact matrix to a file. If not specified, the matrix is displayed in an interactive window. The figure format is deduced from the extension of the file, the supported formats are png, jpg, svg, pdf, ps and eps.

**--dpi <dpi>**

The DPI of the figure, if saving to a file

**-s, --scale <scale>**

Scale transformation of the colormap: linear, log2 or log10. Default is log10.

**-f, --force**

Force display very large matrices ( $\geq 10^8$  pixels). Use at your own risk as it may cause performance issues.

**--zmin** <zmin>

The minimal value of the color scale. Units must match those of the colormap scale. To provide a negative value use a equal sign and quotes, e.g. -zmin='-0.5'

**--zmax** <zmax>

The maximal value of the color scale. Units must match those of the colormap scale. To provide a negative value use a equal sign and quotes, e.g. -zmax='-0.5'

**--cmap** <cmap>

The colormap used to display the contact matrix. See the full list at [http://matplotlib.org/examples/color/colormaps\\_reference.html](http://matplotlib.org/examples/color/colormaps_reference.html)

**--field** <field>

Pixel values to display. [default: count]

---

## 6.15 cooler tree

Display a file's data hierarchy.

```
cooler tree [OPTIONS] URI
```

### Arguments

**URI**

Required argument

### Options

**-L, --level** <level>

---

## 6.16 cooler attrs

Display a file's attribute hierarchy.

```
cooler attrs [OPTIONS] URI
```

### Arguments

**URI**

Required argument

## Options

**-L, --level <level>**

---

## 6.17 cooler ls

List all coolers inside a file.

```
cooler ls [OPTIONS] COOL_PATH
```

## Arguments

**COOL\_PATH**

Required argument

## Options

**-l, --long**

Long listing format

---

## 6.18 cooler cp

Copy a cooler from one file to another or within the same file.

See also: h5copy, h5repack tools from HDF5 suite.

```
cooler cp [OPTIONS] SRC_URI DST_URI
```

## Arguments

**SRC\_URI**

Required argument

**DST\_URI**

Required argument

## Options

**-w, --overwrite**

Truncate and replace destination file if it already exists.

---

## 6.19 cooler mv

Rename a cooler within the same file.

```
cooler mv [OPTIONS] SRC_URI DST_URI
```

### Arguments

**SRC\_URI**

Required argument

**DST\_URI**

Required argument

## Options

**-w, --overwrite**

Truncate and replace destination file if it already exists.

---

## 6.20 cooler ln

Create a hard link to a cooler (rather than a true copy) in the same file. Also supports soft links (in the same file) or external links (different files).

```
cooler ln [OPTIONS] SRC_URI DST_URI
```

### Arguments

**SRC\_URI**

Required argument

**DST\_URI**

Required argument



## Options

**-w, --overwrite**

Truncate and replace destination file if it already exists.

**-s, --soft**

Creates a soft link rather than a hard link if the source and destination file are the same. Otherwise, creates an external link. This type of link uses a path rather than a pointer.

---

## 6.21 cooler makebins

Generate fixed-width genomic bins.

Output a genome segmentation at a fixed resolution as a BED file.

CHROMSIZES\_PATH : UCSC-like chromsizes file, with chromosomes in desired order.

BINSIZE : Resolution (bin size) in base pairs <int>.

```
cooler makebins [OPTIONS] CHROMSIZES_PATH BINSIZE
```

## Arguments

**CHROMSIZES\_PATH**

Required argument

**BINSIZE**

Required argument

## Options

**-o, --out <out>**

Output file (defaults to stdout)

**-H, --header**

Print the header of column names as the first row. [default: False]

**-i, --rel-ids <rel\_ids>**

Include a column of relative bin IDs for each chromosome. Choose whether to report them as 0- or 1-based.

---

## 6.22 cooler digest

Generate fragment-delimited genomic bins.

Output a genome segmentation of restriction fragments as a BED file.

CHROMSIZES\_PATH : UCSC-like chromsizes file, with chromosomes in desired order.

FASTA\_PATH : Genome assembly FASTA file or folder containing FASTA files (uncompressed).

ENZYME : Name of restriction enzyme

```
cooler digest [OPTIONS] CHROMSIZES_PATH FASTA_PATH ENZYME
```

### Arguments

#### CHROMSIZES\_PATH

Required argument

#### FASTA\_PATH

Required argument

#### ENZYME

Required argument

### Options

**-o, --out** <out>

Output file (defaults to stdout)

**-H, --header**

Print the header of column names as the first row. [default: False]

**-i, --rel-ids** <rel\_ids>

Include a column of relative bin IDs for each chromosome. Choose whether to report them as 0- or 1-based.

---

## 6.23 cooler csort

Sort and index a contact list.

Order the mates of each pair record so that all contacts are upper triangular with respect to the chromosome ordering given by the chromosomes file, sort contacts by genomic location, and index the resulting file.

PAIRS\_PATH : Contacts (i.e. read pairs) text file, optionally compressed.

CHROMOSOMES\_PATH : File listing desired chromosomes in the desired order. May be tab-delimited, e.g. a UCSC-style chromsizes file. Contacts mapping to other chromosomes will be discarded.

### Notes

- csort can also be used to sort and index a text representation of a contact *matrix* in bedGraph-like format. In this case, substitute *pos1* and *pos2* with *start1* and *start2*, respectively.
- Requires Unix tools: sort, bgzip + tabix or pairix.

If indexing with Tabix, the output file will have the following properties:

- Upper triangular: the read pairs on each row are assigned to side 1 or 2 in such a way that (chrom1, pos1) is always “less than” (chrom2, pos2)
- Rows are lexicographically sorted by chrom1, pos1, chrom2, pos2; i.e. “positionally sorted”
- Compressed with bgzip [\*]
- Indexed using Tabix [\*] on chrom1 and pos1.

If indexing with Pairix, the output file will have the following properties:

- Upper triangular: the read pairs on each row are assigned to side 1 or 2 in such a way that (chrom1, pos1) is always “less than” (chrom2, pos2)
- Rows are lexicographically sorted by chrom1, chrom2, pos1, pos2; i.e. “block sorted”
- Compressed with bgzip [\*]
- Indexed using Pairix [+] on chrom1, chrom2 and pos1.

[\*] Tabix manpage: <<http://www.htslib.org/doc/tabix.html>>. [+] Pairix on Github: <<https://github.com/4dn-dcic/pairix>>

```
cooler csort [OPTIONS] PAIRS_PATH CHROMOSOMES_PATH
```

## Arguments

### PAIRS\_PATH

Required argument

### CHROMOSOMES\_PATH

Required argument

## Options

- c1, --chrom1 <chrom1>**  
chrom1 field number in the input file (starting from 1) [required]
- c2, --chrom2 <chrom2>**  
chrom2 field number [required]
- p1, --pos1 <pos1>**  
pos1 field number [required]
- p2, --pos2 <pos2>**  
pos2 field number [required]
- i, --index <index>**  
Select the preset sort and indexing options [default: pairix]
- flip-only**  
Only flip mates; no sorting or indexing. Write to stdout. [default: False]
- p, --nproc <nproc>**  
Number of processors [default: 8]

**-0, --zero-based**

Read positions are zero-based [default: False]

**--sep <sep>**

Data delimiter in the input file [default: t]

**--comment-char <comment\_char>**

Comment character to skip header [default: #]

**--sort-options <sort\_options>**

Quoted list of additional options to *sort* command

**-o, --out <out>**

Output gzip file

**-s1, --strand1 <strand1>**

strand1 field number (deprecated)

**-s2, --strand2 <strand2>**

strand2 field number (deprecated)

---

## RELEASE NOTES

### 7.1 v0.9.3

#### 7.1.1 Bug fixes

- Fix estimation of mean bin size when using variable-sized bins #332.
- Fix regression bug to handle multiple convergence statuses in balance CLI #334.

### 7.2 v0.9.2

#### 7.2.1 Bug fixes

Several fixes from @robomics

- Improve handling of uint attributes
- Fix incorrect variance stored by `_balance_cisonly`
- `cloud.py`: fix detection of pandas v2.. causing `IOHandles` error

### 7.3 v0.9.1

Date 2023-01-23

#### 7.3.1 Maintenance

- Export `_IndexingMixin` from `cooler.core` to keep private API used by `cooltools`.

## 7.4 v0.9.0

Date 2023-01-18

### 7.4.1 New features

- New query engine implementation (no user-facing API changes).
- New logging context and verbosity system.

### 7.4.2 API changes

- `cooler.balance_cooler` now uses the same default argument values as the CLI.

### 7.4.3 Schema

- `cooler balance` now inserts `divisive_weights: False` metadata to balancing weights.

### 7.4.4 Maintenance

- Dropped Python 2 support.
- Removed deprecated `io` module.
- Deprecated `tools` module; renamed `parallel`.
- Various dependency maintenance upgrades.
- Modernized CI and dev tools.
- Migrated to `pyproject.toml` and modernized packaging infra.

## 7.5 v0.8.11

Date : 2021-04-01

### 7.5.1 Bug fixes

- Hotfix cooler cload pairs file header parsing to work with the latest version of pandas ( $\geq 1.2$ ).
- Update CLI help for `--balance-args` to clarify usage. By @gfudenberg.

## 7.6 v0.8.10

Date : 2020-09-25

### 7.6.1 Bug fixes

- Fixed the new header parsing in cooler cload pairs to handle esoteric file stream implementations. Specifically GzipFile had stopped working. By @golobor

## 7.7 v0.8.9

Date : 2020-07-17

### 7.7.1 Enhancements

- Added single-cell cooler file flavor (.scool) (#201)

## 7.8 v0.8.8

Date : 2020-06-23

### 7.8.1 Maintenance

- Improved code coverage
- Added missing autodoc for cooler balance
- Dropped pysam and biopython as hard dependencies
- Officially sunseting Python 2.7 support

### 7.8.2 Enhancements

- Added zoom progressions (#203)

### 7.8.3 Bug fixes

- Allow hashes in read IDs in cload pairs (#193)

## 7.9 v0.8.7

Date: 2020-01-12

### 7.9.1 Maintenance

- Code styling with black
- Add coverage reporting

### 7.9.2 Bug fixes

- Replace `json` with `simplejson` to deal with attrs stored as bytes

## 7.10 v0.8.6

Date: 2019-08-12

### 7.10.1 Maintenance

- Added contributing guidelines

### 7.10.2 Bug fixes

- Fixed a related regression that affected selection of the `chrom` column.

Post-release `v0.8.6.post0`: requirements files added to MANIFEST.in

## 7.11 v0.8.5

Date: 2019-04-08

### 7.11.1 Bug fixes

- Fixed a regression that prevented selection of bins excluding the `chrom` column.

## 7.12 v0.8.4

Date: 2019-04-04



### 7.12.1 Enhancements

- When creating coolers from unordered input, change the default temporary dir to be the same as the output file instead of the system tmp (pass '-' to use the system one). #150
- `cooler ls` and `list_coolers()` now output paths in natural order. #153
- New option in `cooler.matrix()` to handle divisive balancing weight vectors.

### 7.12.2 Bug fixes

- Restore function of `--count-as-float` option to `cooler load`
- Fixed partitioning issue sometimes causing some bins to get split during coarsen
- `rename_chroms()` will refresh cached chromosome names #147
- `Cooler.bins()` selector will always properly convert bins/chrom integer IDs to categorical chromosome names when the number of contigs is very large and therefore the HDF5 ENUM header is missing. Before this would only happen when explicitly requesting `convert_enum=True`.

## 7.13 v0.8.3

Date: 2019-02-11

### 7.13.1 Bug fixes

- Fixed import bug in `rename_chroms`
- `create_cooler` no longer requires a "count" column when specifying custom value columns

## 7.14 v0.8.2

Date: 2019-01-20

### 7.14.1 Enhancements

New options for `cooler dump` pixel output:

- `--matrix` option: Applies to symmetric-upper coolers; no-op for square coolers. Generates all lower triangular pixels necessary to fill the requested genomic query window. Without this option, `cooler dump` will only return the data explicitly stored in the pixel table (i.e. upper triangle).
- `-one-based-ids` and `--one-based-starts` convenience options.

### 7.14.2 Bug fixes

- A bug was introduced into the matrix-as-pixels selector in 0.8.0 that also affected `cooler dump`. The behavior has been restored to that in 0.7.

## 7.15 v0.8.1

Date: 2019-01-02

### 7.15.1 Enhancements

- `cooler zoomify` command can take additional base resolutions as input.

### 7.15.2 Bug fixes

- Fixed regression that slowed down pre-processing during `coarsen`.
- Fixed missing import on handling bad URIs.
- Restore but deprecate `cooler.io.ls` for backwards compatibility.

## 7.16 v0.8.0

Date: 2018-12-31

This is a major release from 0.7 and includes an updated format version, and several API changes and deprecations.

### 7.16.1 Schema

- New schema version: v3
- Adds required `storage-mode` metadata attribute. Two possible values: `"symmetric-upper"` indicates a symmetric matrix encoded as upper triangle (previously the only storage mode); `"square"` indicates no special encoding (e.g. for non-symmetric matrices).

### 7.16.2 New features

- Support for **non-symmetric** matrices, e.g. RNA-DNA maps.
  - `Create` function accepts a boolean `symmetric_upper` option to set the storage mode. Default is `True`.
  - Creation commands also use `symmetric_upper` by default, which can be overridden with a flag.
- All main functionality exposed through top-level functions (`create`, `merge`, `coarsen`, `zoomify`, `balance`)
- New commands for generic file operations and file inspection.

### 7.16.3 API changes

- `cooler.annotate()` option replace now defaults to `False`.
- Submodule renaming. Old names are preserved as aliases but are deprecated.
  - `cooler.io` -> `cooler.create`.
  - `cooler.ice` -> `cooler.balance`.
- New top level public functions:
  - `cooler.create_cooler()`. Use instead of `cooler.io.create` and `cooler.io.create_from_unordered`.
  - `cooler.merge_coolers()`
  - `cooler.coarsen_cooler()`
  - `cooler.zoomify_cooler()`
  - `cooler.balance_cooler()`. Alias: `cooler.balance.iterative_correction()`.
- Refactored file operations available in `cooler.fileops`. See the API reference.

### 7.16.4 CLI changes

- Various output options added to `cooler info`, `cooler dump`, `cooler makebins` and `cooler digest`.
- Generic data and attribute hierarchy viewers `cooler tree` and `cooler attrs`.
- Generic `cp`, `mv` and `ln` convenience commands.
- New verbosity and process info options.

### 7.16.5 Maintenance

- Unit tests refactored and re-written for `pytest`.

## 7.17 v0.7.11

Date: 2018-08-17

- Genomic range parser supports humanized units (k/K(b), m/M(b), g/G(b))
- Experimental support for arbitrary aggregation operations in `cooler csort` (e.g. mean, median, max, min)
- Documentation updates

Bug fixes

- Fix newline handling for `csort` when `p1` or `p2` is last column.
- Fix `--count-as-float` regression in `load/cload`.

## 7.18 v0.7.10

Date: 2018-05-07

- Fix a shallow copy bug in `validate_pixels` causing records to sometimes flip twice.
- Add ignore distance (bp) filter to cooler balance
- Start using shuffle filter by default

## 7.19 v0.7.9

Date: 2018-03-30

- Indexed pairs loading commands now provide option for 0- or 1-based positions (1-based by default). #115
- Fixed error introduced into `cload pairix` in last release.

## 7.20 v0.7.8

Date: 2018-03-18

### 7.20.1 Enhancements

- New cooler `cload pairs` command provides index-free loading of pairs.
- Changed name of `create_from_unsorted` to more correct `create_from_unordered`.

### 7.20.2 Bug fixes

- Fixed broken use of single-file temporary store in `create_from_unordered`.
- Added heuristic in `pairix cload` to prevent excessively large chunks. #92
- Added extra checks in `cload pairix` and `cload tabix`. #62, #75

## 7.21 v0.7.7

Date: 2018-03-16

### 7.21.1 Enhancements

- Implementation of unsorted (index-free) loading
  - `cooler.io.create_from_unsorted` takes an iterable of pixel dataframe chunks that need not be properly sorted.
  - Use input sanitization procedures for pairs `sanitize_records` and binned data `sanitize_pixels` to feed data to `create_from_unsorted`. #87 #108 #109

- The `cooler load` command is now index-free: unsorted COO and BG2 input data can be streamed in. #90. This will soon be implemented as an option for loading pairs as well.
- Prevent `cooler balance` command from exiting with non-zero status upon failed convergence using convergence error policies. #93
- Improve the `create` API to support pandas `read_csv`-style `columns` and `dtype` kwargs to add extra value columns or override default dtypes. #108
- Experimental implementation of trans-only balancing. #56

### 7.21.2 Bug fixes

- Fix `argmax` deprecation. #99

## 7.22 v0.7.6

Date: 2017-10-31

### 7.22.1 Enhancements

- Cooler zoomify with explicit resolutions
- Towards standardization of multicooler structure
- Support for loading 1-based COO triplet input files

### 7.22.2 Bug fixes

- Fixed issue of exceeding header limit with too many scaffolds. If header size is exceeded, chrom IDs are stored as raw integers instead of HDF5 enums. There should be no effect at the API level.
- Fixed issue of single-column chromosomes files not working in `cload`.
- Fixed edge case in performing joins when using both `as_pixels` and `join` options in the matrix selector.

Happy Halloween!

## 7.23 v0.7.5

Date: 2017-07-13

- Fix pandas issue affecting cases when loading single chromosomes
- Add transform options to `higlass` API

## 7.24 v0.7.4

Date: 2017-05-25

- Fix regression in automatic `--balance` option in cooler zoomify
- Fix special cases where cooler.io.create and append would not work with certain inputs

## 7.25 v0.7.3

Date: 2017-05-22

- Added function to print higlass zoom resolutions for a given genome and base resolution.

## 7.26 v0.7.2

Date: 2017-05-09

- Improve chunking and fix pickling issue with aggregating very large text datasets
- Restore zoom binsize metadata to higlass files

## 7.27 v0.7.1

Date: 2017-04-29

- cooler load command can now accept supplemental pixel fields and custom field numbers
- Fix parsing errors with unused pixel fields
- Eliminate hard dependence on dask to make pip installs simpler. Conda package will retain dask as a run time requirement.

## 7.28 v0.7.0

Date: 2017-04-27

### 7.28.1 New features

- New Cooler URIs: Full support for Cooler objects anywhere in the data hierarchy of a .cool file
- Experimental dask support via cooler.contrib.dask
- New explicit bin blacklist option for cooler balance
- Various new CLI tools:
  - cooler list
  - cooler copy
  - cooler merge

- `cooler csort` now produces Pairix files by default
- `cooler load` now accepts two types of matrix text input formats
  - 3-column sparse matrix
  - 7-column `bg2.gz` (2D `bedGraph`) indexed with Pairix (e.g. using `csort`)
- `cooler coarsegrain` renamed `cooler coarsen`
- Multi-resolution HiGlass input files can now be generated with the `cooler zoomify` command
- More flexible API functions to create and append columns to Coolers in `cooler.io`

### API/CLI changes

- `cooler.io.create` signature changed; `chromsizes` argument is deprecated.
- `cooler csort` argument order changed

### 7.28.2 Bug fixes

- Chromosome name length restriction removed
- `Cooler.open` function now correctly opens the specific root group of the Cooler and behaves like a proper context manager in all cases

## 7.29 v0.6.6

Date: 2017-03-21

- Chromosome names longer than 32 chars are forbidden for now
- Improved pairix and tabix iterators, dropped need for slow first pass over contacts

## 7.30 v0.6.5

Date: 2017-03-18

- Fixed pairix aggregator to properly deal with autoflipping of pairs

## 7.31 v0.6.4

Date: 2017-03-17

- Migrated higlass multires aggregator to `cooler coarsegrain` command
- Fixed pairix aggregator to properly deal with autoflipping of pairs

## 7.32 v0.6.3

Date: 2017-02-22

- Merge PairixAggregator patch from Soo.
- Update repr string
- Return matrix scale factor in balance stats rather than the bias scale factor: #35.

## 7.33 v0.6.2

Date: 2017-02-12

Fixed regressions in

- cooler cload tabix/pairix failed on non-fixed sized bins
- cooler show

## 7.34 v0.6.1

Date: 2017-02-06

- This fixes stale build used in bdist\_wheel packaging that broke 0.6.0. #29

## 7.35 v0.6.0

Date: 2017-02-03

### 7.35.1 Enhancements

- Dropped Python 3.3 support. Added 3.6 support.
- Added contrib subpackage containing utilities for higlass, including multires aggregation.
- Fixed various issues with synchronizing read/write multiprocessing with HDF5.
- Replacing prints with logging.
- Added sandboxed tools module to develop utilities for out-of-core algorithms using Coolers.

### 7.35.2 New features

- Cooler objects have additional convenience properties chromsizes, chromnames.
- New file introspection functions ls and is\_cooler to support nested Cooler groups.
- Cooler initializer can accept a file path and path to Cooler group.
- cload accepts contact lists in hiclib-style HDF5 format, the legacy tabix-indexed format, and new pairix-indexed format.



### 7.35.3 API/CLI changes

- `create` only accepts a file path and optional group path instead of an open file object.
- `Cooler.matrix` selector now returns a balanced dense 2D NumPy array by default. Explicitly set `balance` to `False` to get raw counts and set `sparse` to `True` to get a `coo_matrix` as per old behavior.
- Command line parameters of `cload` changed significantly

### 7.35.4 Bug fixes

- Fixed bug in `csort` that led to incorrect triangularity of trans read pairs.

## 7.36 v0.5.3

Date: 2016-09-10

- Check for existence of required external tools in CLI
- Fixed `cooler show` incompatibility with older versions of matplotlib
- Fixed `cooler.annotate` to work on empty dataframe input
- Fixed broken pipe signals not getting suppressed on Python 2
- `cooler cload` raises a warning when bin file lists a contig missing from the contact list

## 7.37 v0.5.2

Date: 2016-08-26

- Fix bug in `cooler csort` parsing of chromsizes file.
- Workaround for two locale-related issues on Python 3. Only affects cases where a machine's locale is set to ASCII or Unices which use the ambiguous C or POSIX locales.
- Fix typo in `setup.py` and add `pysam` to dependencies.

## 7.38 v0.5.1

Date: 2016-08-24

- Bug fix in input parser to `cooler csort`
- Update triu reordering awk template in `cooler csort`
- Rename `cooler binnify` to `cooler makebins`. Binnify sounds like “aggregate” which is what `cload` does.

## 7.39 v0.5.0

Date: 2016-08-24

- Most scripts ported over to a new command line interface using the Click framework with many updates.
- New `show` and `info` scripts.
- Updated Readme.
- Minor bug fixes.

## 7.40 v0.4.0

Date: 2016-08-18

### 7.40.1 Schema

- Updated file schema: v2
- `/bins/chroms` is now an enum instead of string column

### 7.40.2 API changes

- Table views are a bit more intuitive: selecting field names on table view objects returns a new view on the subset of columns.
- New API function: `cooler.annotate` for doing joins

### 7.40.3 New Features

- Support for nested Cooler “trees” at any depth in an HDF5 hierarchy
- Refactored `cooler.io` to provide “contact readers” that process different kinds of input (aggregate from a contact list, load from an existing matrix, etc.)
- Added new scripts for contact aggregation, loading, dumping and balancing

## 7.41 v0.3.0

Date: 2016-02-18

- 2D range selector `matrix()` now provides either rectangular data as `coo_matrix` or triangular data as a pixel table dataframe.
- Added binning support for any genome segmentation (i.e., fixed or variable bin width).
- Fixed issues with binning data from mapped read files.
- Genomic locus string parser now accepts ENSEMBL-style number-only chromosome names and FASTA-style sequence names containing pipes.

## 7.42 v0.2.1

Date: 2016-02-07

- Fixed bintable region fetcher

## 7.43 v0.2

Date: 2016-01-17

- First beta release

## 7.44 v0.1

Date: 2015-11-22

- Working initial prototype.
- genindex
- Glossary



## Symbols

`__init__()` (*cooler.Cooler method*), 24

-0

cooler-cload-pairix command line option, 45

cooler-cload-pairs command line option, 43

cooler-cload-tabix command line option, 46

cooler-csort command line option, 61

-H

cooler-digest command line option, 60

cooler-dump command line option, 54

cooler-makebins command line option, 59

-L

cooler-attrs command line option, 57

cooler-tree command line option, 56

-N

cooler-cload-pairs command line option, 43

cooler-load command line option, 48

-V

cooler command line option, 42

--annotate

cooler-dump command line option, 54

--append

cooler-cload-pairs command line option, 44

cooler-coarsen command line option, 50

cooler-load command line option, 48

cooler-merge command line option, 49

--assembly

cooler-cload-hiclib command line option, 47

cooler-cload-pairix command line option, 45

cooler-cload-pairs command line option, 43

cooler-cload-tabix command line option, 46

cooler-load command line option, 48

--balance

cooler-zoomify command line option, 51

--balance-args

cooler-zoomify command line option, 51

--balanced

cooler-dump command line option, 54

cooler-show command line option, 55

--base-uri

cooler-zoomify command line option, 51

--blacklist

cooler-balance command line option, 52

--check

cooler-balance command line option, 52

--chrom1

cooler-cload-pairs command line option, 43

cooler-csort command line option, 61

--chrom2

cooler-cload-pairs command line option, 43

cooler-cload-tabix command line option, 46

cooler-csort command line option, 61

--chunksize

cooler-balance command line option, 52

cooler-cload-hiclib command line option, 47

cooler-cload-pairs command line option, 43

cooler-coarsen command line option, 50

cooler-dump command line option, 54

cooler-load command line option, 48

cooler-merge command line option, 49

cooler-zoomify command line option, 51

--cis-only

cooler-balance command line option, 52

--cmap

cooler-show command line option, 56

--columns

cooler-dump command line option, 54

--comment-char

cooler-cload-pairs command line option, 43

- cooler-csort command line option, 62
- cooler-load command line option, 48
- convergence-policy
  - cooler-balance command line option, 53
- count-as-float
  - cooler-load command line option, 48
- debug
  - cooler command line option, 42
- dpi
  - cooler-show command line option, 55
- factor
  - cooler-coarsen command line option, 50
- field
  - cooler-cload-pairs command line option, 43
  - cooler-coarsen command line option, 50
  - cooler-info command line option, 53
  - cooler-load command line option, 48
  - cooler-merge command line option, 49
  - cooler-show command line option, 56
  - cooler-zoomify command line option, 51
- fill-lower
  - cooler-dump command line option, 54
- flip-only
  - cooler-csort command line option, 61
- float-format
  - cooler-dump command line option, 54
- force
  - cooler-balance command line option, 52
  - cooler-show command line option, 55
- format
  - cooler-load command line option, 48
- header
  - cooler-digest command line option, 60
  - cooler-dump command line option, 54
  - cooler-makebins command line option, 59
- ignore-diags
  - cooler-balance command line option, 52
- ignore-dist
  - cooler-balance command line option, 52
- index
  - cooler-csort command line option, 61
- input-copy-status
  - cooler-cload-pairs command line option, 43
  - cooler-load command line option, 48
- join
  - cooler-dump command line option, 54
- legacy
  - cooler-zoomify command line option, 51
- level
  - cooler-attrs command line option, 57
  - cooler-tree command line option, 56
- long
  - cooler-ls command line option, 57
- mad-max
  - cooler-balance command line option, 52
- max-iters
  - cooler-balance command line option, 52
- max-merge
  - cooler-cload-pairs command line option, 44
- max-split
  - cooler-cload-pairix command line option, 45
  - cooler-cload-tabix command line option, 46
- metadata
  - cooler-cload-hiclib command line option, 47
  - cooler-cload-pairix command line option, 45
  - cooler-cload-pairs command line option, 43
  - cooler-cload-tabix command line option, 46
  - cooler-info command line option, 53
  - cooler-load command line option, 48
- min-count
  - cooler-balance command line option, 52
- min-nnz
  - cooler-balance command line option, 52
- na-rep
  - cooler-dump command line option, 54
- name
  - cooler-balance command line option, 52
- no-balance
  - cooler-dump command line option, 54
- no-delete-temp
  - cooler-cload-pairs command line option, 44
  - cooler-load command line option, 48
- no-symmetric-upper
  - cooler-cload-pairs command line option, 43
  - cooler-load command line option, 48
- nproc
  - cooler-balance command line option, 52
  - cooler-cload-pairix command line option, 45
  - cooler-cload-tabix command line option, 46
  - cooler-coarsen command line option, 50
  - cooler-csort command line option, 61
  - cooler-zoomify command line option, 51
- one-based
  - cooler-load command line option, 48
- one-based-ids

---

```

    cooler-dump command line option, 54
--one-based-starts
    cooler-dump command line option, 54
--out
    cooler-coarsen command line option, 50
    cooler-csort command line option, 62
    cooler-digest command line option, 60
    cooler-dump command line option, 55
    cooler-info command line option, 53
    cooler-makebins command line option, 59
    cooler-show command line option, 55
    cooler-zoomify command line option, 51
--overwrite
    cooler-cp command line option, 58
    cooler-ln command line option, 59
    cooler-mv command line option, 58
--pos1
    cooler-cload-pairs command line option,
        43
    cooler-csort command line option, 61
--pos2
    cooler-cload-pairs command line option,
        43
    cooler-cload-tabix command line option,
        46
    cooler-csort command line option, 61
--range
    cooler-dump command line option, 54
--range2
    cooler-dump command line option, 54
    cooler-show command line option, 55
--rel-ids
    cooler-digest command line option, 60
    cooler-makebins command line option, 59
--resolutions
    cooler-zoomify command line option, 51
--scale
    cooler-show command line option, 55
--sep
    cooler-csort command line option, 62
--soft
    cooler-ln command line option, 59
--sort-options
    cooler-csort command line option, 62
--stdout
    cooler-balance command line option, 52
--storage-options
    cooler-cload-pairs command line option,
        44
    cooler-load command line option, 48
--strand1
    cooler-csort command line option, 62
--strand2
    cooler-csort command line option, 62
--table
    cooler-dump command line option, 54
--temp-dir
    cooler-cload-pairs command line option,
        44
    cooler-load command line option, 48
--tol
    cooler-balance command line option, 52
--trans-only
    cooler-balance command line option, 52
--verbose
    cooler command line option, 42
--version
    cooler command line option, 42
--zero-based
    cooler-cload-pairix command line option,
        45
    cooler-cload-pairs command line option,
        43
    cooler-cload-tabix command line option,
        46
    cooler-csort command line option, 61
--zmax
    cooler-show command line option, 56
--zmin
    cooler-show command line option, 55
-a
    cooler-cload-pairs command line option,
        44
    cooler-coarsen command line option, 50
    cooler-load command line option, 48
    cooler-merge command line option, 49
-b
    cooler-dump command line option, 54
    cooler-show command line option, 55
-c
    cooler-balance command line option, 52
    cooler-cload-hiclib command line option,
        47
    cooler-coarsen command line option, 50
    cooler-dump command line option, 54
    cooler-load command line option, 48
    cooler-merge command line option, 49
    cooler-zoomify command line option, 51
-c1
    cooler-cload-pairs command line option,
        43
    cooler-csort command line option, 61
-c2
    cooler-cload-pairs command line option,
        43
    cooler-cload-tabix command line option,
        46
    cooler-csort command line option, 61

```

- d cooler command line option, [42](#)
  - f cooler-balance command line option, [52](#)  
cooler-dump command line option, [54](#)  
cooler-info command line option, [53](#)  
cooler-load command line option, [48](#)  
cooler-show command line option, [55](#)
  - i cooler-csort command line option, [61](#)  
cooler-digest command line option, [60](#)  
cooler-makebins command line option, [59](#)  
cooler-zoomify command line option, [51](#)
  - k cooler-coarsen command line option, [50](#)  
cooler-dump command line option, [54](#)
  - l cooler-ls command line option, [57](#)
  - m cooler-info command line option, [53](#)
  - n cooler-coarsen command line option, [50](#)  
cooler-zoomify command line option, [51](#)
  - o cooler-coarsen command line option, [50](#)  
cooler-csort command line option, [62](#)  
cooler-digest command line option, [60](#)  
cooler-dump command line option, [55](#)  
cooler-info command line option, [53](#)  
cooler-makebins command line option, [59](#)  
cooler-show command line option, [55](#)  
cooler-zoomify command line option, [51](#)
  - p cooler-balance command line option, [52](#)  
cooler-cload-pairix command line option, [45](#)  
cooler-cload-tabix command line option, [46](#)  
cooler-coarsen command line option, [50](#)  
cooler-csort command line option, [61](#)  
cooler-zoomify command line option, [51](#)
  - p1 cooler-cload-pairs command line option, [43](#)  
cooler-csort command line option, [61](#)
  - p2 cooler-cload-pairs command line option, [43](#)  
cooler-cload-tabix command line option, [46](#)  
cooler-csort command line option, [61](#)
  - r cooler-dump command line option, [54](#)  
cooler-zoomify command line option, [51](#)
  - r2 cooler-dump command line option, [54](#)  
cooler-show command line option, [55](#)
  - s cooler-cload-pairix command line option, [45](#)  
cooler-cload-tabix command line option, [46](#)  
cooler-ln command line option, [59](#)  
cooler-show command line option, [55](#)
  - s1 cooler-csort command line option, [62](#)
  - s2 cooler-csort command line option, [62](#)
  - t cooler-dump command line option, [54](#)
  - v cooler command line option, [42](#)
  - w cooler-cp command line option, [58](#)  
cooler-ln command line option, [59](#)  
cooler-mv command line option, [58](#)
- ## A
- [annotate\(\)](#) (*in module cooler*), [27](#)
- ## B
- [balance\\_cooler\(\)](#) (*in module cooler*), [31](#)  
[binnify\(\)](#) (*in module cooler.util*), [39](#)
- ## BINS
- cooler-cload-hiclib command line option, [46](#)
  - cooler-cload-pairix command line option, [44](#)
  - cooler-cload-pairs command line option, [43](#)
  - cooler-cload-tabix command line option, [45](#)
- [bins\(\)](#) (*cooler.Cooler method*), [25](#)
- ## BINS\_PATH
- cooler-load command line option, [47](#)
- ## BINSIZE
- cooler-makebins command line option, [59](#)
- [binsize](#) (*cooler.Cooler property*), [25](#)
- ## C
- [chromnames](#) (*cooler.Cooler property*), [25](#)
- ## CHROMOSOMES\_PATH
- cooler-csort command line option, [61](#)
- [chroms\(\)](#) (*cooler.Cooler method*), [25](#)
- [chromsizes](#) (*cooler.Cooler property*), [25](#)
- ## CHROMSIZES\_PATH
- cooler-digest command line option, [60](#)
  - cooler-makebins command line option, [59](#)



coarsen\_cooler() (in module cooler), 30

COOL\_PATH

- cooler-balance command line option, 52
- cooler-cload-hiclib command line option, 46
- cooler-cload-pairix command line option, 44
- cooler-cload-pairs command line option, 43
- cooler-cload-tabix command line option, 45
- cooler-coarsen command line option, 50
- cooler-dump command line option, 54
- cooler-info command line option, 53
- cooler-load command line option, 47
- cooler-ls command line option, 57
- cooler-show command line option, 55
- cooler-zoomify command line option, 50

Cooler (class in cooler), 24

cooler command line option

- V, 42
- debug, 42
- verbose, 42
- version, 42
- d, 42
- v, 42

cooler-attrs command line option

- L, 57
- level, 57
- URI, 56

cooler-balance command line option

- blacklist, 52
- check, 52
- chunksize, 52
- cis-only, 52
- convergence-policy, 53
- force, 52
- ignore-diags, 52
- ignore-dist, 52
- mad-max, 52
- max-iters, 52
- min-count, 52
- min-nnz, 52
- name, 52
- nproc, 52
- stdout, 52
- tol, 52
- trans-only, 52
- c, 52
- f, 52
- p, 52
- COOL\_PATH, 52

cooler-cload-hiclib command line option

- assembly, 47
- chunksize, 47
- metadata, 47
- c, 47
- BINS, 46
- COOL\_PATH, 46
- PAIRS\_PATH, 46

cooler-cload-pairix command line option

- 0, 45
- assembly, 45
- max-split, 45
- metadata, 45
- nproc, 45
- zero-based, 45
- p, 45
- s, 45
- BINS, 44
- COOL\_PATH, 44
- PAIRS\_PATH, 44

cooler-cload-pairs command line option

- 0, 43
- N, 43
- append, 44
- assembly, 43
- chrom1, 43
- chrom2, 43
- chunksize, 43
- comment-char, 43
- field, 43
- input-copy-status, 43
- max-merge, 44
- metadata, 43
- no-delete-temp, 44
- no-symmetric-upper, 43
- pos1, 43
- pos2, 43
- storage-options, 44
- temp-dir, 44
- zero-based, 43
- a, 44
- c1, 43
- c2, 43
- p1, 43
- p2, 43
- BINS, 43
- COOL\_PATH, 43
- PAIRS\_PATH, 43

cooler-cload-tabix command line option

- 0, 46
- assembly, 46
- chrom2, 46
- max-split, 46
- metadata, 46
- nproc, 46
- pos2, 46

```
--zero-based, 46
-c2, 46
-p, 46
-p2, 46
-s, 46
BINS, 45
COOL_PATH, 45
PAIRS_PATH, 45
cooler-coarsen command line option
--append, 50
--chunksize, 50
--factor, 50
--field, 50
--nproc, 50
--out, 50
-a, 50
-c, 50
-k, 50
-n, 50
-o, 50
-p, 50
COOL_PATH, 50
cooler-cp command line option
--overwrite, 58
-w, 58
DST_URI, 57
SRC_URI, 57
cooler-csort command line option
-0, 61
--chrom1, 61
--chrom2, 61
--comment-char, 62
--flip-only, 61
--index, 61
--nproc, 61
--out, 62
--pos1, 61
--pos2, 61
--sep, 62
--sort-options, 62
--strand1, 62
--strand2, 62
--zero-based, 61
-c1, 61
-c2, 61
-i, 61
-o, 62
-p, 61
-p1, 61
-p2, 61
-s1, 62
-s2, 62
CHROMOSOMES_PATH, 61
PAIRS_PATH, 61
cooler-digest command line option
-H, 60
--header, 60
--out, 60
--rel-ids, 60
-i, 60
-o, 60
CHROMSIZES_PATH, 60
ENZYME, 60
FASTA_PATH, 60
cooler-dump command line option
-H, 54
--annotate, 54
--balanced, 54
--chunksize, 54
--columns, 54
--fill-lower, 54
--float-format, 54
--header, 54
--join, 54
--na-rep, 54
--no-balance, 54
--one-based-ids, 54
--one-based-starts, 54
--out, 55
--range, 54
--range2, 54
--table, 54
-b, 54
-c, 54
-f, 54
-k, 54
-o, 55
-r, 54
-r2, 54
-t, 54
COOL_PATH, 54
cooler-info command line option
--field, 53
--metadata, 53
--out, 53
-f, 53
-m, 53
-o, 53
COOL_PATH, 53
cooler-ln command line option
--overwrite, 59
--soft, 59
-s, 59
-w, 59
DST_URI, 58
SRC_URI, 58
cooler-load command line option
-N, 48
```

---

```

--append, 48
--assembly, 48
--chunksize, 48
--comment-char, 48
--count-as-float, 48
--field, 48
--format, 48
--input-copy-status, 48
--metadata, 48
--no-delete-temp, 48
--no-symmetric-upper, 48
--one-based, 48
--storage-options, 48
--temp-dir, 48
-a, 48
-c, 48
-f, 48
BINS_PATH, 47
COOL_PATH, 47
PIXELS_PATH, 47
cooler-ls command line option
--long, 57
-l, 57
COOL_PATH, 57
cooler-makebins command line option
-H, 59
--header, 59
--out, 59
--rel-ids, 59
-i, 59
-o, 59
BINSIZE, 59
CHROMSIZES_PATH, 59
cooler-merge command line option
--append, 49
--chunksize, 49
--field, 49
-a, 49
-c, 49
IN_PATHS, 49
OUT_PATH, 49
cooler-mv command line option
--overwrite, 58
-w, 58
DST_URI, 58
SRC_URI, 58
cooler-show command line option
--balanced, 55
--cmap, 56
--dpi, 55
--field, 56
--force, 55
--out, 55
--range2, 55
--scale, 55
--zmax, 56
--zmin, 55
-b, 55
-f, 55
-o, 55
-r2, 55
-s, 55
COOL_PATH, 55
RANGE, 55
cooler-tree command line option
-L, 56
--level, 56
URI, 56
cooler-zoomify command line option
--balance, 51
--balance-args, 51
--base-uri, 51
--chunksize, 51
--field, 51
--legacy, 51
--nproc, 51
--out, 51
--resolutions, 51
-c, 51
-i, 51
-n, 51
-o, 51
-p, 51
-r, 51
COOL_PATH, 50
cp() (in module cooler.fileops), 36
create_cooler() (in module cooler), 28
create_scool() (in module cooler), 33

D
digest() (in module cooler.util), 39
DST_URI
    cooler-cp command line option, 57
    cooler-ln command line option, 58
    cooler-mv command line option, 58

E
ENZYME
    cooler-digest command line option, 60
extent() (cooler.Cooler method), 25

F
FASTA_PATH
    cooler-digest command line option, 60
fetch_chromsizes() (in module cooler.util), 38

I
IN_PATHS

```

cooler-merge command line option, 49  
info (*cooler.Cooler* property), 25  
is\_cooler() (*in module cooler.fileops*), 36  
is\_multires\_file() (*in module cooler.fileops*), 36

## L

list\_coolers() (*in module cooler.fileops*), 36  
ln() (*in module cooler.fileops*), 37

## M

matrix() (*cooler.Cooler* method), 25  
merge\_coolers() (*in module cooler*), 29  
mv() (*in module cooler.fileops*), 37

## O

offset() (*cooler.Cooler* method), 26  
open() (*cooler.Cooler* method), 27  
OUT\_PATH  
cooler-merge command line option, 49

## P

PAIRS\_PATH  
cooler-cload-hiclib command line option, 46  
cooler-cload-pairix command line option, 44  
cooler-cload-pairs command line option, 43  
cooler-cload-tabix command line option, 45  
cooler-csort command line option, 61  
partition() (*in module cooler.util*), 37  
pixels() (*cooler.Cooler* method), 27  
PIXELS\_PATH  
cooler-load command line option, 47

## R

RANGE  
cooler-show command line option, 55  
read\_chromsizes() (*in module cooler.util*), 38  
rename\_chroms() (*in module cooler*), 32

## S

sanitize\_pixels() (*in module cooler.create*), 35  
sanitize\_records() (*in module cooler.create*), 35  
SRC\_URI  
cooler-cp command line option, 57  
cooler-ln command line option, 58  
cooler-mv command line option, 58  
storage\_mode (*cooler.Cooler* property), 27

## U

URI

cooler-attrs command line option, 56  
cooler-tree command line option, 56

## Z

zoomify\_cooler() (*in module cooler*), 31