CHAPTER

# TWELVE

# DATA PERSISTENCE

The modules described in this chapter support storing Python data in a persistent form on disk. The *pickle* and *marshal* modules can turn many Python data types into a stream of bytes and then recreate the objects from the bytes. The various DBM-related modules support a family of hash-based file formats that store a mapping of strings to other strings.

The list of modules described in this chapter is:

## 12.1 pickle — Python object serialization

**Source code:** Lib/pickle.py

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The *pickle* module implements binary protocols for serializing and de-serializing a Python object structure. *"Pickling"* is the process whereby a Python object hierarchy is converted into a byte stream, and *"unpickling"* is the inverse operation, whereby a byte stream (from a *binary file* or *bytes-like object*) is converted back into an object hierarchy. Pickling (and unpickling) is alternatively known as "serialization", "marshalling,"[1] or "flattening"; however, to avoid confusion, the terms used here are "pickling" and "unpickling".

**Warning:** The *pickle* module is not secure against erroneous or maliciously constructed data. Never unpickle data received from an untrusted or unauthenticated source.

### 12.1.1 Relationship to other Python modules

#### Comparison with marshal

Python has a more primitive serialization module called *marshal*, but in general *pickle* should always be the preferred way to serialize Python objects. *marshal* exists primarily to support Python's `.pyc` files.

The *pickle* module differs from *marshal* in several significant ways:

- The *pickle* module keeps track of the objects it has already serialized, so that later references to the same object won't be serialized again. *marshal* doesn't do this.

  This has implications both for recursive objects and object sharing. Recursive objects are objects that contain references to themselves. These are not handled by marshal, and in fact, attempting to marshal recursive objects will crash your Python interpreter. Object sharing happens when there are multiple references to the same object in different places in the object hierarchy being serialized. *pickle* stores such objects only once, and ensures that all other references point to the master copy. Shared objects remain shared, which can be very important for mutable objects.

[1] Don't confuse this with the *marshal* module

- *marshal* cannot be used to serialize user-defined classes and their instances. *pickle* can save and restore class instances transparently, however the class definition must be importable and live in the same module as when the object was stored.
- The *marshal* serialization format is not guaranteed to be portable across Python versions. Because its primary job in life is to support `.pyc` files, the Python implementers reserve the right to change the serialization format in non-backwards compatible ways should the need arise. The *pickle* serialization format is guaranteed to be backwards compatible across Python releases provided a compatible pickle protocol is chosen and pickling and unpickling code deals with Python 2 to Python 3 type differences if your data is crossing that unique breaking change language boundary.

#### Comparison with `json`

There are fundamental differences between the pickle protocols and JSON (JavaScript Object Notation):

- JSON is a text serialization format (it outputs unicode text, although most of the time it is then encoded to `utf-8`), while pickle is a binary serialization format;
- JSON is human-readable, while pickle is not;
- JSON is interoperable and widely used outside of the Python ecosystem, while pickle is Python-specific;
- JSON, by default, can only represent a subset of the Python built-in types, and no custom classes; pickle can represent an extremely large number of Python types (many of them automatically, by clever usage of Python's introspection facilities; complex cases can be tackled by implementing *specific object APIs*).

**See also:**

The *json* module: a standard library module allowing JSON serialization and deserialization.

### 12.1.2 Data stream format

The data format used by *pickle* is Python-specific. This has the advantage that there are no restrictions imposed by external standards such as JSON or XDR (which can't represent pointer sharing); however it means that non-Python programs may not be able to reconstruct pickled Python objects.

By default, the *pickle* data format uses a relatively compact binary representation. If you need optimal size characteristics, you can efficiently *compress* pickled data.

The module *pickletools* contains tools for analyzing data streams generated by *pickle*. *pickletools* source code has extensive comments about opcodes used by pickle protocols.

There are currently 5 different protocols which can be used for pickling. The higher the protocol used, the more recent the version of Python needed to read the pickle produced.

- Protocol version 0 is the original "human-readable" protocol and is backwards compatible with earlier versions of Python.
- Protocol version 1 is an old binary format which is also compatible with earlier versions of Python.
- Protocol version 2 was introduced in Python 2.3. It provides much more efficient pickling of *new-style class*es. Refer to **PEP 307** for information about improvements brought by protocol 2.
- Protocol version 3 was added in Python 3.0. It has explicit support for *bytes* objects and cannot be unpickled by Python 2.x. This is the default protocol, and the recommended protocol when compatibility with other Python 3 versions is required.
- Protocol version 4 was added in Python 3.4. It adds support for very large objects, pickling more kinds of objects, and some data format optimizations. Refer to **PEP 3154** for information about improvements brought by protocol 4.

**Note:** Serialization is a more primitive notion than persistence; although *pickle* reads and writes file objects, it does not handle the issue of naming persistent objects, nor the (even more complicated) issue of concurrent access to persistent objects. The *pickle* module can transform a complex object into a byte stream and it can transform the byte stream into an object with the same internal structure. Perhaps the most obvious thing to do with these byte streams is to write them onto a file, but it is also conceivable to send them across a network or store them in a database. The *shelve* module provides a simple interface to pickle and unpickle objects on DBM-style database files.

### 12.1.3 Module Interface

To serialize an object hierarchy, you simply call the *dumps()* function. Similarly, to de-serialize a data stream, you call the *loads()* function. However, if you want more control over serialization and de-serialization, you can create a *Pickler* or an *Unpickler* object, respectively.

The *pickle* module provides the following constants:

**pickle.HIGHEST_PROTOCOL**
An integer, the highest *protocol version* available. This value can be passed as a *protocol* value to functions *dump()* and *dumps()* as well as the *Pickler* constructor.

**pickle.DEFAULT_PROTOCOL**
An integer, the default *protocol version* used for pickling. May be less than *HIGHEST_PROTOCOL*. Currently the default protocol is 3, a new protocol designed for Python 3.

The *pickle* module provides the following functions to make the pickling process more convenient:

**pickle.dump**(*obj*, *file*, *protocol=None*, ***, *fix_imports=True*)
Write a pickled representation of *obj* to the open *file object* *file*. This is equivalent to `Pickler(file, protocol).dump(obj)`.

The optional *protocol* argument, an integer, tells the pickler to use the given protocol; supported protocols are 0 to *HIGHEST_PROTOCOL*. If not specified, the default is *DEFAULT_PROTOCOL*. If a negative number is specified, *HIGHEST_PROTOCOL* is selected.

The *file* argument must have a write() method that accepts a single bytes argument. It can thus be an on-disk file opened for binary writing, an *io.BytesIO* instance, or any other custom object that meets this interface.

If *fix_imports* is true and *protocol* is less than 3, pickle will try to map the new Python 3 names to the old module names used in Python 2, so that the pickle data stream is readable with Python 2.

**pickle.dumps**(*obj*, *protocol=None*, ***, *fix_imports=True*)
Return the pickled representation of the object as a *bytes* object, instead of writing it to a file.

Arguments *protocol* and *fix_imports* have the same meaning as in *dump()*.

**pickle.load**(*file*, ***, *fix_imports=True*, *encoding="ASCII"*, *errors="strict"*)
Read a pickled object representation from the open *file object* *file* and return the reconstituted object hierarchy specified therein. This is equivalent to `Unpickler(file).load()`.

The protocol version of the pickle is detected automatically, so no protocol argument is needed. Bytes past the pickled object's representation are ignored.

The argument *file* must have two methods, a read() method that takes an integer argument, and a readline() method that requires no arguments. Both methods should return bytes. Thus *file* can be an on-disk file opened for binary reading, an *io.BytesIO* object, or any other custom object that meets this interface.

Optional keyword arguments are *fix_imports*, *encoding* and *errors*, which are used to control compatibility support for pickle stream generated by Python 2. If *fix_imports* is true, pickle will try to map the old Python 2 names to the new names used in Python 3. The *encoding* and *errors* tell pickle how to decode 8-bit string instances pickled by Python 2; these default to 'ASCII' and 'strict', respectively. The *encoding* can be 'bytes' to read these 8-bit string instances as bytes objects. Using `encoding='latin1'` is required for unpickling NumPy arrays and instances of *datetime*, *date* and *time* pickled by Python 2.

**pickle.loads**(*bytes_object*, ***, *fix_imports=True*, *encoding="ASCII"*, *errors="strict"*)
Read a pickled object hierarchy from a *bytes* object and return the reconstituted object hierarchy specified therein.

The protocol version of the pickle is detected automatically, so no protocol argument is needed. Bytes past the pickled object's representation are ignored.

Optional keyword arguments are *fix_imports*, *encoding* and *errors*, which are used to control compatibility support for pickle stream generated by Python 2. If *fix_imports* is true, pickle will try to map the old Python 2 names to the new names used in Python 3. The *encoding* and *errors* tell pickle how to decode 8-bit string instances pickled by Python 2; these default to 'ASCII' and 'strict', respectively. The *encoding* can be 'bytes' to read these 8-bit string instances as bytes objects. Using `encoding='latin1'` is required for unpickling NumPy arrays and instances of *datetime*, *date* and *time* pickled by Python 2.

The *pickle* module defines three exceptions:

**exception pickle.PickleError**
Common base class for the other pickling exceptions. It inherits *Exception*.

**exception pickle.PicklingError**
Error raised when an unpicklable object is encountered by *Pickler*. It inherits *PickleError*.

Refer to *What can be pickled and unpickled?* to learn what kinds of objects can be pickled.

**exception pickle.UnpicklingError**
Error raised when there is a problem unpickling an object, such as a data corruption or a security violation. It inherits *PickleError*.

Note that other exceptions may also be raised during unpickling, including (but not necessarily limited to) AttributeError, EOFError, ImportError, and IndexError.

The *pickle* module exports two classes, *Pickler* and *Unpickler*:

**class pickle.Pickler**(*file*, *protocol=None*, ***, *fix_imports=True*)
This takes a binary file for writing a pickle data stream.

The optional *protocol* argument, an integer, tells the pickler to use the given protocol; supported protocols are 0 to *HIGHEST_PROTOCOL*. If not specified, the default is *DEFAULT_PROTOCOL*. If a negative number is specified, *HIGHEST_PROTOCOL* is selected.

The *file* argument must have a write() method that accepts a single bytes argument. It can thus be an on-disk file opened for binary writing, an *io.BytesIO* instance, or any other custom object that meets this interface.

If *fix_imports* is true and *protocol* is less than 3, pickle will try to map the new Python 3 names to the old module names used in Python 2, so that the pickle data stream is readable with Python 2.

**dump**(*obj*)
Write a pickled representation of *obj* to the open file object given in the constructor.

**persistent_id**(*obj*)
Do nothing by default. This exists so a subclass can override it.

If *persistent_id()* returns `None`, *obj* is pickled as usual. Any other value causes *Pickler* to emit the returned value as a persistent ID for *obj*. The meaning of this persistent ID should be

defined by *Unpickler.persistent_load()*. Note that the value returned by *persistent_id()* cannot itself have a persistent ID.

See *Persistence of External Objects* for details and examples of uses.

**dispatch_table**
A pickler object's dispatch table is a registry of *reduction functions* of the kind which can be declared using *copyreg.pickle()*. It is a mapping whose keys are classes and whose values are reduction functions. A reduction function takes a single argument of the associated class and should conform to the same interface as a *__reduce__()* method.

By default, a pickler object will not have a *dispatch_table* attribute, and it will instead use the global dispatch table managed by the *copyreg* module. However, to customize the pickling for a specific pickler object one can set the *dispatch_table* attribute to a dict-like object. Alternatively, if a subclass of *Pickler* has a *dispatch_table* attribute then this will be used as the default dispatch table for instances of that class.

See *Dispatch Tables* for usage examples.

New in version 3.3.

**fast**
Deprecated. Enable fast mode if set to a true value. The fast mode disables the usage of memo, therefore speeding the pickling process by not generating superfluous PUT opcodes. It should not be used with self-referential objects, doing otherwise will cause *Pickler* to recurse infinitely.

Use *pickletools.optimize()* if you need more compact pickles.

**class pickle.Unpickler**(*file*, ***, *fix_imports=True*, *encoding="ASCII"*, *errors="strict"*)
This takes a binary file for reading a pickle data stream.

The protocol version of the pickle is detected automatically, so no protocol argument is needed.

The argument *file* must have two methods, a read() method that takes an integer argument, and a readline() method that requires no arguments. Both methods should return bytes. Thus *file* can be an on-disk file object opened for binary reading, an *io.BytesIO* object, or any other custom object that meets this interface.

Optional keyword arguments are *fix_imports*, *encoding* and *errors*, which are used to control compatibility support for pickle stream generated by Python 2. If *fix_imports* is true, pickle will try to map the old Python 2 names to the new names used in Python 3. The *encoding* and *errors* tell pickle how to decode 8-bit string instances pickled by Python 2; these default to 'ASCII' and 'strict', respectively. The *encoding* can be 'bytes' to read these 8-bit string instances as bytes objects.

**load()**
Read a pickled object representation from the open file object given in the constructor, and return the reconstituted object hierarchy specified therein. Bytes past the pickled object's representation are ignored.

**persistent_load**(*pid*)
Raise an *UnpicklingError* by default.

If defined, *persistent_load()* should return the object specified by the persistent ID *pid*. If an invalid persistent ID is encountered, an *UnpicklingError* should be raised.

See *Persistence of External Objects* for details and examples of uses.

**find_class**(*module*, *name*)
Import *module* if necessary and return the object called *name* from it, where the *module* and *name* arguments are *str* objects. Note, unlike its name suggests, *find_class()* is also used for finding functions.

Subclasses may override this to gain control over what type of objects and how they can be loaded, potentially reducing security risks. Refer to *Restricting Globals* for details.

### 12.1.4 What can be pickled and unpickled?

The following types can be pickled:

- `None`, `True`, and `False`
- integers, floating point numbers, complex numbers
- strings, bytes, bytearrays
- tuples, lists, sets, and dictionaries containing only picklable objects
- functions defined at the top level of a module (using `def`, not `lambda`)
- built-in functions defined at the top level of a module
- classes that are defined at the top level of a module
- instances of such classes whose *__dict__* or the result of calling *__getstate__()* is picklable (see section *Pickling Class Instances* for details).

Attempts to pickle unpicklable objects will raise the *PicklingError* exception; when this happens, an unspecified number of bytes may have already been written to the underlying file. Trying to pickle a highly recursive data structure may exceed the maximum recursion depth, a *RecursionError* will be raised in this case. You can carefully raise this limit with *sys.setrecursionlimit()*.

Note that functions (built-in and user-defined) are pickled by "fully qualified" name reference, not by value.[2] This means that only the function name is pickled, along with the name of the module the function is defined in. Neither the function's code, nor any of its function attributes are pickled. Thus the defining module must be importable in the unpickling environment, and the module must contain the named object, otherwise an exception will be raised.[3]

Similarly, classes are pickled by named reference, so the same restrictions in the unpickling environment apply. Note that none of the class's code or data is pickled, so in the following example the class attribute `attr` is not restored in the unpickling environment:

```
class Foo:
    attr = 'A class attribute'

picklestring = pickle.dumps(Foo)
```

These restrictions are why picklable functions and classes must be defined in the top level of a module.

Similarly, when class instances are pickled, their class's code and data are not pickled along with them. Only the instance data are pickled. This is done on purpose, so you can fix bugs in a class or add methods to the class and still load objects that were created with an earlier version of the class. If you plan to have long-lived objects that will see many versions of a class, it may be worthwhile to put a version number in the objects so that suitable conversions can be made by the class's *__setstate__()* method.

### 12.1.5 Pickling Class Instances

In this section, we describe the general mechanisms available to you to define, customize, and control how class instances are pickled and unpickled.

In most cases, no additional code is needed to make instances picklable. By default, pickle will retrieve the class and the attributes of an instance via introspection. When a class instance is unpickled, its `__init__()` method is usually *not* invoked. The default behaviour first creates an uninitialized instance and then restores the saved attributes. The following code shows an implementation of this behaviour:

[2] This is why `lambda` functions cannot be pickled: all `lambda` functions share the same name: `<lambda>`.
[3] The exception raised will likely be an *ImportError* or an *AttributeError* but it could be something else.

```
def save(obj):
    return (obj.__class__, obj.__dict__)

def load(cls, attributes):
    obj = cls.__new__(cls)
    obj.__dict__.update(attributes)
    return obj
```

Classes can alter the default behaviour by providing one or several special methods:

`object.__getnewargs_ex__()`
: In protocols 2 and newer, classes that implements the *__getnewargs_ex__()* method can dictate the values passed to the `__new__()` method upon unpickling. The method must return a pair `(args, kwargs)` where *args* is a tuple of positional arguments and *kwargs* a dictionary of named arguments for constructing the object. Those will be passed to the `__new__()` method upon unpickling.

  You should implement this method if the `__new__()` method of your class requires keyword-only arguments. Otherwise, it is recommended for compatibility to implement *__getnewargs__()*.

  Changed in version 3.6: *__getnewargs_ex__()* is now used in protocols 2 and 3.

`object.__getnewargs__()`
: This method serves a similar purpose as *__getnewargs_ex__()*, but supports only positional arguments. It must return a tuple of arguments `args` which will be passed to the `__new__()` method upon unpickling.

  *__getnewargs__()* will not be called if *__getnewargs_ex__()* is defined.

  Changed in version 3.6: Before Python 3.6, *__getnewargs__()* was called instead of *__getnewargs_ex__()* in protocols 2 and 3.

`object.__getstate__()`
: Classes can further influence how their instances are pickled; if the class defines the method *__getstate__()*, it is called and the returned object is pickled as the contents for the instance, instead of the contents of the instance's dictionary. If the *__getstate__()* method is absent, the instance's *__dict__* is pickled as usual.

`object.__setstate__(`*state*`)`
: Upon unpickling, if the class defines *__setstate__()*, it is called with the unpickled state. In that case, there is no requirement for the state object to be a dictionary. Otherwise, the pickled state must be a dictionary and its items are assigned to the new instance's dictionary.

  ---

  **Note:** If *__getstate__()* returns a false value, the *__setstate__()* method will not be called upon unpickling.

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Refer to the section *Handling Stateful Objects* for more information about how to use the methods *__getstate__()* and *__setstate__()*.

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**Note:** At unpickling time, some methods like `__getattr__()`, `__getattribute__()`, or `__setattr__()` may be called upon the instance. In case those methods rely on some internal invariant being true, the type should implement *__getnewargs__()* or *__getnewargs_ex__()* to establish such an invariant; otherwise, neither `__new__()` nor `__init__()` will be called.

---

As we shall see, pickle does not use directly the methods described above. In fact, these methods are part of the copy protocol which implements the *__reduce__()* special method. The copy protocol provides a

unified interface for retrieving the data necessary for pickling and copying objects.[4]

Although powerful, implementing *__reduce__()* directly in your classes is error prone. For this reason, class designers should use the high-level interface (i.e., *__getnewargs_ex__()*, *__getstate__()* and *__setstate__()*) whenever possible. We will show, however, cases where using *__reduce__()* is the only option or leads to more efficient pickling or both.

`object.__reduce__()`

The interface is currently defined as follows. The *__reduce__()* method takes no argument and shall return either a string or preferably a tuple (the returned object is often referred to as the "reduce value").

If a string is returned, the string should be interpreted as the name of a global variable. It should be the object's local name relative to its module; the pickle module searches the module namespace to determine the object's module. This behaviour is typically useful for singletons.

When a tuple is returned, it must be between two and five items long. Optional items can either be omitted, or `None` can be provided as their value. The semantics of each item are in order:

- A callable object that will be called to create the initial version of the object.
- A tuple of arguments for the callable object. An empty tuple must be given if the callable does not accept any argument.
- Optionally, the object's state, which will be passed to the object's *__setstate__()* method as previously described. If the object has no such method then, the value must be a dictionary and it will be added to the object's *__dict__* attribute.
- Optionally, an iterator (and not a sequence) yielding successive items. These items will be appended to the object either using `obj.append(item)` or, in batch, using `obj.extend(list_of_items)`. This is primarily used for list subclasses, but may be used by other classes as long as they have `append()` and `extend()` methods with the appropriate signature. (Whether `append()` or `extend()` is used depends on which pickle protocol version is used as well as the number of items to append, so both must be supported.)
- Optionally, an iterator (not a sequence) yielding successive key-value pairs. These items will be stored to the object using `obj[key] = value`. This is primarily used for dictionary subclasses, but may be used by other classes as long as they implement `__setitem__()`.

`object.__reduce_ex__(`*protocol*`)`

Alternatively, a *__reduce_ex__()* method may be defined. The only difference is this method should take a single integer argument, the protocol version. When defined, pickle will prefer it over the *__reduce__()* method. In addition, *__reduce__()* automatically becomes a synonym for the extended version. The main use for this method is to provide backwards-compatible reduce values for older Python releases.

### Persistence of External Objects

For the benefit of object persistence, the *pickle* module supports the notion of a reference to an object outside the pickled data stream. Such objects are referenced by a persistent ID, which should be either a string of alphanumeric characters (for protocol 0)[5] or just an arbitrary object (for any newer protocol).

The resolution of such persistent IDs is not defined by the *pickle* module; it will delegate this resolution to the user defined methods on the pickler and unpickler, *persistent_id()* and *persistent_load()* respectively.

[4] The *copy* module uses this protocol for shallow and deep copying operations.

[5] The limitation on alphanumeric characters is due to the fact the persistent IDs, in protocol 0, are delimited by the newline character. Therefore if any kind of newline characters occurs in persistent IDs, the resulting pickle will become unreadable.

To pickle objects that have an external persistent id, the pickler must have a custom *persistent_id()* method that takes an object as an argument and returns either `None` or the persistent id for that object. When `None` is returned, the pickler simply pickles the object as normal. When a persistent ID string is returned, the pickler will pickle that object, along with a marker so that the unpickler will recognize it as a persistent ID.

To unpickle external objects, the unpickler must have a custom *persistent_load()* method that takes a persistent ID object and returns the referenced object.

Here is a comprehensive example presenting how persistent ID can be used to pickle external objects by reference.

```
# Simple example presenting how persistent ID can be used to pickle
# external objects by reference.

import pickle
import sqlite3
from collections import namedtuple

# Simple class representing a record in our database.
MemoRecord = namedtuple("MemoRecord", "key, task")

class DBPickler(pickle.Pickler):

    def persistent_id(self, obj):
        # Instead of pickling MemoRecord as a regular class instance, we emit a
        # persistent ID.
        if isinstance(obj, MemoRecord):
            # Here, our persistent ID is simply a tuple, containing a tag and a
            # key, which refers to a specific record in the database.
            return ("MemoRecord", obj.key)
        else:
            # If obj does not have a persistent ID, return None. This means obj
            # needs to be pickled as usual.
            return None


class DBUnpickler(pickle.Unpickler):

    def __init__(self, file, connection):
        super().__init__(file)
        self.connection = connection

    def persistent_load(self, pid):
        # This method is invoked whenever a persistent ID is encountered.
        # Here, pid is the tuple returned by DBPickler.
        cursor = self.connection.cursor()
        type_tag, key_id = pid
        if type_tag == "MemoRecord":
            # Fetch the referenced record from the database and return it.
            cursor.execute("SELECT * FROM memos WHERE key=?", (str(key_id),))
            key, task = cursor.fetchone()
            return MemoRecord(key, task)
        else:
```

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```
            # Always raises an error if you cannot return the correct object.
            # Otherwise, the unpickler will think None is the object referenced
            # by the persistent ID.
            raise pickle.UnpicklingError("unsupported persistent object")


def main():
    import io
    import pprint

    # Initialize and populate our database.
    conn = sqlite3.connect(":memory:")
    cursor = conn.cursor()
    cursor.execute("CREATE TABLE memos(key INTEGER PRIMARY KEY, task TEXT)")
    tasks = (
        'give food to fish',
        'prepare group meeting',
        'fight with a zebra',
        )
    for task in tasks:
        cursor.execute("INSERT INTO memos VALUES(NULL, ?)", (task,))

    # Fetch the records to be pickled.
    cursor.execute("SELECT * FROM memos")
    memos = [MemoRecord(key, task) for key, task in cursor]
    # Save the records using our custom DBPickler.
    file = io.BytesIO()
    DBPickler(file).dump(memos)

    print("Pickled records:")
    pprint.pprint(memos)

    # Update a record, just for good measure.
    cursor.execute("UPDATE memos SET task='learn italian' WHERE key=1")

    # Load the records from the pickle data stream.
    file.seek(0)
    memos = DBUnpickler(file, conn).load()

    print("Unpickled records:")
    pprint.pprint(memos)


if __name__ == '__main__':
    main()
```

### Dispatch Tables

If one wants to customize pickling of some classes without disturbing any other code which depends on pickling, then one can create a pickler with a private dispatch table.

The global dispatch table managed by the *copyreg* module is available as `copyreg.dispatch_table`. There-

fore, one may choose to use a modified copy of `copyreg.dispatch_table` as a private dispatch table.

For example

```
f = io.BytesIO()
p = pickle.Pickler(f)
p.dispatch_table = copyreg.dispatch_table.copy()
p.dispatch_table[SomeClass] = reduce_SomeClass
```

creates an instance of *pickle.Pickler* with a private dispatch table which handles the `SomeClass` class specially. Alternatively, the code

```
class MyPickler(pickle.Pickler):
    dispatch_table = copyreg.dispatch_table.copy()
    dispatch_table[SomeClass] = reduce_SomeClass
f = io.BytesIO()
p = MyPickler(f)
```

does the same, but all instances of `MyPickler` will by default share the same dispatch table. The equivalent code using the *copyreg* module is

```
copyreg.pickle(SomeClass, reduce_SomeClass)
f = io.BytesIO()
p = pickle.Pickler(f)
```

### Handling Stateful Objects

Here's an example that shows how to modify pickling behavior for a class. The `TextReader` class opens a text file, and returns the line number and line contents each time its `readline()` method is called. If a `TextReader` instance is pickled, all attributes *except* the file object member are saved. When the instance is unpickled, the file is reopened, and reading resumes from the last location. The *__setstate__()* and *__getstate__()* methods are used to implement this behavior.

```
class TextReader:
    """Print and number lines in a text file."""

    def __init__(self, filename):
        self.filename = filename
        self.file = open(filename)
        self.lineno = 0

    def readline(self):
        self.lineno += 1
        line = self.file.readline()
        if not line:
            return None
        if line.endswith('\n'):
            line = line[:-1]
        return "%i: %s" % (self.lineno, line)

    def __getstate__(self):
        # Copy the object's state from self.__dict__ which contains
        # all our instance attributes. Always use the dict.copy()
        # method to avoid modifying the original state.
```

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```
        state = self.__dict__.copy()
        # Remove the unpicklable entries.
        del state['file']
        return state

    def __setstate__(self, state):
        # Restore instance attributes (i.e., filename and lineno).
        self.__dict__.update(state)
        # Restore the previously opened file's state. To do so, we need to
        # reopen it and read from it until the line count is restored.
        file = open(self.filename)
        for _ in range(self.lineno):
            file.readline()
        # Finally, save the file.
        self.file = file
```

A sample usage might be something like this:

```
>>> reader = TextReader("hello.txt")
>>> reader.readline()
'1: Hello world!'
>>> reader.readline()
'2: I am line number two.'
>>> new_reader = pickle.loads(pickle.dumps(reader))
>>> new_reader.readline()
'3: Goodbye!'
```

### 12.1.6 Restricting Globals

By default, unpickling will import any class or function that it finds in the pickle data. For many applications, this behaviour is unacceptable as it permits the unpickler to import and invoke arbitrary code. Just consider what this hand-crafted pickle data stream does when loaded:

```
>>> import pickle
>>> pickle.loads(b"cos\nsystem\n(S'echo hello world'\ntR.")
hello world
0
```

In this example, the unpickler imports the *os.system()* function and then apply the string argument "echo hello world". Although this example is inoffensive, it is not difficult to imagine one that could damage your system.

For this reason, you may want to control what gets unpickled by customizing *Unpickler.find_class()*. Unlike its name suggests, *Unpickler.find_class()* is called whenever a global (i.e., a class or a function) is requested. Thus it is possible to either completely forbid globals or restrict them to a safe subset.

Here is an example of an unpickler allowing only few safe classes from the *builtins* module to be loaded:

```
import builtins
import io
import pickle
```

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```
safe_builtins = {
    'range',
    'complex',
    'set',
    'frozenset',
    'slice',
}

class RestrictedUnpickler(pickle.Unpickler):

    def find_class(self, module, name):
        # Only allow safe classes from builtins.
        if module == "builtins" and name in safe_builtins:
            return getattr(builtins, name)
        # Forbid everything else.
        raise pickle.UnpicklingError("global '%s.%s' is forbidden" %
                                     (module, name))

def restricted_loads(s):
    """Helper function analogous to pickle.loads()."""
    return RestrictedUnpickler(io.BytesIO(s)).load()
```

A sample usage of our unpickler working has intended:

```
>>> restricted_loads(pickle.dumps([1, 2, range(15)]))
[1, 2, range(0, 15)]
>>> restricted_loads(b"cos\nsystem\n(S'echo hello world'\ntR.")
Traceback (most recent call last):
  ...
pickle.UnpicklingError: global 'os.system' is forbidden
>>> restricted_loads(b'cbuiltins\neval\n'
...                  b'(S\'getattr(__import__("os"), "system")'
...                  b'("echo hello world")\'\ntR.')
Traceback (most recent call last):
  ...
pickle.UnpicklingError: global 'builtins.eval' is forbidden
```

As our examples shows, you have to be careful with what you allow to be unpickled. Therefore if security is a concern, you may want to consider alternatives such as the marshalling API in *xmlrpc.client* or third-party solutions.

### 12.1.7 Performance

Recent versions of the pickle protocol (from protocol 2 and upwards) feature efficient binary encodings for several common features and built-in types. Also, the *pickle* module has a transparent optimizer written in C.

### 12.1.8 Examples

For the simplest code, use the *dump()* and *load()* functions.

```
import pickle

# An arbitrary collection of objects supported by pickle.
data = {
    'a': [1, 2.0, 3, 4+6j],
    'b': ("character string", b"byte string"),
    'c': {None, True, False}
}

with open('data.pickle', 'wb') as f:
    # Pickle the 'data' dictionary using the highest protocol available.
    pickle.dump(data, f, pickle.HIGHEST_PROTOCOL)
```

The following example reads the resulting pickled data.

```
import pickle

with open('data.pickle', 'rb') as f:
    # The protocol version used is detected automatically, so we do not
    # have to specify it.
    data = pickle.load(f)
```

**See also:**

**Module** *copyreg* Pickle interface constructor registration for extension types.

**Module** *pickletools* Tools for working with and analyzing pickled data.

**Module** *shelve* Indexed databases of objects; uses *pickle*.

**Module** *copy* Shallow and deep object copying.

**Module** *marshal* High-performance serialization of built-in types.

## 12.2 copyreg — Register pickle support functions

**Source code:** Lib/copyreg.py

---

The *copyreg* module offers a way to define functions used while pickling specific objects. The *pickle* and *copy* modules use those functions when pickling/copying those objects. The module provides configuration information about object constructors which are not classes. Such constructors may be factory functions or class instances.

copyreg.**constructor**(*object*)
Declares *object* to be a valid constructor. If *object* is not callable (and hence not valid as a constructor), raises *TypeError*.

copyreg.**pickle**(*type*, *function*, *constructor=None*)
Declares that *function* should be used as a "reduction" function for objects of type *type*. *function* should return either a string or a tuple containing two or three elements.

The optional *constructor* parameter, if provided, is a callable object which can be used to reconstruct the object when called with the tuple of arguments returned by *function* at pickling time. *TypeError* will be raised if *object* is a class or *constructor* is not callable.

See the *pickle* module for more details on the interface expected of *function* and *constructor*. Note that the *dispatch_table* attribute of a pickler object or subclass of *pickle.Pickler* can also be used for declaring reduction functions.

### 12.2.1 Example

The example below would like to show how to register a pickle function and how it will be used:

```
>>> import copyreg, copy, pickle
>>> class C(object):
...     def __init__(self, a):
...         self.a = a
...
>>> def pickle_c(c):
...     print("pickling a C instance...")
...     return C, (c.a,)
...
>>> copyreg.pickle(C, pickle_c)
>>> c = C(1)
>>> d = copy.copy(c)  # doctest: +SKIP
pickling a C instance...
>>> p = pickle.dumps(c)  # doctest: +SKIP
pickling a C instance...
```

## 12.3 shelve — Python object persistence

**Source code:** Lib/shelve.py

---

A "shelf" is a persistent, dictionary-like object. The difference with "dbm" databases is that the values (not the keys!) in a shelf can be essentially arbitrary Python objects — anything that the *pickle* module can handle. This includes most class instances, recursive data types, and objects containing lots of shared sub-objects. The keys are ordinary strings.

**shelve.open**(*filename*, *flag='c'*, *protocol=None*, *writeback=False*)

Open a persistent dictionary. The filename specified is the base filename for the underlying database. As a side-effect, an extension may be added to the filename and more than one file may be created. By default, the underlying database file is opened for reading and writing. The optional *flag* parameter has the same interpretation as the *flag* parameter of *dbm.open()*.

By default, version 3 pickles are used to serialize values. The version of the pickle protocol can be specified with the *protocol* parameter.

Because of Python semantics, a shelf cannot know when a mutable persistent-dictionary entry is modified. By default modified objects are written *only* when assigned to the shelf (see *Example*). If the optional *writeback* parameter is set to `True`, all entries accessed are also cached in memory, and written back on *sync()* and *close()*; this can make it handier to mutate mutable entries in the persistent dictionary, but, if many entries are accessed, it can consume vast amounts of memory for the cache, and it can make the close operation very slow since all accessed entries are written back (there is no way to determine which accessed entries are mutable, nor which ones were actually mutated).

---

**Note:** Do not rely on the shelf being closed automatically; always call *close()* explicitly when you don't need it any more, or use *shelve.open()* as a context manager:

```
with shelve.open('spam') as db:
    db['eggs'] = 'eggs'
```

**Warning:** Because the *shelve* module is backed by *pickle*, it is insecure to load a shelf from an untrusted source. Like with pickle, loading a shelf can execute arbitrary code.

Shelf objects support all methods supported by dictionaries. This eases the transition from dictionary based scripts to those requiring persistent storage.

Two additional methods are supported:

`Shelf.sync()`
Write back all entries in the cache if the shelf was opened with *writeback* set to *True*. Also empty the cache and synchronize the persistent dictionary on disk, if feasible. This is called automatically when the shelf is closed with *close()*.

`Shelf.close()`
Synchronize and close the persistent *dict* object. Operations on a closed shelf will fail with a *ValueError*.

**See also:**

Persistent dictionary recipe with widely supported storage formats and having the speed of native dictionaries.

### 12.3.1 Restrictions

- The choice of which database package will be used (such as *dbm.ndbm* or *dbm.gnu*) depends on which interface is available. Therefore it is not safe to open the database directly using *dbm*. The database is also (unfortunately) subject to the limitations of *dbm*, if it is used — this means that (the pickled representation of) the objects stored in the database should be fairly small, and in rare cases key collisions may cause the database to refuse updates.
- The *shelve* module does not support *concurrent* read/write access to shelved objects. (Multiple simultaneous read accesses are safe.) When a program has a shelf open for writing, no other program should have it open for reading or writing. Unix file locking can be used to solve this, but this differs across Unix versions and requires knowledge about the database implementation used.

`class shelve.Shelf(`*dict*, *protocol=None*, *writeback=False*, *keyencoding='utf-8'*`)`
A subclass of *collections.abc.MutableMapping* which stores pickled values in the *dict* object.

By default, version 3 pickles are used to serialize values. The version of the pickle protocol can be specified with the *protocol* parameter. See the *pickle* documentation for a discussion of the pickle protocols.

If the *writeback* parameter is `True`, the object will hold a cache of all entries accessed and write them back to the *dict* at sync and close times. This allows natural operations on mutable entries, but can consume much more memory and make sync and close take a long time.

The *keyencoding* parameter is the encoding used to encode keys before they are used with the underlying dict.

A *Shelf* object can also be used as a context manager, in which case it will be automatically closed when the `with` block ends.

Changed in version 3.2: Added the *keyencoding* parameter; previously, keys were always encoded in UTF-8.

Changed in version 3.4: Added context manager support.

**class shelve.BsdDbShelf**(*dict*, *protocol=None*, *writeback=False*, *keyencoding='utf-8'*)
A subclass of *Shelf* which exposes `first()`, `next()`, `previous()`, `last()` and `set_location()` which are available in the third-party `bsddb` module from pybsddb but not in other database modules. The *dict* object passed to the constructor must support those methods. This is generally accomplished by calling one of `bsddb.hashopen()`, `bsddb.btopen()` or `bsddb.rnopen()`. The optional *protocol*, *writeback*, and *keyencoding* parameters have the same interpretation as for the *Shelf* class.

**class shelve.DbfilenameShelf**(*filename*, *flag='c'*, *protocol=None*, *writeback=False*)
A subclass of *Shelf* which accepts a *filename* instead of a dict-like object. The underlying file will be opened using *dbm.open()*. By default, the file will be created and opened for both read and write. The optional *flag* parameter has the same interpretation as for the *open()* function. The optional *protocol* and *writeback* parameters have the same interpretation as for the *Shelf* class.

### 12.3.2 Example

To summarize the interface (`key` is a string, `data` is an arbitrary object):

```
import shelve

d = shelve.open(filename)  # open -- file may get suffix added by low-level
                           # library

d[key] = data              # store data at key (overwrites old data if
                           # using an existing key)
data = d[key]              # retrieve a COPY of data at key (raise KeyError
                           # if no such key)
del d[key]                 # delete data stored at key (raises KeyError
                           # if no such key)

flag = key in d            # true if the key exists
klist = list(d.keys())     # a list of all existing keys (slow!)

# as d was opened WITHOUT writeback=True, beware:
d['xx'] = [0, 1, 2]        # this works as expected, but...
d['xx'].append(3)          # *this doesn't!* -- d['xx'] is STILL [0, 1, 2]!

# having opened d without writeback=True, you need to code carefully:
temp = d['xx']             # extracts the copy
temp.append(5)             # mutates the copy
d['xx'] = temp             # stores the copy right back, to persist it

# or, d=shelve.open(filename,writeback=True) would let you just code
# d['xx'].append(5) and have it work as expected, BUT it would also
# consume more memory and make the d.close() operation slower.

d.close()                  # close it
```

**See also:**

**Module** *dbm* Generic interface to `dbm`-style databases.

**Module** *pickle* Object serialization used by *shelve*.

## 12.4 marshal — Internal Python object serialization

This module contains functions that can read and write Python values in a binary format. The format is specific to Python, but independent of machine architecture issues (e.g., you can write a Python value to a file on a PC, transport the file to a Sun, and read it back there). Details of the format are undocumented on purpose; it may change between Python versions (although it rarely does).[1]

This is not a general "persistence" module. For general persistence and transfer of Python objects through RPC calls, see the modules *pickle* and *shelve*. The *marshal* module exists mainly to support reading and writing the "pseudo-compiled" code for Python modules of `.pyc` files. Therefore, the Python maintainers reserve the right to modify the marshal format in backward incompatible ways should the need arise. If you're serializing and de-serializing Python objects, use the *pickle* module instead – the performance is comparable, version independence is guaranteed, and pickle supports a substantially wider range of objects than marshal.

**Warning:** The *marshal* module is not intended to be secure against erroneous or maliciously constructed data. Never unmarshal data received from an untrusted or unauthenticated source.

Not all Python object types are supported; in general, only objects whose value is independent from a particular invocation of Python can be written and read by this module. The following types are supported: booleans, integers, floating point numbers, complex numbers, strings, bytes, bytearrays, tuples, lists, sets, frozensets, dictionaries, and code objects, where it should be understood that tuples, lists, sets, frozensets and dictionaries are only supported as long as the values contained therein are themselves supported. The singletons *None*, *Ellipsis* and *StopIteration* can also be marshalled and unmarshalled. For format *version* lower than 3, recursive lists, sets and dictionaries cannot be written (see below).

There are functions that read/write files as well as functions operating on bytes-like objects.

The module defines these functions:

`marshal.dump`(*value*, *file*[, *version*])

Write the value on the open file. The value must be a supported type. The file must be a writeable *binary file*.

If the value has (or contains an object that has) an unsupported type, a *ValueError* exception is raised — but garbage data will also be written to the file. The object will not be properly read back by *load()*.

The *version* argument indicates the data format that `dump` should use (see below).

`marshal.load`(*file*)

Read one value from the open file and return it. If no valid value is read (e.g. because the data has a different Python version's incompatible marshal format), raise *EOFError*, *ValueError* or *TypeError*. The file must be a readable *binary file*.

**Note:** If an object containing an unsupported type was marshalled with *dump()*, *load()* will substitute `None` for the unmarshallable type.

[1] The name of this module stems from a bit of terminology used by the designers of Modula-3 (amongst others), who use the term "marshalling" for shipping of data around in a self-contained form. Strictly speaking, "to marshal" means to convert some data from internal to external form (in an RPC buffer for instance) and "unmarshalling" for the reverse process.

`marshal.dumps(`*value*[, *version*]`)`
Return the bytes object that would be written to a file by `dump(value, file)`. The value must be a supported type. Raise a *ValueError* exception if value has (or contains an object that has) an unsupported type.

The *version* argument indicates the data format that `dumps` should use (see below).

`marshal.loads(`*bytes*`)`
Convert the *bytes-like object* to a value. If no valid value is found, raise *EOFError*, *ValueError* or *TypeError*. Extra bytes in the input are ignored.

In addition, the following constants are defined:

`marshal.version`
Indicates the format that the module uses. Version 0 is the historical format, version 1 shares interned strings and version 2 uses a binary format for floating point numbers. Version 3 adds support for object instancing and recursion. The current version is 4.

## 12.5 `dbm` — Interfaces to Unix "databases"

**Source code:** Lib/dbm/___init___.py

---

*dbm* is a generic interface to variants of the DBM database — *dbm.gnu* or *dbm.ndbm*. If none of these modules is installed, the slow-but-simple implementation in module *dbm.dumb* will be used. There is a third party interface to the Oracle Berkeley DB.

`exception dbm.error`
A tuple containing the exceptions that can be raised by each of the supported modules, with a unique exception also named *dbm.error* as the first item — the latter is used when *dbm.error* is raised.

`dbm.whichdb(`*filename*`)`
This function attempts to guess which of the several simple database modules available — *dbm.gnu*, *dbm.ndbm* or *dbm.dumb* — should be used to open a given file.

Returns one of the following values: `None` if the file can't be opened because it's unreadable or doesn't exist; the empty string (`''`) if the file's format can't be guessed; or a string containing the required module name, such as `'dbm.ndbm'` or `'dbm.gnu'`.

`dbm.open(`*file*, *flag='r'*, *mode=0o666*`)`
Open the database file *file* and return a corresponding object.

If the database file already exists, the *whichdb()* function is used to determine its type and the appropriate module is used; if it does not exist, the first module listed above that can be imported is used.

The optional *flag* argument can be:

| Value | Meaning |
|---|---|
| `'r'` | Open existing database for reading only (default) |
| `'w'` | Open existing database for reading and writing |
| `'c'` | Open database for reading and writing, creating it if it doesn't exist |
| `'n'` | Always create a new, empty database, open for reading and writing |

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal `0o666` (and will be modified by the prevailing umask).

The object returned by *open()* supports the same basic functionality as dictionaries; keys and their corresponding values can be stored, retrieved, and deleted, and the `in` operator and the `keys()` method are available, as well as `get()` and `setdefault()`.

Changed in version 3.2: `get()` and `setdefault()` are now available in all database modules.

Key and values are always stored as bytes. This means that when strings are used they are implicitly converted to the default encoding before being stored.

These objects also support being used in a `with` statement, which will automatically close them when done.

Changed in version 3.4: Added native support for the context management protocol to the objects returned by *open()*.

The following example records some hostnames and a corresponding title, and then prints out the contents of the database:

```
import dbm

# Open database, creating it if necessary.
with dbm.open('cache', 'c') as db:

    # Record some values
    db[b'hello'] = b'there'
    db['www.python.org'] = 'Python Website'
    db['www.cnn.com'] = 'Cable News Network'

    # Note that the keys are considered bytes now.
    assert db[b'www.python.org'] == b'Python Website'
    # Notice how the value is now in bytes.
    assert db['www.cnn.com'] == b'Cable News Network'

    # Often-used methods of the dict interface work too.
    print(db.get('python.org', b'not present'))

    # Storing a non-string key or value will raise an exception (most
    # likely a TypeError).
    db['www.yahoo.com'] = 4

# db is automatically closed when leaving the with statement.
```

**See also:**

**Module** *shelve* Persistence module which stores non-string data.

The individual submodules are described in the following sections.

### 12.5.1 `dbm.gnu` — GNU's reinterpretation of dbm

**Source code:** Lib/dbm/gnu.py

---

This module is quite similar to the *dbm* module, but uses the GNU library `gdbm` instead to provide some additional functionality. Please note that the file formats created by *dbm.gnu* and *dbm.ndbm* are incompatible.

The *dbm.gnu* module provides an interface to the GNU DBM library. `dbm.gnu.gdbm` objects behave like mappings (dictionaries), except that keys and values are always converted to bytes before storing. Printing a `gdbm` object doesn't print the keys and values, and the `items()` and `values()` methods are not supported.

**exception dbm.gnu.error**
Raised on *dbm.gnu*-specific errors, such as I/O errors. *KeyError* is raised for general mapping errors like specifying an incorrect key.

**dbm.gnu.open**(*filename*[, *flag*[, *mode*]])
Open a gdbm database and return a gdbm object. The *filename* argument is the name of the database file.

The optional *flag* argument can be:

| Value | Meaning |
|---|---|
| 'r' | Open existing database for reading only (default) |
| 'w' | Open existing database for reading and writing |
| 'c' | Open database for reading and writing, creating it if it doesn't exist |
| 'n' | Always create a new, empty database, open for reading and writing |

The following additional characters may be appended to the flag to control how the database is opened:

| Value | Meaning |
|---|---|
| 'f' | Open the database in fast mode. Writes to the database will not be synchronized. |
| 's' | Synchronized mode. This will cause changes to the database to be immediately written to the file. |
| 'u' | Do not lock database. |

Not all flags are valid for all versions of gdbm. The module constant open_flags is a string of supported flag characters. The exception *error* is raised if an invalid flag is specified.

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0o666.

In addition to the dictionary-like methods, gdbm objects have the following methods:

**gdbm.firstkey**()
It's possible to loop over every key in the database using this method and the *nextkey()* method. The traversal is ordered by gdbm's internal hash values, and won't be sorted by the key values. This method returns the starting key.

**gdbm.nextkey**(*key*)
Returns the key that follows *key* in the traversal. The following code prints every key in the database db, without having to create a list in memory that contains them all:

```
k = db.firstkey()
while k != None:
    print(k)
    k = db.nextkey(k)
```

**gdbm.reorganize**()
If you have carried out a lot of deletions and would like to shrink the space used by the gdbm file, this routine will reorganize the database. gdbm objects will not shorten the length of a database file except by using this reorganization; otherwise, deleted file space will be kept and reused as new (key, value) pairs are added.

**gdbm.sync**()
When the database has been opened in fast mode, this method forces any unwritten data to be written to the disk.

**gdbm.close**()
Close the gdbm database.

### 12.5.2 dbm.ndbm — Interface based on ndbm

**Source code:** Lib/dbm/ndbm.py

---

The *dbm.ndbm* module provides an interface to the Unix "(n)dbm" library. Dbm objects behave like mappings (dictionaries), except that keys and values are always stored as bytes. Printing a `dbm` object doesn't print the keys and values, and the `items()` and `values()` methods are not supported.

This module can be used with the "classic" ndbm interface or the GNU GDBM compatibility interface. On Unix, the `configure` script will attempt to locate the appropriate header file to simplify building this module.

**exception** dbm.ndbm.error
Raised on *dbm.ndbm*-specific errors, such as I/O errors. *KeyError* is raised for general mapping errors like specifying an incorrect key.

dbm.ndbm.library
Name of the `ndbm` implementation library used.

dbm.ndbm.open(*filename*[, *flag*[, *mode*]])
Open a dbm database and return a `ndbm` object. The *filename* argument is the name of the database file (without the `.dir` or `.pag` extensions).

The optional *flag* argument must be one of these values:

| Value | Meaning |
|---|---|
| `'r'` | Open existing database for reading only (default) |
| `'w'` | Open existing database for reading and writing |
| `'c'` | Open database for reading and writing, creating it if it doesn't exist |
| `'n'` | Always create a new, empty database, open for reading and writing |

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal `0o666` (and will be modified by the prevailing umask).

In addition to the dictionary-like methods, `ndbm` objects provide the following method:

ndbm.close()
Close the `ndbm` database.

### 12.5.3 dbm.dumb — Portable DBM implementation

**Source code:** Lib/dbm/dumb.py

---

**Note:** The *dbm.dumb* module is intended as a last resort fallback for the *dbm* module when a more robust module is not available. The *dbm.dumb* module is not written for speed and is not nearly as heavily used as the other database modules.

---

The *dbm.dumb* module provides a persistent dictionary-like interface which is written entirely in Python. Unlike other modules such as *dbm.gnu* no external library is required. As with other persistent mappings, the keys and values are always stored as bytes.

The module defines the following:

exception dbm.dumb.error
: Raised on *dbm.dumb*-specific errors, such as I/O errors. *KeyError* is raised for general mapping errors like specifying an incorrect key.

dbm.dumb.open(*filename*[, *flag*[, *mode*]])
: Open a dumbdbm database and return a dumbdbm object. The *filename* argument is the basename of the database file (without any specific extensions). When a dumbdbm database is created, files with .dat and .dir extensions are created.

  The optional *flag* argument supports only the semantics of 'c' and 'n' values. Other values will default to database being always opened for update, and will be created if it does not exist.

  The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0o666 (and will be modified by the prevailing umask).

  **Warning:** It is possible to crash the Python interpreter when loading a database with a sufficiently large/complex entry due to stack depth limitations in Python's AST compiler.

  Changed in version 3.5: *open()* always creates a new database when the flag has the value 'n'.

  Deprecated since version 3.6, will be removed in version 3.8: Creating database in 'r' and 'w' modes. Modifying database in 'r' mode.

  In addition to the methods provided by the *collections.abc.MutableMapping* class, dumbdbm objects provide the following methods:

  dumbdbm.sync()
  : Synchronize the on-disk directory and data files. This method is called by the Shelve.sync() method.

  dumbdbm.close()
  : Close the dumbdbm database.

## 12.6 sqlite3 — DB-API 2.0 interface for SQLite databases

**Source code:** Lib/sqlite3/

---

SQLite is a C library that provides a lightweight disk-based database that doesn't require a separate server process and allows accessing the database using a nonstandard variant of the SQL query language. Some applications can use SQLite for internal data storage. It's also possible to prototype an application using SQLite and then port the code to a larger database such as PostgreSQL or Oracle.

The sqlite3 module was written by Gerhard Häring. It provides a SQL interface compliant with the DB-API 2.0 specification described by **PEP 249**.

To use the module, you must first create a *Connection* object that represents the database. Here the data will be stored in the example.db file:

```
import sqlite3
conn = sqlite3.connect('example.db')
```

You can also supply the special name :memory: to create a database in RAM.

Once you have a *Connection*, you can create a *Cursor* object and call its *execute()* method to perform SQL commands:

```
c = conn.cursor()

# Create table
c.execute('''CREATE TABLE stocks
             (date text, trans text, symbol text, qty real, price real)''')

# Insert a row of data
c.execute("INSERT INTO stocks VALUES ('2006-01-05','BUY','RHAT',100,35.14)")

# Save (commit) the changes
conn.commit()

# We can also close the connection if we are done with it.
# Just be sure any changes have been committed or they will be lost.
conn.close()
```

The data you've saved is persistent and is available in subsequent sessions:

```
import sqlite3
conn = sqlite3.connect('example.db')
c = conn.cursor()
```

Usually your SQL operations will need to use values from Python variables. You shouldn't assemble your query using Python's string operations because doing so is insecure; it makes your program vulnerable to an SQL injection attack (see https://xkcd.com/327/ for humorous example of what can go wrong).

Instead, use the DB-API's parameter substitution. Put `?` as a placeholder wherever you want to use a value, and then provide a tuple of values as the second argument to the cursor's *execute()* method. (Other database modules may use a different placeholder, such as `%s` or `:1`.) For example:

```
# Never do this -- insecure!
symbol = 'RHAT'
c.execute("SELECT * FROM stocks WHERE symbol = '%s'" % symbol)

# Do this instead
t = ('RHAT',)
c.execute('SELECT * FROM stocks WHERE symbol=?', t)
print(c.fetchone())

# Larger example that inserts many records at a time
purchases = [('2006-03-28', 'BUY', 'IBM', 1000, 45.00),
             ('2006-04-05', 'BUY', 'MSFT', 1000, 72.00),
             ('2006-04-06', 'SELL', 'IBM', 500, 53.00),
            ]
c.executemany('INSERT INTO stocks VALUES (?,?,?,?,?)', purchases)
```

To retrieve data after executing a SELECT statement, you can either treat the cursor as an *iterator*, call the cursor's *fetchone()* method to retrieve a single matching row, or call *fetchall()* to get a list of the matching rows.

This example uses the iterator form:

```
>>> for row in c.execute('SELECT * FROM stocks ORDER BY price'):
        print(row)
```

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```
('2006-01-05', 'BUY', 'RHAT', 100, 35.14)
('2006-03-28', 'BUY', 'IBM', 1000, 45.0)
('2006-04-06', 'SELL', 'IBM', 500, 53.0)
('2006-04-05', 'BUY', 'MSFT', 1000, 72.0)
```

**See also:**

**https://github.com/ghaering/pysqlite** The pysqlite web page – sqlite3 is developed externally under the name "pysqlite".

**https://www.sqlite.org** The SQLite web page; the documentation describes the syntax and the available data types for the supported SQL dialect.

**https://www.w3schools.com/sql/** Tutorial, reference and examples for learning SQL syntax.

**PEP 249 - Database API Specification 2.0** PEP written by Marc-André Lemburg.

### 12.6.1 Module functions and constants

`sqlite3.version`
The version number of this module, as a string. This is not the version of the SQLite library.

`sqlite3.version_info`
The version number of this module, as a tuple of integers. This is not the version of the SQLite library.

`sqlite3.sqlite_version`
The version number of the run-time SQLite library, as a string.

`sqlite3.sqlite_version_info`
The version number of the run-time SQLite library, as a tuple of integers.

`sqlite3.PARSE_DECLTYPES`
This constant is meant to be used with the *detect_types* parameter of the *connect()* function.

Setting it makes the *sqlite3* module parse the declared type for each column it returns. It will parse out the first word of the declared type, i. e. for "integer primary key", it will parse out "integer", or for "number(10)" it will parse out "number". Then for that column, it will look into the converters dictionary and use the converter function registered for that type there.

`sqlite3.PARSE_COLNAMES`
This constant is meant to be used with the *detect_types* parameter of the *connect()* function.

Setting this makes the SQLite interface parse the column name for each column it returns. It will look for a string formed [mytype] in there, and then decide that 'mytype' is the type of the column. It will try to find an entry of 'mytype' in the converters dictionary and then use the converter function found there to return the value. The column name found in *Cursor.description* is only the first word of the column name, i. e. if you use something like `'as "x [datetime]"'` in your SQL, then we will parse out everything until the first blank for the column name: the column name would simply be "x".

`sqlite3.connect(`*database*[, *timeout*, *detect_types*, *isolation_level*, *check_same_thread*, *factory*, *cached_statements*, *uri*]`)`
Opens a connection to the SQLite database file *database*. By default returns a *Connection* object, unless a custom *factory* is given.

*database* is a *path-like object* giving the pathname (absolute or relative to the current working directory) of the database file to be opened. You can use `":memory:"` to open a database connection to a database that resides in RAM instead of on disk.

When a database is accessed by multiple connections, and one of the processes modifies the database, the SQLite database is locked until that transaction is committed. The *timeout* parameter specifies

how long the connection should wait for the lock to go away until raising an exception. The default for the timeout parameter is 5.0 (five seconds).

For the *isolation_level* parameter, please see the *isolation_level* property of *Connection* objects.

SQLite natively supports only the types TEXT, INTEGER, REAL, BLOB and NULL. If you want to use other types you must add support for them yourself. The *detect_types* parameter and the using custom **converters** registered with the module-level *register_converter()* function allow you to easily do that.

*detect_types* defaults to 0 (i. e. off, no type detection), you can set it to any combination of *PARSE_DECLTYPES* and *PARSE_COLNAMES* to turn type detection on.

By default, *check_same_thread* is *True* and only the creating thread may use the connection. If set *False*, the returned connection may be shared across multiple threads. When using multiple threads with the same connection writing operations should be serialized by the user to avoid data corruption.

By default, the *sqlite3* module uses its *Connection* class for the connect call. You can, however, subclass the *Connection* class and make *connect()* use your class instead by providing your class for the *factory* parameter.

Consult the section *SQLite and Python types* of this manual for details.

The *sqlite3* module internally uses a statement cache to avoid SQL parsing overhead. If you want to explicitly set the number of statements that are cached for the connection, you can set the *cached_statements* parameter. The currently implemented default is to cache 100 statements.

If *uri* is true, *database* is interpreted as a URI. This allows you to specify options. For example, to open a database in read-only mode you can use:

```
db = sqlite3.connect('file:path/to/database?mode=ro', uri=True)
```

More information about this feature, including a list of recognized options, can be found in the SQLite URI documentation.

Changed in version 3.4: Added the *uri* parameter.

Changed in version 3.7: *database* can now also be a *path-like object*, not only a string.

**sqlite3.register_converter**(*typename*, *callable*)

Registers a callable to convert a bytestring from the database into a custom Python type. The callable will be invoked for all database values that are of the type *typename*. Confer the parameter *detect_types* of the *connect()* function for how the type detection works. Note that *typename* and the name of the type in your query are matched in case-insensitive manner.

**sqlite3.register_adapter**(*type*, *callable*)

Registers a callable to convert the custom Python type *type* into one of SQLite's supported types. The callable *callable* accepts as single parameter the Python value, and must return a value of the following types: int, float, str or bytes.

**sqlite3.complete_statement**(*sql*)

Returns *True* if the string *sql* contains one or more complete SQL statements terminated by semicolons. It does not verify that the SQL is syntactically correct, only that there are no unclosed string literals and the statement is terminated by a semicolon.

This can be used to build a shell for SQLite, as in the following example:

```
# A minimal SQLite shell for experiments

import sqlite3

con = sqlite3.connect(":memory:")
```

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```
con.isolation_level = None
cur = con.cursor()

buffer = ""

print("Enter your SQL commands to execute in sqlite3.")
print("Enter a blank line to exit.")

while True:
    line = input()
    if line == "":
        break
    buffer += line
    if sqlite3.complete_statement(buffer):
        try:
            buffer = buffer.strip()
            cur.execute(buffer)

            if buffer.lstrip().upper().startswith("SELECT"):
                print(cur.fetchall())
        except sqlite3.Error as e:
            print("An error occurred:", e.args[0])
        buffer = ""

con.close()
```

sqlite3.**enable_callback_tracebacks**(*flag*)

By default you will not get any tracebacks in user-defined functions, aggregates, converters, authorizer callbacks etc. If you want to debug them, you can call this function with *flag* set to `True`. Afterwards, you will get tracebacks from callbacks on `sys.stderr`. Use *False* to disable the feature again.

### 12.6.2 Connection Objects

**class** sqlite3.**Connection**

A SQLite database connection has the following attributes and methods:

**isolation_level**

Get or set the current default isolation level. *None* for autocommit mode or one of "DEFERRED", "IMMEDIATE" or "EXCLUSIVE". See section *Controlling Transactions* for a more detailed explanation.

**in_transaction**

*True* if a transaction is active (there are uncommitted changes), *False* otherwise. Read-only attribute.

New in version 3.2.

**cursor**(*factory=Cursor*)

The cursor method accepts a single optional parameter *factory*. If supplied, this must be a callable returning an instance of *Cursor* or its subclasses.

**commit**()

This method commits the current transaction. If you don't call this method, anything you did since the last call to `commit()` is not visible from other database connections. If you wonder why

you don't see the data you've written to the database, please check you didn't forget to call this method.

**rollback()**
This method rolls back any changes to the database since the last call to *commit()*.

**close()**
This closes the database connection. Note that this does not automatically call *commit()*. If you just close your database connection without calling *commit()* first, your changes will be lost!

**execute**(*sql*[, *parameters*])
This is a nonstandard shortcut that creates a cursor object by calling the *cursor()* method, calls the cursor's *execute()* method with the *parameters* given, and returns the cursor.

**executemany**(*sql*[, *parameters*])
This is a nonstandard shortcut that creates a cursor object by calling the *cursor()* method, calls the cursor's *executemany()* method with the *parameters* given, and returns the cursor.

**executescript**(*sql_script*)
This is a nonstandard shortcut that creates a cursor object by calling the *cursor()* method, calls the cursor's *executescript()* method with the given *sql_script*, and returns the cursor.

**create_function**(*name*, *num_params*, *func*)
Creates a user-defined function that you can later use from within SQL statements under the function name *name*. *num_params* is the number of parameters the function accepts (if *num_params* is -1, the function may take any number of arguments), and *func* is a Python callable that is called as the SQL function.

The function can return any of the types supported by SQLite: bytes, str, int, float and `None`.

Example:

```
import sqlite3
import hashlib

def md5sum(t):
    return hashlib.md5(t).hexdigest()

con = sqlite3.connect(":memory:")
con.create_function("md5", 1, md5sum)
cur = con.cursor()
cur.execute("select md5(?)", (b"foo",))
print(cur.fetchone()[0])
```

**create_aggregate**(*name*, *num_params*, *aggregate_class*)
Creates a user-defined aggregate function.

The aggregate class must implement a `step` method, which accepts the number of parameters *num_params* (if *num_params* is -1, the function may take any number of arguments), and a `finalize` method which will return the final result of the aggregate.

The `finalize` method can return any of the types supported by SQLite: bytes, str, int, float and `None`.

Example:

```
import sqlite3

class MySum:
    def __init__(self):
```

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```
        self.count = 0

    def step(self, value):
        self.count += value

    def finalize(self):
        return self.count

con = sqlite3.connect(":memory:")
con.create_aggregate("mysum", 1, MySum)
cur = con.cursor()
cur.execute("create table test(i)")
cur.execute("insert into test(i) values (1)")
cur.execute("insert into test(i) values (2)")
cur.execute("select mysum(i) from test")
print(cur.fetchone()[0])
```

**create_collation**(*name*, *callable*)

Creates a collation with the specified *name* and *callable*. The callable will be passed two string arguments. It should return -1 if the first is ordered lower than the second, 0 if they are ordered equal and 1 if the first is ordered higher than the second. Note that this controls sorting (ORDER BY in SQL) so your comparisons don't affect other SQL operations.

Note that the callable will get its parameters as Python bytestrings, which will normally be encoded in UTF-8.

The following example shows a custom collation that sorts "the wrong way":

```
import sqlite3

def collate_reverse(string1, string2):
    if string1 == string2:
        return 0
    elif string1 < string2:
        return 1
    else:
        return -1

con = sqlite3.connect(":memory:")
con.create_collation("reverse", collate_reverse)

cur = con.cursor()
cur.execute("create table test(x)")
cur.executemany("insert into test(x) values (?)", [("a",), ("b",)])
cur.execute("select x from test order by x collate reverse")
for row in cur:
    print(row)
con.close()
```

To remove a collation, call `create_collation` with `None` as callable:

```
con.create_collation("reverse", None)
```

**interrupt**()

You can call this method from a different thread to abort any queries that might be executing on the connection. The query will then abort and the caller will get an exception.

**set_authorizer**(*authorizer_callback*)
This routine registers a callback. The callback is invoked for each attempt to access a column of a table in the database. The callback should return `SQLITE_OK` if access is allowed, `SQLITE_DENY` if the entire SQL statement should be aborted with an error and `SQLITE_IGNORE` if the column should be treated as a NULL value. These constants are available in the *sqlite3* module.

The first argument to the callback signifies what kind of operation is to be authorized. The second and third argument will be arguments or *None* depending on the first argument. The 4th argument is the name of the database ("main", "temp", etc.) if applicable. The 5th argument is the name of the inner-most trigger or view that is responsible for the access attempt or *None* if this access attempt is directly from input SQL code.

Please consult the SQLite documentation about the possible values for the first argument and the meaning of the second and third argument depending on the first one. All necessary constants are available in the *sqlite3* module.

**set_progress_handler**(*handler*, *n*)
This routine registers a callback. The callback is invoked for every *n* instructions of the SQLite virtual machine. This is useful if you want to get called from SQLite during long-running operations, for example to update a GUI.

If you want to clear any previously installed progress handler, call the method with *None* for *handler*.

Returning a non-zero value from the handler function will terminate the currently executing query and cause it to raise an *OperationalError* exception.

**set_trace_callback**(*trace_callback*)
Registers *trace_callback* to be called for each SQL statement that is actually executed by the SQLite backend.

The only argument passed to the callback is the statement (as string) that is being executed. The return value of the callback is ignored. Note that the backend does not only run statements passed to the *Cursor.execute()* methods. Other sources include the transaction management of the Python module and the execution of triggers defined in the current database.

Passing *None* as *trace_callback* will disable the trace callback.

New in version 3.3.

**enable_load_extension**(*enabled*)
This routine allows/disallows the SQLite engine to load SQLite extensions from shared libraries. SQLite extensions can define new functions, aggregates or whole new virtual table implementations. One well-known extension is the fulltext-search extension distributed with SQLite.

Loadable extensions are disabled by default. See[1].

New in version 3.2.

```
import sqlite3

con = sqlite3.connect(":memory:")

# enable extension loading
con.enable_load_extension(True)
```

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[1] The sqlite3 module is not built with loadable extension support by default, because some platforms (notably Mac OS X) have SQLite libraries which are compiled without this feature. To get loadable extension support, you must pass –enable-loadable-sqlite-extensions to configure.

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```
# Load the fulltext search extension
con.execute("select load_extension('./fts3.so')")

# alternatively you can load the extension using an API call:
# con.load_extension("./fts3.so")

# disable extension loading again
con.enable_load_extension(False)

# example from SQLite wiki
con.execute("create virtual table recipe using fts3(name, ingredients)")
con.executescript("""
    insert into recipe (name, ingredients) values ('broccoli stew', 'broccoli␣
↪peppers cheese tomatoes');
    insert into recipe (name, ingredients) values ('pumpkin stew', 'pumpkin␣
↪onions garlic celery');
    insert into recipe (name, ingredients) values ('broccoli pie', 'broccoli␣
↪cheese onions flour');
    insert into recipe (name, ingredients) values ('pumpkin pie', 'pumpkin␣
↪sugar flour butter');
    """)
for row in con.execute("select rowid, name, ingredients from recipe where name␣
↪match 'pie'"):
    print(row)
```

**load_extension**(*path*)

This routine loads a SQLite extension from a shared library. You have to enable extension loading with *enable_load_extension()* before you can use this routine.

Loadable extensions are disabled by default. See[1].

New in version 3.2.

**row_factory**

You can change this attribute to a callable that accepts the cursor and the original row as a tuple and will return the real result row. This way, you can implement more advanced ways of returning results, such as returning an object that can also access columns by name.

Example:

```
import sqlite3

def dict_factory(cursor, row):
    d = {}
    for idx, col in enumerate(cursor.description):
        d[col[0]] = row[idx]
    return d

con = sqlite3.connect(":memory:")
con.row_factory = dict_factory
cur = con.cursor()
cur.execute("select 1 as a")
print(cur.fetchone()["a"])
```

If returning a tuple doesn't suffice and you want name-based access to columns, you should consider setting *row_factory* to the highly-optimized *sqlite3.Row* type. *Row* provides both index-based and case-insensitive name-based access to columns with almost no memory overhead. It will probably be better than your own custom dictionary-based approach or even a db_row based solution.

**text_factory**

Using this attribute you can control what objects are returned for the TEXT data type. By default, this attribute is set to *str* and the *sqlite3* module will return Unicode objects for TEXT. If you want to return bytestrings instead, you can set it to *bytes*.

You can also set it to any other callable that accepts a single bytestring parameter and returns the resulting object.

See the following example code for illustration:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()

AUSTRIA = "\xd6sterreich"

# by default, rows are returned as Unicode
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert row[0] == AUSTRIA

# but we can make sqlite3 always return bytestrings ...
con.text_factory = bytes
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert type(row[0]) is bytes
# the bytestrings will be encoded in UTF-8, unless you stored garbage in the
# database ...
assert row[0] == AUSTRIA.encode("utf-8")

# we can also implement a custom text_factory ...
# here we implement one that appends "foo" to all strings
con.text_factory = lambda x: x.decode("utf-8") + "foo"
cur.execute("select ?", ("bar",))
row = cur.fetchone()
assert row[0] == "barfoo"
```

**total_changes**

Returns the total number of database rows that have been modified, inserted, or deleted since the database connection was opened.

**iterdump()**

Returns an iterator to dump the database in an SQL text format. Useful when saving an in-memory database for later restoration. This function provides the same capabilities as the .dump command in the **sqlite3** shell.

Example:

```
# Convert file existing_db.db to SQL dump file dump.sql
import sqlite3
```

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```
con = sqlite3.connect('existing_db.db')
with open('dump.sql', 'w') as f:
    for line in con.iterdump():
        f.write('%s\n' % line)
```

**backup**(*target*, ***, *pages=0*, *progress=None*, *name="main"*, *sleep=0.250*)

This method makes a backup of a SQLite database even while it's being accessed by other clients, or concurrently by the same connection. The copy will be written into the mandatory argument *target*, that must be another *Connection* instance.

By default, or when *pages* is either `0` or a negative integer, the entire database is copied in a single step; otherwise the method performs a loop copying up to *pages* pages at a time.

If *progress* is specified, it must either be `None` or a callable object that will be executed at each iteration with three integer arguments, respectively the *status* of the last iteration, the *remaining* number of pages still to be copied and the *total* number of pages.

The *name* argument specifies the database name that will be copied: it must be a string containing either `"main"`, the default, to indicate the main database, `"temp"` to indicate the temporary database or the name specified after the `AS` keyword in an `ATTACH DATABASE` statement for an attached database.

The *sleep* argument specifies the number of seconds to sleep by between successive attempts to backup remaining pages, can be specified either as an integer or a floating point value.

Example 1, copy an existing database into another:

```
import sqlite3

def progress(status, remaining, total):
    print(f'Copied {total-remaining} of {total} pages...')

con = sqlite3.connect('existing_db.db')
with sqlite3.connect('backup.db') as bck:
    con.backup(bck, pages=1, progress=progress)
```

Example 2, copy an existing database into a transient copy:

```
import sqlite3

source = sqlite3.connect('existing_db.db')
dest = sqlite3.connect(':memory:')
source.backup(dest)
```

Availability: SQLite 3.6.11 or higher

New in version 3.7.

### 12.6.3 Cursor Objects

**class sqlite3.Cursor**

A *Cursor* instance has the following attributes and methods.

**execute**(*sql*[, *parameters*])

Executes an SQL statement. The SQL statement may be parameterized (i. e. placeholders instead

of SQL literals). The *sqlite3* module supports two kinds of placeholders: question marks (qmark style) and named placeholders (named style).

Here's an example of both styles:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table people (name_last, age)")

who = "Yeltsin"
age = 72

# This is the qmark style:
cur.execute("insert into people values (?, ?)", (who, age))

# And this is the named style:
cur.execute("select * from people where name_last=:who and age=:age", {"who":␣
↪who, "age": age})

print(cur.fetchone())
```

*execute()* will only execute a single SQL statement. If you try to execute more than one statement with it, it will raise a *Warning*. Use *executescript()* if you want to execute multiple SQL statements with one call.

**executemany**(*sql*, *seq_of_parameters*)

Executes an SQL command against all parameter sequences or mappings found in the sequence *seq_of_parameters*. The *sqlite3* module also allows using an *iterator* yielding parameters instead of a sequence.

```
import sqlite3

class IterChars:
    def __init__(self):
        self.count = ord('a')

    def __iter__(self):
        return self

    def __next__(self):
        if self.count > ord('z'):
            raise StopIteration
        self.count += 1
        return (chr(self.count - 1),) # this is a 1-tuple

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table characters(c)")

theIter = IterChars()
cur.executemany("insert into characters(c) values (?)", theIter)

cur.execute("select c from characters")
```

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```
print(cur.fetchall())
```

Here's a shorter example using a *generator*:

```
import sqlite3
import string

def char_generator():
    for c in string.ascii_lowercase:
        yield (c,)

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table characters(c)")

cur.executemany("insert into characters(c) values (?)", char_generator())

cur.execute("select c from characters")
print(cur.fetchall())
```

**executescript**(*sql_script*)

This is a nonstandard convenience method for executing multiple SQL statements at once. It issues a `COMMIT` statement first, then executes the SQL script it gets as a parameter.

*sql_script* can be an instance of *str*.

Example:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.executescript("""
    create table person(
        firstname,
        lastname,
        age
    );

    create table book(
        title,
        author,
        published
    );

    insert into book(title, author, published)
    values (
        'Dirk Gently''s Holistic Detective Agency',
        'Douglas Adams',
        1987
    );
    """)
```

**fetchone**()

Fetches the next row of a query result set, returning a single sequence, or *None* when no more data is available.

**fetchmany**(*size=cursor.arraysize*)
Fetches the next set of rows of a query result, returning a list. An empty list is returned when no more rows are available.

The number of rows to fetch per call is specified by the *size* parameter. If it is not given, the cursor's arraysize determines the number of rows to be fetched. The method should try to fetch as many rows as indicated by the size parameter. If this is not possible due to the specified number of rows not being available, fewer rows may be returned.

Note there are performance considerations involved with the *size* parameter. For optimal performance, it is usually best to use the arraysize attribute. If the *size* parameter is used, then it is best for it to retain the same value from one *fetchmany()* call to the next.

**fetchall**()
Fetches all (remaining) rows of a query result, returning a list. Note that the cursor's arraysize attribute can affect the performance of this operation. An empty list is returned when no rows are available.

**close**()
Close the cursor now (rather than whenever `__del__` is called).

The cursor will be unusable from this point forward; a *ProgrammingError* exception will be raised if any operation is attempted with the cursor.

**rowcount**
Although the *Cursor* class of the *sqlite3* module implements this attribute, the database engine's own support for the determination of "rows affected"/"rows selected" is quirky.

For *executemany()* statements, the number of modifications are summed up into *rowcount*.

As required by the Python DB API Spec, the *rowcount* attribute "is -1 in case no `executeXX()` has been performed on the cursor or the rowcount of the last operation is not determinable by the interface". This includes `SELECT` statements because we cannot determine the number of rows a query produced until all rows were fetched.

With SQLite versions before 3.6.5, *rowcount* is set to 0 if you make a `DELETE FROM table` without any condition.

**lastrowid**
This read-only attribute provides the rowid of the last modified row. It is only set if you issued an `INSERT` or a `REPLACE` statement using the *execute()* method. For operations other than `INSERT` or `REPLACE` or when *executemany()* is called, *lastrowid* is set to *None*.

If the `INSERT` or `REPLACE` statement failed to insert the previous successful rowid is returned.

Changed in version 3.6: Added support for the `REPLACE` statement.

**arraysize**
Read/write attribute that controls the number of rows returned by *fetchmany()*. The default value is 1 which means a single row would be fetched per call.

**description**
This read-only attribute provides the column names of the last query. To remain compatible with the Python DB API, it returns a 7-tuple for each column where the last six items of each tuple are *None*.

It is set for `SELECT` statements without any matching rows as well.

**connection**
This read-only attribute provides the SQLite database *Connection* used by the *Cursor* object.

A *Cursor* object created by calling *con.cursor()* will have a *connection* attribute that refers to *con*:

```
>>> con = sqlite3.connect(":memory:")
>>> cur = con.cursor()
>>> cur.connection == con
True
```

### 12.6.4 Row Objects

**class sqlite3.Row**

A *Row* instance serves as a highly optimized *row_factory* for *Connection* objects. It tries to mimic a tuple in most of its features.

It supports mapping access by column name and index, iteration, representation, equality testing and *len()*.

If two *Row* objects have exactly the same columns and their members are equal, they compare equal.

**keys()**

This method returns a list of column names. Immediately after a query, it is the first member of each tuple in *Cursor.description*.

Changed in version 3.5: Added support of slicing.

Let's assume we initialize a table as in the example given above:

```
conn = sqlite3.connect(":memory:")
c = conn.cursor()
c.execute('''create table stocks
(date text, trans text, symbol text,
 qty real, price real)''')
c.execute("""insert into stocks
          values ('2006-01-05','BUY','RHAT',100,35.14)""")
conn.commit()
c.close()
```

Now we plug *Row* in:

```
>>> conn.row_factory = sqlite3.Row
>>> c = conn.cursor()
>>> c.execute('select * from stocks')
<sqlite3.Cursor object at 0x7f4e7dd8fa80>
>>> r = c.fetchone()
>>> type(r)
<class 'sqlite3.Row'>
>>> tuple(r)
('2006-01-05', 'BUY', 'RHAT', 100.0, 35.14)
>>> len(r)
5
>>> r[2]
'RHAT'
>>> r.keys()
['date', 'trans', 'symbol', 'qty', 'price']
>>> r['qty']
```

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```
100.0
>>> for member in r:
...     print(member)
...
2006-01-05
BUY
RHAT
100.0
35.14
```

### 12.6.5 Exceptions

**exception sqlite3.Warning**
A subclass of *Exception*.

**exception sqlite3.Error**
The base class of the other exceptions in this module. It is a subclass of *Exception*.

**exception sqlite3.DatabaseError**
Exception raised for errors that are related to the database.

**exception sqlite3.IntegrityError**
Exception raised when the relational integrity of the database is affected, e.g. a foreign key check fails. It is a subclass of *DatabaseError*.

**exception sqlite3.ProgrammingError**
Exception raised for programming errors, e.g. table not found or already exists, syntax error in the SQL statement, wrong number of parameters specified, etc. It is a subclass of *DatabaseError*.

**exception sqlite3.OperationalError**
Exception raised for errors that are related to the database's operation and not necessarily under the control of the programmer, e.g. an unexpected disconnect occurs, the data source name is not found, a transaction could not be processed, etc. It is a subclass of *DatabaseError*.

**exception sqlite3.NotSupportedError**
Exception raised in case a method or database API was used which is not supported by the database, e.g. calling the *rollback()* method on a connection that does not support transaction or has transactions turned off. It is a subclass of *DatabaseError*.

### 12.6.6 SQLite and Python types

#### Introduction

SQLite natively supports the following types: `NULL`, `INTEGER`, `REAL`, `TEXT`, `BLOB`.

The following Python types can thus be sent to SQLite without any problem:

| Python type | SQLite type |
|---|---|
| *None* | NULL |
| *int* | INTEGER |
| *float* | REAL |
| *str* | TEXT |
| *bytes* | BLOB |

This is how SQLite types are converted to Python types by default:

| SQLite type | Python type |
|---|---|
| NULL | *None* |
| INTEGER | *int* |
| REAL | *float* |
| TEXT | depends on *text_factory*, *str* by default |
| BLOB | *bytes* |

The type system of the *sqlite3* module is extensible in two ways: you can store additional Python types in a SQLite database via object adaptation, and you can let the *sqlite3* module convert SQLite types to different Python types via converters.

### Using adapters to store additional Python types in SQLite databases

As described before, SQLite supports only a limited set of types natively. To use other Python types with SQLite, you must **adapt** them to one of the sqlite3 module's supported types for SQLite: one of NoneType, int, float, str, bytes.

There are two ways to enable the *sqlite3* module to adapt a custom Python type to one of the supported ones.

### Letting your object adapt itself

This is a good approach if you write the class yourself. Let's suppose you have a class like this:

```
class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y
```

Now you want to store the point in a single SQLite column. First you'll have to choose one of the supported types first to be used for representing the point. Let's just use str and separate the coordinates using a semicolon. Then you need to give your class a method `__conform__(self, protocol)` which must return the converted value. The parameter *protocol* will be `PrepareProtocol`.

```
import sqlite3

class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

    def __conform__(self, protocol):
        if protocol is sqlite3.PrepareProtocol:
            return "%f;%f" % (self.x, self.y)

con = sqlite3.connect(":memory:")
cur = con.cursor()

p = Point(4.0, -3.2)
cur.execute("select ?", (p,))
print(cur.fetchone()[0])
```

### Registering an adapter callable

The other possibility is to create a function that converts the type to the string representation and register the function with *register_adapter()*.

```
import sqlite3

class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

def adapt_point(point):
    return "%f;%f" % (point.x, point.y)

sqlite3.register_adapter(Point, adapt_point)

con = sqlite3.connect(":memory:")
cur = con.cursor()

p = Point(4.0, -3.2)
cur.execute("select ?", (p,))
print(cur.fetchone()[0])
```

The *sqlite3* module has two default adapters for Python's built-in *datetime.date* and *datetime.datetime* types. Now let's suppose we want to store *datetime.datetime* objects not in ISO representation, but as a Unix timestamp.

```
import sqlite3
import datetime
import time

def adapt_datetime(ts):
    return time.mktime(ts.timetuple())

sqlite3.register_adapter(datetime.datetime, adapt_datetime)

con = sqlite3.connect(":memory:")
cur = con.cursor()

now = datetime.datetime.now()
cur.execute("select ?", (now,))
print(cur.fetchone()[0])
```

### Converting SQLite values to custom Python types

Writing an adapter lets you send custom Python types to SQLite. But to make it really useful we need to make the Python to SQLite to Python roundtrip work.

Enter converters.

Let's go back to the `Point` class. We stored the x and y coordinates separated via semicolons as strings in SQLite.

First, we'll define a converter function that accepts the string as a parameter and constructs a `Point` object from it.

**Note:** Converter functions **always** get called with a *bytes* object, no matter under which data type you sent the value to SQLite.

```
def convert_point(s):
    x, y = map(float, s.split(b";"))
    return Point(x, y)
```

Now you need to make the *sqlite3* module know that what you select from the database is actually a point. There are two ways of doing this:

- Implicitly via the declared type
- Explicitly via the column name

Both ways are described in section *Module functions and constants*, in the entries for the constants *PARSE_DECLTYPES* and *PARSE_COLNAMES*.

The following example illustrates both approaches.

```
import sqlite3

class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

    def __repr__(self):
        return "(%f;%f)" % (self.x, self.y)

def adapt_point(point):
    return ("%f;%f" % (point.x, point.y)).encode('ascii')

def convert_point(s):
    x, y = list(map(float, s.split(b";")))
    return Point(x, y)

# Register the adapter
sqlite3.register_adapter(Point, adapt_point)

# Register the converter
sqlite3.register_converter("point", convert_point)

p = Point(4.0, -3.2)

#########################
# 1) Using declared types
con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_DECLTYPES)
cur = con.cursor()
cur.execute("create table test(p point)")

cur.execute("insert into test(p) values (?)", (p,))
cur.execute("select p from test")
print("with declared types:", cur.fetchone()[0])
cur.close()
con.close()
```

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```
#######################
# 1) Using column names
con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_COLNAMES)
cur = con.cursor()
cur.execute("create table test(p)")

cur.execute("insert into test(p) values (?)", (p,))
cur.execute('select p as "p [point]" from test')
print("with column names:", cur.fetchone()[0])
cur.close()
con.close()
```

### Default adapters and converters

There are default adapters for the date and datetime types in the datetime module. They will be sent as ISO dates/ISO timestamps to SQLite.

The default converters are registered under the name "date" for *datetime.date* and under the name "timestamp" for *datetime.datetime*.

This way, you can use date/timestamps from Python without any additional fiddling in most cases. The format of the adapters is also compatible with the experimental SQLite date/time functions.

The following example demonstrates this.

```
import sqlite3
import datetime

con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_DECLTYPES|sqlite3.PARSE_
↪COLNAMES)
cur = con.cursor()
cur.execute("create table test(d date, ts timestamp)")

today = datetime.date.today()
now = datetime.datetime.now()

cur.execute("insert into test(d, ts) values (?, ?)", (today, now))
cur.execute("select d, ts from test")
row = cur.fetchone()
print(today, "=>", row[0], type(row[0]))
print(now, "=>", row[1], type(row[1]))

cur.execute('select current_date as "d [date]", current_timestamp as "ts [timestamp]"')
row = cur.fetchone()
print("current_date", row[0], type(row[0]))
print("current_timestamp", row[1], type(row[1]))
```

If a timestamp stored in SQLite has a fractional part longer than 6 numbers, its value will be truncated to microsecond precision by the timestamp converter.

### 12.6.7 Controlling Transactions

The underlying sqlite3 library operates in autocommit mode by default, but the Python *sqlite3* module by default does not.

autocommit mode means that statements that modify the database take effect immediately. A BEGIN or SAVEPOINT statement disables autocommit mode, and a COMMIT, a ROLLBACK, or a RELEASE that ends the outermost transaction, turns autocommit mode back on.

The Python *sqlite3* module by default issues a BEGIN statement implicitly before a Data Modification Language (DML) statement (i.e. INSERT/UPDATE/DELETE/REPLACE).

You can control which kind of BEGIN statements *sqlite3* implicitly executes via the *isolation_level* parameter to the *connect()* call, or via the isolation_level property of connections. If you specify no *isolation_level*, a plain BEGIN is used, which is equivalent to specifying DEFERRED. Other possible values are IMMEDIATE and EXCLUSIVE.

You can disable the *sqlite3* module's implicit transaction management by setting isolation_level to None. This will leave the underlying sqlite3 library operating in autocommit mode. You can then completely control the transaction state by explicitly issuing BEGIN, ROLLBACK, SAVEPOINT, and RELEASE statements in your code.

Changed in version 3.6: *sqlite3* used to implicitly commit an open transaction before DDL statements. This is no longer the case.

### 12.6.8 Using sqlite3 efficiently

#### Using shortcut methods

Using the nonstandard execute(), executemany() and executescript() methods of the *Connection* object, your code can be written more concisely because you don't have to create the (often superfluous) *Cursor* objects explicitly. Instead, the *Cursor* objects are created implicitly and these shortcut methods return the cursor objects. This way, you can execute a SELECT statement and iterate over it directly using only a single call on the *Connection* object.

```
import sqlite3

persons = [
    ("Hugo", "Boss"),
    ("Calvin", "Klein")
    ]

con = sqlite3.connect(":memory:")

# Create the table
con.execute("create table person(firstname, lastname)")

# Fill the table
con.executemany("insert into person(firstname, lastname) values (?, ?)", persons)

# Print the table contents
for row in con.execute("select firstname, lastname from person"):
    print(row)

print("I just deleted", con.execute("delete from person").rowcount, "rows")
```

#### Accessing columns by name instead of by index

One useful feature of the *sqlite3* module is the built-in *sqlite3.Row* class designed to be used as a row factory.

Rows wrapped with this class can be accessed both by index (like tuples) and case-insensitively by name:

```
import sqlite3

con = sqlite3.connect(":memory:")
con.row_factory = sqlite3.Row

cur = con.cursor()
cur.execute("select 'John' as name, 42 as age")
for row in cur:
    assert row[0] == row["name"]
    assert row["name"] == row["nAmE"]
    assert row[1] == row["age"]
    assert row[1] == row["AgE"]
```

#### Using the connection as a context manager

Connection objects can be used as context managers that automatically commit or rollback transactions. In the event of an exception, the transaction is rolled back; otherwise, the transaction is committed:

```
import sqlite3

con = sqlite3.connect(":memory:")
con.execute("create table person (id integer primary key, firstname varchar unique)")

# Successful, con.commit() is called automatically afterwards
with con:
    con.execute("insert into person(firstname) values (?)", ("Joe",))

# con.rollback() is called after the with block finishes with an exception, the
# exception is still raised and must be caught
try:
    with con:
        con.execute("insert into person(firstname) values (?)", ("Joe",))
except sqlite3.IntegrityError:
    print("couldn't add Joe twice")
```

### 12.6.9 Common issues

#### Multithreading

Older SQLite versions had issues with sharing connections between threads. That's why the Python module disallows sharing connections and cursors between threads. If you still try to do so, you will get an exception at runtime.

The only exception is calling the *interrupt()* method, which only makes sense to call from a different thread.