Python 3 for Scientists

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Version 1.7, August 2021

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About this course

Welcome!

- We’re glad you’re here
- Class has hands-on labs for nearly every chapter
- Please make a name tent

Instructor name:

Instructor e-mail:

Have Fun!

Classroom etiquette for in-person learning

- Noisemakers off
- No phone conversations
- Come and go quietly during class.

Please turn off cell phone ringers and other noisemakers.

If you need to have a phone conversation, please leave the classroom.

We’re all adults here; feel free to leave the clasroom if you need to use the restroom, make a phone call, etc. You don’t have to wait for a lab or break, but please try not to disturb others.

Classroom etiquette for remote learning

- Mic off when you’re not speaking. If multiple mics are on, it makes it difficult to hear
- The instructor doesn’t know you need help unless you tell them. It’s ok to ask for helpl a lot.
- Ask questions. Ask questions. Ask questions.
- INTERACT with the instructor and other students.
- Log off the remote S/W at the end of the day

IMPORTANT Please do not bring any exploding penguins to class. They might maim, dismember, or otherwise disturb your fellow students.

Course Outline

Day 1

Chapter 1 The Python Environment
Chapter 2 Getting Started
Chapter 3 Flow Control
Chapter 4 Array Types

Day 2

Chapter 5 Working with Files
Chapter 6 Dictionaries and Sets
Chapter 7 Functions Modules Packages
Chapter 8 Errors and Exception Handling

Day 3

Chapter 9 Using the Standard Library
Chapter 10 Pythonic Programming
Chapter 11 Introduction to Python Classes
Chapter 12 EffectiveScripts

Day 4

Chapter 13 Developer tools
Chapter 14 Using openpyxl with Excel spreadsheets
Chapter 15 Serializing Data
Chapter 16 iPython and Jupyter

Day 5

Chapter 17 Introduction to NumPy
Chapter 18 Introduction to SciPy
Chapter 19 Introduction to pandas
Chapter 20 Introduction to Matplotlib

NOTE The actual schedule varies with circumstances. The last day may include *ad hoc* topics requested by students

Student files

You will need to load some student files onto your computer. The files are in a compressed archive. When you extract them onto your computer, they will all be extracted into a directory named **py3forsci**. See the setup guide for details.

What's in the files?

py3forsci contains data and other files needed for the exercises
py3forsci/EXAMPLES/ contains the examples from the course manuals.
py3forsci/ANSWERS/ contains sample answers to the labs.
py3forsci/DATA/ contains data used in examples and answers
py3forsci/SETUP/ contains any needed setup scripts (may be empty)
py3forsci/TEMP/ initially empty; used by some examples for output files
py3forsci/NOTEBOOKS/ Jupyter notebooks for use in class

NOTE The student files do not contain Python itself. It will need to be installed separately. This has probably already been done for you.

Examples

Nearly all examples from the course manual are provided in EXAMPLES subdirectory. Many of the examples have callouts — numbers that refer to notes just below the code.

It will look like this:

Example

cmd_line_args.py

```
#!/usr/bin/env python

import sys   ①

print(sys.argv) ②

name = sys.argv[1]  ③
print("name is", name)
```

① Import the **sys** module

② Print all parameters, including script itself

③ Get the first actual parameter

cmd_line_args.py apple mango 123

```
['/Users/jstrick/curr/courses/python//examples3/cmd_line_args.py', 'apple', 'mango',
'123']
name is apple
```

Lab Exercises

- Relax – the labs are not quizzes
- Feel free to modify labs
- Ask the instructor for help
- Work on your own scripts or data
- Answers are in py3forsci/ANSWERS

Appendices

- Appendix A: Where do I go from here?
- Appendix B: Virtual Environments
- Appendix C: Python Bibliography
- Appendix D: Multiprogramming

Chapter 1: The Python Environment

Objectives

- Using the interpreter
- Getting help
- Running scripts on Windows, Linux, and Mac
- Learning best editors and IDEs

> I think the real key to Python's platform independence is that it was conceived right from the start as only very loosely tied to Unix.
>
> — Guido van Rossum

Starting Python

- Type **python** (or **python3**) at a command prompt
- **python** should be in your PATH
- If python was not found, install it or add directory to PATH

To start the Python interpreter, just type **python** (or **python3**) at the command prompt. If you get an error message, one of two things has happened:

- Python is not installed on your computer
- The interpreter (`python`) is not in your PATH variable

If the interpreter is not in your PATH

If the directory where the interpreter lives is not in your PATH variable, you have several choices.

Type the full path

Start **python** by typing the full path to the interpreter (e.g., C:\python35\python or /usr/bin/python)

Add the directory to PATH temporarily

Windows (at a command prompt)

```
set PATH="%PATH%";c:\python35
```

Linux/Mac

```
PATH="$PATH:/usr/dev/bin"   sh,ksh,bash
setenv PATH "$PATH:/usr/dev/bin"    csh,tcsh
```

Add the directory to PATH permanently

Windows

Right-click on the **My Computer** icon. Select **Properties**, and then select the **Advanced** tab. Click on the **Environment Variables** button, then double-click on **PATH** in the **System Variables** area at the bottom of the dialog. Add the directory for the Python interpreter to the existing value and click OK. Be sure to separate the path from existing text with a semicolon.

Linux/Mac

Add a line to your shell startup file (e.g. .bash_profile, .profile, etc.) to add the directory containing the Python interpreter to your PATH variable .

The command should look something like

```
PATH="$PATH:/path/to/python"
```

Using the interpreter

- Type any Python statement or expression
- Prompt is >>>
- Command line editing supported
- Ctrl-D (Unix) or Ctrl-Z <Enter> (Windows) to exit

Once you have started the Python interpreter, it provides an interactive interpreter. The prompt is ">>>". You can type in any Python commands at this prompt.

For Windows, it supports the editing keys on a standard keyboard, which include Home, End, etc., as well as the arrow keys. Normal PC shortcuts such as Ctrl-RightArrow to jump to the next word also work.

For other systems, Python supports **GNU readline** editing, which uses emacs-style commands. These commands are detailed in the table below.

On all versions, you can use arrow keys and backspace to edit the line.

As of version 3.4, the interpreter does autocomplete when you press the TAB key

Table 1. emacs-style command line editing

Emacs-mode Command	Function
^P	Previous command
^N	Next command
^F	Forward 1 character
^B	Back 1 character
^A	Beginning of line
^E	End of line
^D	Delete character under cursor
^K	Delete to end of line

Trying out a few commands

Try out the following commands in the interpreter:

```
>>> print("Hello, world")
Hello, world
>>> print(4 + 3)
7
>>> print(10/3)
3.3333333333333335
>>>
```

You don’t really need **print()**

```
>>> "Hello, world"
'Hello, world'
>>> 4 + 3
7
>>>
```

When you press <Enter>, the interpreter evaluates and prints out whatever you typed in.

NOTE If you have **ipython** installed, use **ipython** for a better interactive interpreter (**ipython** is included with Anaconda).

Running Python scripts

- Use Python interpreter
- Same for any OS

To run a Python script (a file with the extension **.py**, call the Python interpreter with the script as its argument:

```
python myscript.py
```

This will work on any operating system.

NOTE If you are sure that Python is installed, and the above technique does not work, it might be because the Python interpreter is not in your path. See the earlier discussion about adding the python executable to your path.

Using pydoc

From the Python interpreter

Type

```
>>> help(thing)
```

Where *thing* can be either the name (in quotes) of a function, module or package, or the actual (imported) function, module, or package object.

```
>>> help(len)
Help on built-in function len in module builtins:

len(obj, /)
    Return the number of items in a container.
```

From a command line

Use `pydoc name` to display the documentation for *name*, which can be the name of a function, module, package, or a method or attribute of an object.

```
$ pydoc len
Help on built-in function len in module __builtin__:

len(...)
    len(object) -> integer

    Return the number of items of a sequence or mapping.
```

NOTE On Windows, open an Anaconda prompt (if available) to make sure that **pydoc** is in the search path.

TIP Run pydoc -k <keyword> to search packages by keyword

From iPython

iPython makes it easy to get help. Just put a question mark before or after an object, and it will display help.

```
In [1]: len?
Signature: len(obj, /)
Docstring: Return the number of items in a container.
Type:      builtin_function_or_method
```

Python Editors and IDEs

- Editor is programmer’s most-used tool
- Select Python-aware editor or IDE
- Many open source and commercial choices

There are two pages on the Python Wiki that discuss editors and IDEs:

```
http://wiki.python.org/moin/PythonEditors
http://wiki.python.org/moin/IntegratedDevelopmentEnvironments
```

PyCharm Community Edition is the most full-featured free IDE available. Other good multi-platform IDEs include Spyder, Eclipse, Visual Studio Code, and Sublime Edit. These work on Windows, Unix/Linux, and Mac platforms and probably some others.

Chapter 1 Exercises

Exercise 1-1 (hello.py)

Using any editor, write a "Hello, world" python script.

Run the script from the command line.

Open the script in your IDE and run it from there.

TIP In PyCharm, you can right-click (Ctrl-click on Mac) the script’s tab and select **Run**

Chapter 2: Getting Started

Objectives

- Using variables
- Understanding dynamic typing
- Working with text
- Working with numbers
- Writing output to the screen
- Getting command line parameters
- Reading keyboard input

Using variables

- Variables are created when assigned to
- May hold any type of data
- Names are case sensitive
- Names may be any length

Variables in Python are created by assigning a value to them. They are created and destroyed as needed by the interpreter. Variables may hold any type of data, including string, numeric, or Boolean. The data type is dynamically determined by the type of data assigned.

Variable names are composed of letters, digits, and underscores, and may not start with a digit. Any Unicode character that corresponds to a letter or digit may also be used.

Variable names are case sensitive, and may be any length. `Spam`, `SPAM`, and `spam` are three different variables.

A variable *must* be assigned a value. A value of `None` (null) may be assigned if no particular value is needed. It is good practice to make variable names consistent. The Python style guide Pep 8 (https://www.python.org/dev/peps/pep-0008) suggests:

```
all_lower_case_with_underscores
```

Example

```
quantity = 5
historian = "AJP Taylor"
final_result = 123.456
program_status = None
```

Keywords and Builtins

- Keywords are reserved
- Using a keyword as a variable is a syntax error
- 72 builtin functions
- Builtins *may* be overwritten (but it's not a big deal)

Python keywords may not be used as names. You cannot say `class = 'Sophomore'`.

On the other hand, any of Python's 72 builtin functions, such as `len()` or `int()` may be used as identifiers, but that will overwrite the builtin's functionality, so you shouldn't do that.

TIP Be especially careful not to use `dir`, `file`, `id`, `len`, `max`, `min`, and `sum` as variable names, as these are all builtin function names.

Python 3 Keywords

```
False     class     finally   is        return
None      continue  for       lambda    try
True      def       from      nonlocal  while
and       del       global    not       with
as        elif      if        or        yield
assert    else      import    pass
break     except    in        raise
```

Table 2. Builtin functions

abs()	float()*	object()*
all()	format()	oct()
any()	frozenset()*	open()
ascii()	getattr()	ord()
bin()	globals()	pow()
bool()*	hasattr()	print()
bytearray()*	hash()	property()*
bytes()*	help()	quit()
callable()	hex()	range()*
chr()	id()	repr()
classmethod()*	input()	reversed()*
compile()	int()*	round()
complex()*	isinstance()	set()*
copyright()	issubclass()	setattr()
credits()	iter()	slice()*
delattr()	len()	sorted()
dict()*	license()	staticmethod()*
dir()	list()*	str()*
divmod()	locals()	sum()
enumerate()*	map()*	super()*
eval()	max()	tuple()*
exec()	memoryview()*	type()*
exit()	min()	vars()
filter()*	next()	zip()*

*These functions are class constructors

Variable typing

- Python is strongly and dynamically typed
- Type based on assigned value

Python is a strongly typed language. That means that whenever you assign a value to a name, it is given a *type*. Python has many types built into the interpreter, such as `int`, `str`, and `float`. There are also many packages providing types, such as `date`, `re`, or `urllib`.

Certain operations are only valid with the appropriate types.

WARNING Python does not automatically convert strings to numbers or numbers to strings.

Strings

- All strings are Unicode
- String literals
  - Single-delimited (single-line only)
  - Triple-delimited (can be multi-line)
- Use single-quote or double-quote symbols
- Backslashes introduce *escape sequences*
- Strings can be raw (escape sequences not interpreted)

All python strings are Unicode strings. They can be initialized with several types of string literals. Strings support escape characters, such as \t and \n, for non-printable characters.

Single-delimited string literals

- Enclosed in pair of single or double quotes
- May not contain embedded newlines
- Backslash is treated specially.

Single-delimited strings are enclosed in a pair of single or double quotes.

Escape codes, which start with a backslash, are interpreted specially. This makes it possible to include control characters such as tab and newline in a string.

Single-delimited strings may not contain an embedded newline; that is, they may not be spread over multiple physical lines. They may contain \n, the escape code for a new line.

There is no difference in meaning between single and double quotes. The term "single-quoted" in the Python documentation means that there is one quote symbol at each end of the sting literal.

TIP Adjacent string literals are concatenated.

Example

```
name = "John Smith"
title = 'Grand Poobah'
color = "red"
size = "large"
poem = "I think that I will never see\na poem lovely as a tree"
```

Triple-delimited string literals

- Used for multi-line strings
- Can have embedded quote characters
- Used for docstrings

Triple-delimited strings use three double or single quotes at each end of the text. They are the same as single-delimited strings, except that individual single or double quotes are left alone, and that embedded newlines are preserved.

Triple-delimited text is used for text containing literal quotes as well as documentation and boiler-plate text.

Example

```
name = """James Earl "Jimmy" Carter"""
warning = """
Professional driver on closed course
Do not attempt
Your mileage may vary
Ask your doctor if Python is right for you
"""

query = '''
from contacts
where zipcode = '90210'
order by lname
'''
```

NOTE The quotes on both ends of the text must match – use either all single or all double quotes, whether it's a normal or a triple-delimited literal.

Raw string literals

- Start with **r**
- Do not interpret backslashes

If a literal starts with **r** before the quote marks, then it is a raw string literal. Backslashes are not interpreted.

This is handy if the text to be output contains literal backslashes, such as many regular expression patterns, or Windows path names.

Example

```
pat = r"\w+\s+\w+"
loc = r"c:\temp"
msg = r"please put a newline character (\n) after each line"
```

This is similar to the use of single quotes in some other languages.

Unicode characters

- Use \uXXXX to specify non-ASCII Unicode characters
- XXXX is Unicode value in hex
- \N\{*NAME*} also OK

Unicode characters may be embedded in literal strings. Use the Unicode value for the character in the form \uXXXX, where XXXX is the hex version of the character’s code point.

You can also specify the Unicode character name using the syntax \N{name}.

For code points above FFFF, use \UXXXXXXXX (note capital "U").

Raw strings accept the \u or \U notation, but do not accept \N{}.

See http://www.unicode.org/charts for lists of Unicode character names

Example

unicode.py

```
#!/usr/bin/env python

print('26\u00B0')  ①
print('26\N{DEGREE SIGN}')  ②
print(r'26\u00B0\n')  ③
print()

print('we spent \u20ac1.23M for an original C\u00e9zanne') ④
print("Romance in F\u266F Major")
print()

data = ['\U0001F95A', '\U0001F414']  ⑤
print("unsorted:", data)
print("sorted:", sorted(data))
```

① Use \uXXXX where XXXX is the Unicode value in hex

② The Unicode entity name can be used, enclosed in \N{}

③ \N{} is not expanded in raw strings

④ More examples.

⑤ Python answers the age-old question.

unicode.py

```
26°
26°
26\u00B0\n

we spent €1.23M for an original Cézanne
Romance in F▯ Major

unsorted: ['▯', '▯']
sorted: ['▯', '▯']
```

Table 3. Escape Sequences

Sequence	Description
\newline	Embedded newline
\\\\	Backslash
\\'	Single quote
\\"	Double quote
\a	BEL
\b	BACKSPACE
\f	FORMFEED
\n	LINEFEED
\N{name}	Unicode named code point *name*
\r	Carriage Return
\t	TAB
\uxxxx	16-bit Unicode code point
\Uxxxxxxxx	32-bit Unicode code point (for values above 0xFFFF)
\ooo	Char with octal ASCII value ooo
\xhh	Character with hex ASCII value hh

String operators and methods

- Methods called from string objects
- Some builtin functions apply to strings
- Strings cannot be modified in-place
- Modified copies of strings are returned

Python has a rich set of operators and methods for manipulating strings.

Methods are called from string objects (variables) using "dot notation" – *STR*.method(). Some builtin functions are not called from strings, such as **len()**.

Strings are *immutable* – they can not be changed (modified in-place). Many string functions return a modified copy of the string.

Use + (plus) to concatenate two strings.

String methods may be chained. That is, you can call a string method on the string returned by another method.

If you need a substring function, that is provided by the **slice** operation in the **Array Types** chapter.

String methods may be called on literal strings as well

```
s = 'Barney Rubble'
print(s.upper())
print(s.count('b'))
print(s.lower().count('b'))

print(",".join(some_list))
print("abc".upper())
```

Example

strings.py

```
#!/usr/bin/env python

a = "My hovercraft is full of EELS"

print("original:", a)
print("upper:", a.upper())
print("lower:", a.lower())
print("swapcase:", a.swapcase()) ①
print("title:", a.title())  ②
print("e count (normal):", a.count('e'))
print("e count (lower-case):", a.lower().count('e')) ③
print("found EELS at:", a.find('EELS'))
print("found WOLVERINES at:", a.find('WOLVERINES')) ④

b = "graham"
print("Capitalized:", b.capitalize()) ⑤
```

① Swap upper and lower case

② All words are capitalized

③ Methods can be chained. The next method is called on the object returned by the previous method.

④ Returns -1 if substring not found

⑤ Capitalizes first character of string, only if it is a letter

strings.py

```
original: My hovercraft is full of EELS
upper: MY HOVERCRAFT IS FULL OF EELS
lower: my hovercraft is full of eels
swapcase: mY HOVERCRAFT IS FULL OF eels
title: My Hovercraft Is Full Of Eels
e count (normal): 1
e count (lower-case): 3
found EELS at: 25
found WOLVERINES at: -1
Capitalized: Graham
```

String Methods

Table 4. string methods

Method	Description
S.capitalize()	Return a capitalized version of S, i.e. make the first character have upper case and the rest lower case.
S.casefold()	Return a version of S suitable for caseless comparisons.
S.center(width[, fillchar])	Return S centered in a string of length width. Padding is done using the specified fill character (default is a space)
S.count(sub, [, start[, end]])	Return the number of non-overlapping occurrences of substring sub. Optional arguments start and end specify a substring to search.
S.encode(encoding='utf-8', errors='strict')	Encode S using the codec registered for encoding. Default encoding is 'utf-8'. errors may be given to set a different error handling scheme. Default is 'strict' meaning that encoding errors raise a UnicodeEncodeError. Other possible values are 'ignore', 'replace' and 'xmlcharrefreplace' as well as any other name registered with codecs.register_error that can handle UnicodeEncodeErrors.
S.endswith(suffix[, start[, end]])	Return True if S ends with the specified suffix, False otherwise. With optional start, test S beginning at that position. With optional end, stop comparing S at that position. suffix can also be a tuple of strings to try.
S.expandtabs(tabsize=8)	Return a copy of S where all tab characters are expanded using spaces. If tabsize is not given, a tab size of 8 characters is assumed.
S.find(sub[, start[, end]])	Return the lowest index in S where substring sub is found, such that sub is contained within S[start:end]. Optional arguments start and end are interpreted as in slice notation. Returns -1 on failure.
S.format(*args, **kwargs)	Return a formatted version of S, using substitutions from args and kwargs. The substitutions are identified by braces ('{' and '}').
S.format_map(mapping)	Return a formatted version of S, using substitutions from mapping. The substitutions are identified by braces ('{' and '}').
S.index(sub[, start[, end]])	Like find() but raise ValueError when the substring is not found.
S.isalnum()	Return True if all characters in S are alphanumeric and there is at least one character in S, False otherwise.
S.isalpha()	Return True if all characters in S are alphabetic and there is at least one character in S, False otherwise.
S.isdecimal()	Return True if there are only decimal characters in S, False otherwise.

Method	Description
S.isdigit()	Return True if all characters in S are digits and there is at least one character in S, False otherwise.
S.isidentifier()	Return True if S is a valid identifier according to the language definition.
S.islower()	Return True if all cased characters in S are lowercase and there is at least one cased character in S, False otherwise.
S.isnumeric()	Return True if there are only numeric characters in S, False otherwise.
S.isprintable()	Return True if all characters in S are considered printable in repr() or S is empty, False otherwise.
S.isspace()	Return True if all characters in S are whitespace and there is at least one character in S, False otherwise.
S.istitle()	Return True if S is a titlecased string and there is at least one character in S, i.e. upper- and titlecase characters may only follow uncased characters and lowercase characters only cased ones. Return False otherwise.
S.isupper()	Return True if all cased characters in S are uppercase and there is at least one cased character in S, False otherwise.
S.join(iterable)	Return a string which is the concatenation of the strings in the iterable. The separator between elements is the string from which join() is called
S.ljust(width[, fillchar])	Return S left-justified in a Unicode string of length width. Padding is done using the specified fill character (default is a space).
S.lower()	Return a copy of the string S converted to lowercase.
S.lstrip([chars])	Return a copy of the string S with leading whitespace removed. If chars is given and not None, remove characters in chars instead.
S.partition(sep)	Search for the separator sep in S, and return the part before it, the separator itself, and the part after it. If the separator is not found, return S and two empty strings.
S.replace(old, new[, count])	Return a copy of S with all occurrences of substring old replaced by new. If the optional argument count is given, only the first count occurrences are replaced.
S.rfind(sub[, start[, end]])	Return the highest index in S where substring sub is found, such that sub is contained within S[start:end]. Optional arguments start and end are interpreted as in slice notation. Return -1 on failure.
S.rindex(sub[, start[, end]])	Like rfind() but raise ValueError when the substring is not found.
S.rjust(width[, fillchar])	Return S right-justified in a string of length width. Padding is done using the specified fill character (default is a space).

Method	Description
S.rpartition(sep)	Search for the separator sep in S, starting at the end of S, and return the part before it, the separator itself, and the part after it. If the separator is not found, return two empty strings and
S.rsplit(sep=None, maxsplit=-1)	Return a list of the words in S, using sep as the delimiter string, starting at the end of the string and working to the front. If maxsplit is given, at most maxsplit splits are done. If sep is not specified, any whitespace string is a separator.
S.rstrip([chars])	Return a copy of the string S with trailing whitespace removed. If chars is given and not None, remove characters in chars instead.
S.split(sep=None, maxsplit=-1)	Return a list of the words in S, using sep as the delimiter string. If maxsplit is given, at most maxsplit splits are done. If sep is not specified or is None, any whitespace string is a separator and empty strings are removed from the result.
S.splitlines([keepends])	Return a list of the lines in S, breaking at line boundaries. Line breaks are not included in the resulting list unless keepends is given and true.
S.startswith(prefix[, start[, end]])	Return True if S starts with the specified prefix, False otherwise. With optional start, test S beginning at that position. With optional end, stop comparing S at that position. prefix can also be a tuple of strings to try.
S.strip([chars])	Return a copy of the string S with leading and trailing whitespace removed. If chars is given and not None, remove characters in chars instead.
S.swapcase()	Return a copy of S with uppercase characters converted to lowercase and vice versa.
S.title()	Return a titlecased version of S, i.e. words start with title case characters, all remaining cased characters have lower case.
S.translate(table)	Return a copy of the string S, where all characters have been mapped through the given translation table, which must be a mapping of Unicode ordinals to Unicode ordinals, strings, or None. Unmapped characters are left untouched. Characters mapped to None are deleted.
S.upper()	Return a copy of S converted to uppercase.
S.zfill(width)	Pad a numeric string S with zeros on the left, to fill a field of the specified width. The string S is never truncated.

Numeric literals

- Four kinds of numeric objects
  - Booleans
  - Integers
  - Floats
  - Complex numbers
- Integer literals can be decimal, octal, or hexadecimal
- Floating point can be traditional or scientific notation

Boolean

Boolean values can be 1 (true) or 0 (false). The keywords True and False can be used to represent these values, as well.

Integers

Integers can be specified as decimal, octal, or hexadecimal. Prefix the number with 0o for octal, 0x for hex, or 0b for binary. Integers are signed, and can be arbitrarily large.

Floats

Floating point integers may be specified in traditional format or in scientific notation.

Complex Numbers

Complex numbers may be specified by adding J to the end of the number.

Example

numeric.py

```
#!/usr/bin/env python

a = 5
b = 10
c = 20.22
d = 0o123       ①
e = 0xdeadbeef  ②
f = 0b10011101  ③

print("a, b, c", a, b, c)
print("a + b", a + b)
print("a + c", a + c)
print("d", d)
print("e", e)
print("f", f)
```

① Octal

② Hex

③ Binary

numeric.py

```
a, b, c 5 10 20.22
a + b 15
a + c 25.22
d 83
e 3735928559
f 157
```

Math operators and expressions

- Many built-in operators and expressions
- Operations between integers and floats result in floats

Python has many math operators and functions. Later in this course we will look at some libraries with extended math functionality.

Most of the operators should look familiar; a few may not:

Division

Division (/) always returns a float result.

Assignment-with-operation

Python supports C-style assignment-with-operation. For instance, x += 5 adds 5 to variable x. This works for nearly any operator in the format:

```
VARIABLE OP=VALUE       e.g. x += 1
```

is equivalent to

```
VARIABLE = VARIABLE OP VALUE    e.g. x = x + 1
```

Exponentiation

To raise a number to a power, use the ** (exponentiation) operator or the pow() function.

Floored Division

Using the floored division operator //, the result is always rounded down to the nearest whole number.

Order of operations

*P*lease *E*xcuse *M*y *D*ear *A*unt *S*ally!

Parentheses, Exponents, Multiplication or Division, Addition or Subtraction (but use parentheses for readability)

Example

math_operators.py

```
#!/usr/bin/env python

x = 22
x += 10  ①

y = 5
y *= 3  ①

print("x:", x)
print("y:", y)

print("2 ** 16", 2 ** 16)

print("x / y", x / y)
print("x // y", x // y)  ②
```

① Same as x = x + 1, y = y * 3, *etc.*

② Returns floored result (rounded down to nearest whole number)

math_operators.py

```
x: 32
y: 15
2 ** 16 65536
x / y 2.1333333333333333
x // y 2
```

NOTE Python does not have the ++ and — (post-increment and post-decrement) operators common to many languages derived from C.

Table 5. Python Math Operators and Functions

Operator or Function	What it does
x + y	sum of x and y
x – y	difference of x and y
x * y	product of x and y
x / y	quotient of x and y
x // y	(floored) quotient of x and y
x % y	remainder of x / y
-x	x negated
+x	x unchanged
abs(x)	absolute value or magnitude of x
int(x)	x converted to integer
float(x)	x converted to floating point
complex(re,im)	a complex number with real part re, imaginary part im. im defaults to zero.
c.conjugate()	conjugate of the complex number c
divmod(x, y)	the pair (x // y, x % y)
pow(x, y) x ** y	x raised to the power y

Converting among types

- No automatic conversion between numbers and strings
- Builtin functions
    - int() convert string or number to integer
    - float() convert string or number to float
    - str() convert anything to string
    - bool() convert anything to bool
    - list() convert any iterable to a list
    - tuple() convert any iterable to a tuple
    - set() convert any iterable to a set
    - dict() convert any iterable of pairs to a dict

Python is dynamically typed; if you assign a number to a variable, it will raise an error if you use it with a string operator or function; likewise, if you assign a string, you can’t use it with numeric operators.

There are built-in functions to do these conversions. Use int(s) to convert string s to an integer. Use str(n) to convert anything to a string, and so forth.

If the string passed to int() or float() contains characters other than digits or minus sign, a runtime error is raised. Leading or trailing whitespace, however, are ignored. Thus " 123 " is OK, but "123ABC" is not.

Writing to the screen

- Use print() function
- Adds spaces between arguments (by default)
- Adds newline at end (by default)
- Use **sep** parameter for alternate separator
- Use **end** parameter for alternate ending

To output text to the screen, use the print function. It takes a list of one or more arguments, and writes them to the screen. By default, it puts a space between them and ends with a newline.

Two special named arguments can modify the default behavior. The *sep* parameter specifies what is output between items, and *end* specifies what is written after all the arguments.

Example

print_examples.py

```
#!/usr/bin/env python

print("Hello, world")
print("#------------------------")

print("Hello,", end=' ')  ①
print("world")
print("#------------------------")

print("Hello,", end=' ')
print("world", end='!')  ②
print("#------------------------")

x = "Hello"
y = "world"

print(x, y)  ③
print("#------------------------")

print(x, y, sep=', ')  ④
print("#------------------------")

print(x, y, sep='')  ⑤
print("#------------------------")
```

① Print space instead of newline at the end

② Print bang instead of newline at end

③ Item separator is space instead of comma

④ Item separator is comma + space

⑤ Item separator is empty string

print_examples.py

```
Hello, world
#-----------------------
Hello, world
#-----------------------
Hello, world!#-----------------------
Hello world
#-----------------------
Hello, world
#-----------------------
Helloworld
#-----------------------
```

String Formatting

- Use the .format() method
- Syntax: "template".format(VALUES)
- Placeholders: {left_curly}Num:FlagsWidthType{right_curly}

Strings have a format() method which allows variables and other objects to be embedded in strings and optionally formatted. Parameters to format() are numbered starting with 0, and are formatted by the correspondingly numbered placeholders in the string. However, if no numbers are specified, the placeholders will be auto-numbered from left to right, starting with 0. You cannot mix number and non-numbered placeholders in the same format string.

A placeholder looks like this: {} (for auto-numbering), or {*n*} (for manual numbering). To add formatting flags, follow the parameter number (if any) with a colon, then the type and other flags. You can also used named parameters, and specify the name rather than the parameter index.

Builtin types to not need to have the type specified, but you may specify the width of the formatted value, the number of decimal points, or other type-specific details.

For instance, {0} will use default formatting for the first parameter; {2:04d} will format the third parameter as an integer, padded with zeroes to four characters wide.

There are many more ways of using format(); this discussion describes some of the basics.

To include literal braces in the string, double them: {{ }}.

See [string_formatting] for details on formatting.

TIP For even more information, check out the PyDoc topic FORMATTING, or section 6.1.3.1 [ttps://docs.python.org/3/library/string.html#format-specification-mini-language] of The Python Standard Library documentation, the **Format Specification Mini-Language**.

NOTE Python 3.6 added *f-strings*, which will further simplify embedding variables in strings. See Pep 0498 [https://www.python.org/dev/peps/pep-0498/]

Example

string_formatting.py

```
#!/usr/bin/env python

name = "Tim"
count = 5
avg = 3.456
info = 2093

print("Name is [{:<10s}]".format(name))  ①
print("Name is [{:>10s}]".format(name))  ②
print("count is {:03d} avg is {:.2f}".format(count, avg))  ③

print("info is {0} {0:d} {0:o} {0:x}".format(info))  ④
print("info is {0} {0:d} {0:#o} {0:#x}".format(info))  ⑤

print("${:,d}".format(38293892))  ⑥

print("It is {temp} in {city}".format(city='Orlando', temp=85))  ⑦
```

① < means left justify (default for non-numbers), 10 is field width, s formats a string

② > means right justify

③ .2f means round a float to 2 decimal points

④ d is decimal, o is octal, x is hex

⑤ # means add 0x, 0o, etc.

⑥ , means add commas to numeric value

⑦ parameters can be selected by name instead of position :b ***string_formatting.py***

```
Name is [Tim       ]
Name is [       Tim]
count is 005 avg is 3.46
info is 2093 2093 4055 82d
info is 2093 2093 0o4055 0x82d
$38,293,892
It is 85 in Orlando
```

Legacy String Formatting

- Use the % operator
- Syntax: "template" % (VALUES)
- Similar to printf() in C

Prior to Python 2.6, the % operator was used for formatting. It returns a string that results from filling in a template string with placeholders in specified formats. :

```
%flagW.Ptype
```

where W is width, P is precision (max width or # decimal places)

The placeholders are similar to standard formatting, but are positional rather than numbered, and are specified with a percent sign, rather than braces.

If there is only one value to format, the value does not need parentheses.

WARNING Legacy string formatting is deprecated as of Python 3.1, and may be removed in the future. It supports most of the same formatting features as the new style.

Table 6. Legacy formatting types

d,i	decimal integer
o	octal integer
u	unsigned decimal integer
x,X	hex integer (lower, UPPER case)
e,E	scientific notation (lower, UPPER case)
f,F	floating point
g,G	autochoose between e and f
c	character
r	string (using repr() method)
s	string (using str() method)
%	literal percent sign

Table 7. Legacy formatting flags

-	left justify (default is right justification)
#	use alternate format
0	left-pad number with zeros
+	precede number with + or -
(blank)	precede positive number with blank, negative with -

Example

string_formatting_legacy.py

```
#!/usr/bin/env python

name = "Tim"
count = 5
avg = 3.456
info = 2093

print("Name is [%-10s]" % name)   ①
print("Name is [%10s]" % name)   ②
print("count is %03d avg is %.2f" % (count, avg)) ③

print("info is %d %o %x" % (info, info, info))      ④
print("info is %d %o %x" % ((info,) * 3))    ⑤

print("info is %d %#oo %#x" % (info, info, info))    ⑥
```

① Dash means left justify string

② Right justify (default)

③ Argument to % is either a single variable or a tuple

④ Arguments must be repeated to be used more than once

⑤ Obscure way of doing the same thing Note: (x,) is singleton tuple

⑥ # means add 0x, 0o, etc.

string_formatting_legacy.py

```
Name is [Tim       ]
Name is [       Tim]
count is 005 avg is 3.46
info is 2093 4055 82d
info is 2093 4055 82d
info is 2093 0o4055o 0x82d
```

Command line parameters

- Use the **argv** list that is part of the sys module
- sys must be imported
- Element 0 is the script name itself

To get the command line parameters, use the list sys.argv. This requires importing the sys module. To access elements of this list, use square brackets and the element number. The first element (index 0) is the name of the script, so sys.argv[1] is the first argument to your script.

Example

sys_argv.py

```
#!/usr/bin/env python

import sys

print(sys.argv)
print()

name = sys.argv[1]  ①
print("name is", name)
```

① First command line parameter

sys_argv.py Gawain

```
['/Users/jstrick/curr/courses/python//examples3/sys_argv.py', 'Gawain']

name is Gawain
```

TIP If you use an index for a non-existent parameter, an error will be raised and your script will exit. In later chapters you will learn how to check the size of a list, as well as how to trap the error.

Reading from the keyboard

- Use input()
- Provides a prompt string
- Use int() or float() to convert input to numeric values

To read a line from the keyboard, use input(). The parameter is a prompt string, and it returns the text that was entered. You can use int() or float() to convert the input to an integer or a floating-point number.

TIP If you use int() or float() to convert a string, a fatal error will be raised if the string contains any non-numeric characters or any embedded spaces. Leading and trailing spaces will be ignored.

Example

keyboard_input.py

```
#!/usr/bin/env python

name = input("What is your name: ")
quest = input("What is your quest? ")
print(name, "seeks", quest)

raw_num = input("Enter number: ")  ①
num = int(raw_num)  ②

print("2 times", num, "is ", 2 * num)
```

① input is always a string

② convert to numbers as needed

keyboard_input.py

```
What is your name:  Sir Lancelot
What is your quest?  the Grail
Sir Lancelot seeks the Grail
Enter number:  5
2 times 5 is  10
```

Chapter 2 Exercises

Exercise 2-1 (c2f.py)

Write a Celsius to Fahrenheit converter. Your script should prompt the user for a Celsius temperature, then print out the Fahrenheit equivalent.

To run the script at a command prompt:

```
python c2f.py
```

(or run from PyCharm/VS Code/Spyder etc)

The program prompts the user, and the user enters the temperature to be converted.

The formula is `F = ((9 * C) / 5 ) + 32`. Be sure to convert the user-entered value into a float.

Test your script with the following values: 100, 0, 37, -40

Exercise 2-2 (c2f_batch.py)

Create another C to F converter. This time, your script should take the Celsius temperature from the command line and output the Fahrenheit value.

To run the script at a command prompt:

```
python c2f_batch.py 100
```

(or run from PyCharm/VS Code/Spyder etc)

Test with the values from **c2f.py**.

These two programs should be identical, except for the input.

Exercise 2-3 (string_fun.py)

Write a script to prompt the user for a full name. Once the name is read in, do the following:

- Print out the name as-is
- Print the name in upper case
- Print the name in title case
- Print the number of occurrences of 'j'
- Print the length of the name
- Print the position (offset) of "jacob" in the string

Run the program, and enter "john jacob jingleheimer schmidt"

Chapter 3: Flow Control

Objectives

- Understanding how code blocks are delimited
- Implementing conditionals with the if statement
- Learning relational and Boolean operators
- Exiting a while loop before the condition is false

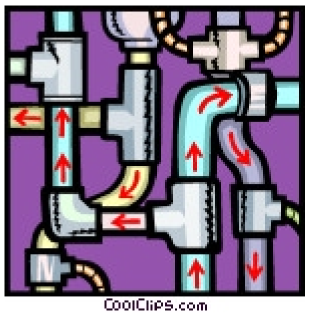
About flow control

- Controls order of execution
- Conditionals and loops
- Uses Boolean logic

Flow control means being able to conditionally execute some lines of code, while skipping others, depending on input, or being able to repeat some lines of code.

In Python, the flow control statements are if, while, and for.

NOTE Another kind of flow control is a function, which goes off to some other code, executes it, and returns to the current location. We'll cover functions in a later chapter.



What’s with the white space?

- Blocks defined by indenting
- No braces or BEGIN-END keywords
- Enforces what good programmers do anyway
- Be consistent (suggested indent is 4 spaces)

One of the first things that most programmers learn about Python is that whitespace is significant. This might seem wrong to many; however, you will find that it was a great decision by Guido, because it enforces what programmers should be doing anyway.

It’s very simple: After a line introducing a block structure (if statement, for/while loop, function definition, or class definition), all indented statements under the line are part of the block. Blocks may be nested, as in any language. The nested block has more indentation. A block ends when the interpreter sees a line with less indentation than the previous line.

Example

```
if value > 6:           start if statement
    print(value)        body of if

linecount = 0
for line in config:         start for loop
    if line.startswith("global"):   start if (body of for)
        print(line)         body of if
    linecount += 1          back to body of for
```

TIP Be consistent with indenting – use either all tabs or all spaces. Most editors can be set to your preference. (Guido suggests using 4 spaces).

if and elif

- The basic conditional statement is if
- Use else for alternatives
- elif provides nested if-else

The basic conditional statement in Python is if expression:. If the expression is true, then all statements in the block will be executed.

Example

```
if EXPR:
    statement
    statement
    ...
```

The expression does not require parentheses; only the colon at the end of the if statement is required.

In Python, a value is *false* if it is numeric zero, an empty container (string, list, tuple, dictionary, set, etc.), the builtin **False** object, or **None**. All other values are *true*.

The values **True** and **False** are predefined to have values of 1 and 0, respectively.

If an else statement is present, statements in the else block will be executed when the if statement is false.

For nested if-then, use the elif statement, which combines an if with an else. This is useful when the decision has more than two possibilities.

True and **False** are case-sensitive.

WARNING

Don’t say

```
if x == True:
```

unless you really mean that x could only be 0 (False) or 1 (True). Just say

```
if x:
```

Conditional Expressions

- Used for simple if-then-else conditions

When you have a simple if-then-else condition, you can use the conditional expression. If the condition is true, the first expression is returned; otherwise the second expression is returned.

```
value = expr1 if condition else expr2
```

This is a shortcut for

```
if condition:
    value = expr1
else:
    value = expr2
```

Example

```
print(long_message if DEBUGGING else short_message)

audience = 'j' if is_juvenile(curr_book_rec) else 'a'

file_mode = 'a' if APPEND_MODE else 'w'
```

Relational Operators

- Compare two objects
- Overloaded for different types of data
- Numbers cannot be compared to strings

```
==      !=     <      >      >=     <=
```

Python has six relational operators, implementing equality or greater than/less than comparisons. They can be used with most types of objects. All relational operators return **True** or **False**.

NOTE Strings and numbers cannot be compared using any of the greater-than or less-than operators. Also, no string is equal to any number.

Example

if_else.py

```
#!/usr/bin/env python

raw_temp = input("Enter the temperature: ")
temp = int(raw_temp)

if temp < 76:
    print("Don't go swimming")

num = int(input("Enter a number: "))
if num > 1000000:
    print(num, "is a big number")
else:
    print("your number is", num)

raw_hour = input("Enter the hour: ")
hour = int(raw_hour)

if hour < 12:
    print("Good morning")
elif hour < 18:                    ①
    print("Good afternoon")
elif hour < 23:
    print("Good evening")
else:
    print("You're up late")
```

① **elif** is short for "else if", and always requires an expression to check

if_else.py

```
Enter the temperature:  50
Don't go swimming
Enter a number:  9999999
9999999 is a big number
Enter the hour:  8
Good morning
```

Boolean operators

- Combine Boolean values
- Can be used with any expressions
- Short-circuit
- Return last operand evaluated

The Boolean operators **and**, **or**, and **not** may be used to combine Boolean values. These do not need to be of type bool – the values will be converted as necessary.

These operators short-circuit; they only evaluate the right operand if it is needed to determine the value. In the expression **a() or b()**, if **a()** returns True, **b()** is not called.

The return values of Boolean operators are the last operand evaluated. **4 and 5** returns 5. **0 or 4** returns 4.

Table 8. Boolean Operators

Expression	Value
AND	
12 and 5	5
5 and 12	12
0 and 12	0
12 and 0	0
"" and 12	""
12 and ""	""
OR	
12 or 5	12
5 or 12	5
0 or 12	12
12 or 0	12
"" or 12	12
12 or ""	12

while loops

- Loop while some condition is **True**
- Used for getting input until user quits
- Used to create services (AKA daemons)

```
while EXPR:
    statement
    statement
    ...
```

The **while** loop is used to execute code as long as some expression is true. Examples include reading input from the keyboard until the users signals they are done, or a network server looping forever with a **while True:** loop.

In Python, the **for** loop does much of the work done by a while loop in other languages.

NOTE Unlike many languages, reading a file in Python generally uses a **for** loop.

Alternate ways to exit a loop

- **break** exits loop completely
- **continue** goes to next iteration

Sometimes it is convenient to exit a loop without regard to the loop expression. The **break** statement exits the smallest enclosing loop.

This is used when repeatedly requesting user input. The loop condition is set to **True**, and when the user enters a specified value, the break statement is executed.

Other times it is convenient to abandon the current iteration and go back to the top of the loop without further processing. For this, use the **continue** statement.

Example

while_loop_examples.py

```
#!/usr/bin/env python

print("Welcome to ticket sales\n")

while True:  ①
    raw_quantity = input("Enter quantity to purchase (or q to quit): ")
    if raw_quantity == '':
        continue  ②
    if raw_quantity.lower() == 'q':
        print("goodbye!")
        break  ③

    quantity = int(raw_quantity)  # could validate via try/except
    print("sending {} ticket(s)".format(quantity))
```

① Loop "forever"

② Skip rest of loop; start back at top

③ Exit loop

while_loop_examples.py

```
Welcome to ticket sales

Enter quantity to purchase (or q to quit):  4
sending 4 ticket(s)
Enter quantity to purchase (or q to quit):
Enter quantity to purchase (or q to quit):  2
sending 2 ticket(s)
Enter quantity to purchase (or q to quit):  q
goodbye!
```

Chapter 3 Exercises

Exercise 3-1 (c2f_loop.py)

Redo **c2f.py** to repeatedly prompt the user for a Celsius temperature to convert to Fahrenheit and then print. If the user just presses **Return**, go back to the top of the loop. Quit when the user enters "q".

TIP read in the temperature, test for "q" or "", and only then convert the temperature to a float.#

Exercise 3-2 (guess.py)

Write a guessing game program. You will think of a number from 1 to 25, and the computer will guess until it figures out the number. Each time, the computer will ask "Is this your number? "; You will enter "l" for too low, "h" for too high, or "y" when the computer has got it. Print appropriate prompts and responses.

TIP

1. Start with max_val = 26 and min_val = 0
2. guess is always (max_val + min_val)//2 *Note integer division operator*
3. If current guess is too high, next guess should be halfway between lowest and current guess, and we know that the number is less than guess, so set max_val = guess
4. If current guess is too low, next guess should be halfway between current and maximum, and we know that the number is more than guess, so set min_val = guess

TIP If you need more help, see next page for pseudocode. When you get it working for 1 to 25, try it for 1 to 1,000,000. (Set max_value to 1000001).

Exercise 3-3 (guessx.py)

Get the maximum number from the command line *or* prompt the user to input the maximum, or both (if no value on command line, then prompt).

Pseudocode for guess.py

```
MAXVAL=26
MINVAL=0
while TRUE
    GUESS = int((MAXVAL + MINVAL)/2)
    prompt "Is your guess GUESS? "
    read ANSWER
    if ANSWER is "y"
        PRINT "I got it!"
        EXIT LOOP
    if ANSWER is "h"
        MAXVAL=GUESS
    if ANSWER is "l"
        MINVAL=GUESS
```

Chapter 4: Array Types

Objectives

- Using single and multidimensional lists and tuples
- Indexing and slicing sequential types
- Looping over sequences
- Tracking indices with enumerate()
- Using range() to get numeric lists
- Transforming lists

About Array Types

- Array types
  - str
  - bytes
  - list
  - tuple
- Common properties of array types
  - Same syntax for indexing/slicing
  - Share some common methods and functions
  - All can be iterated over with a for loop

Python provides many data types for working with multiple values. Some of these are array types. These hold values in a sequence, such that they can be retrieved by a numerical index.

A str is an array of characters. A bytes object is array of bytes.

All array types may be indexed in the same way, retrieving a single item or a slice (multiple values) of the sequence.

Array types have some features in common with other container types, such as dictionaries and sets. These other container types will be covered in a later chapter.

All array types support iteration over their elements with a for loop.

Example

typical_arrays.py

```
#!/usr/bin/env python

fruits = ['apple', 'cherry', 'orange', 'kiwi', 'banana', 'pear', 'fig']
name = "Eric Idle"
knight = 'King', 'Arthur', 'Britain'

print(fruits[3])  ①
print(name[2])  ②
print(knight[1])  ③
```

typical_arrays.py

```
kiwi
i
Arthur
```

Lists

- Array of objects
- Create with **list()** or [ ]
- Add items with append(), extend(), or insert
- Remove items with del, pop(), or remove()

A list is one of the fundamental Python data types. Lists are used to store multiple values. The values may be similar – all numbers, all user names, and so forth; they may also be completely different. Due to the dynamic nature of Python, a list may hold values of any type, including other lists.

Create a list with the **list()** class or a pair of square brackets. A list can be Initialized with a comma-separated list of values.

Table 9. List Methods (note L represents a list)

Method	Description
del L[i]	delete element at index i (keyword, not function)
L.append(x)	add single value x to end of L
L.count(x)	return count of elements whose value is x
L.extend(*iter*)	individually add elements of *iter* to end of L

L.index(x)
L.index(x, i)
L.index(x, i, j)
	return index of first element whose value is x (after index i, before index j)

L.insert(i, x)	insert element x at offset i

L.pop()
L.pop(i)
	remove element at index i (default -1) from L and return it

L.remove(x)	remove first element of L whose value is x
L.clear()	remove all elements and leave the list empty
L.reverse()	reverses L in place

L.sort()
L.sort(key=func)
	sort L in place – func is function to derive key from one element

Example

creating_lists.py

```
#!/usr/bin/env python

list1 = list()  ①
list2 = ['apple', 'banana', 'mango']  ②
list3 = []  ③
list4 = 'apple banana mango'.split()  ④

print("list1:", list1)
print("list2:", list2)
print("list3:", list3)
print("list4:", list4)

print("list2[0]:", list2[0])  ⑤
print("list4[2]:", list4[2])  ⑥

print("list4[-1]:", list4[-1])  ⑦
```

① Create new empty list

② Initialize list

③ Create new empty list

④ Create list of strings with less typing

⑤ First element of **list2**

⑥ Third element of **list4**

⑦ *Last* element of **list4**

creating_lists.py

```
list1: []
list2: ['apple', 'banana', 'mango']
list3: []
list4: ['apple', 'banana', 'mango']
list2[0]: apple
list4[2]: mango
list4[-1]: mango
```

Indexing and slicing

- Use brackets for index
- Use slice for multiple values
- Same syntax for strings, lists, and tuples

Python is very flexible in selecting elements from a list. All selections are done by putting an index or a range of indices in square brackets after the list's name.

To get a single element, specify the index (0-based) of the element in square brackets:

```
foo =  [ "apple", "banana", "cherry", "date", "elderberry",
   "fig","grape" ]

foo[1]  the 2nd element of list foo -- banana
```

To get more than one element, use a slice, which specifies the beginning element (inclusive) and the ending element (exclusive):

```
foo[2:5]    foo[2], foo[3], foo[4] but NOT foo[5] ▯ cherry, date, elderberry
```

If you omit the starting index of a slice, it defaults to 0:

```
foo[:5] foo[0], foo[1], foo[2], foo[3], foo[4] ▯ apple,banana,cherry, date, elderberry
```

If you omit the end element, it defaults to the length of the list.

```
foo[4:] foo[4], foo[5], foo[6] ▯ elderberry, fig, grape
```

A negative offset is subtracted from the length of the list, so -1 is the last element of the list, and -2 is the next-to-the-last element of the list, and so forth:

```
foo[-1] foo[len(foo)-1] or foo[6] ▯ grape
foo[-3] foo[len(foo)-3] or foo[4] ▯ elderberry
```

The general syntax for a slice is

```
s[start:stop:step]
```

which means all elements s[N], where

```
start <= N < stop,
```

and start is incremented by step

TIP Remember that start is **IN**clusive but stop is **EX**clusive.

Example

indexing_and_slicing.py

```
#!/usr/bin/env python

pythons = ["Idle", "Cleese", "Chapman", "Gilliam", "Palin", "Jones"]

characters = "Roger", "Old Woman", "Prince Herbert", "Brother Maynard"

phrase = "She turned me into a newt"

print("pythons:", pythons)
print("pythons[0]", pythons[0])  ①
print("pythons[5]", pythons[5])  ②
print("pythons[0:3]", pythons[0:3])  ③
print("pythons[2:]", pythons[2:])  ④
print("pythons[:2]", pythons[:2])  ⑤
print("pythons[1:-1]", pythons[1:-1])  ⑥
print("pythons[0::2]", pythons[0::2])  ⑦
print("pythons[1::2]", pythons[1::2])  ⑧

pythons[3] = "Innes"
print("pythons:", pythons)
print()

print("characters", characters)
print("characters[2]", characters[2])
print("characters[1:]", characters[1:])

# characters[2] = "Patsy"  # ERROR -- can't assign to tuple
print()
print("phrase", phrase)
print("phrase[0]", phrase[0])
print("phrase[-1]", phrase[-1])  ⑨
print("phrase[21:25]", phrase[21:25])
print("phrase[21:]", phrase[21:])
print("phrase[:10]", phrase[:10])
print("phrase[::2]", phrase[::2])
```

① First element

② Sixth element

③ First 3 elements

④ Third element through the end

⑤ First 2 elements

⑥ Second through next-to-last element

⑦ Every other element, starting with first

⑧ Every other element, starting with second

⑨ Last element

indexing_and_slicing.py

```
pythons: ['Idle', 'Cleese', 'Chapman', 'Gilliam', 'Palin', 'Jones']
pythons[0] Idle
pythons[5] Jones
pythons[0:3] ['Idle', 'Cleese', 'Chapman']
pythons[2:] ['Chapman', 'Gilliam', 'Palin', 'Jones']
pythons[:2] ['Idle', 'Cleese']
pythons[1:-1] ['Cleese', 'Chapman', 'Gilliam', 'Palin']
pythons[0::2] ['Idle', 'Chapman', 'Palin']
pythons[1::2] ['Cleese', 'Gilliam', 'Jones']
pythons: ['Idle', 'Cleese', 'Chapman', 'Innes', 'Palin', 'Jones']

characters ('Roger', 'Old Woman', 'Prince Herbert', 'Brother Maynard')
characters[2] Prince Herbert
characters[1:] ('Old Woman', 'Prince Herbert', 'Brother Maynard')

phrase She turned me into a newt
phrase[0] S
phrase[-1] t
phrase[21:25] newt
phrase[21:] newt
phrase[:10] She turned
phrase[::2] Setre eit  et
```

Iterating through a sequence

- use a **for** loop
- works with lists, tuples, strings, or any other iterable
- Syntax

```
for var ... in iterable:
    statement
    statement
    ...
```

To iterate through the values of a list, use the **for** statement. The variable takes on each value in the sequence, and keeps the value of the last item when the loop has finished.

To exit the loop early, use the break statement. To skip the remainder of an iteration, and return to the top of the loop, use the continue statement.

for loops can be used with any iterable object.

TIP The loop variable retains the last value it was set to in the loop even after the loop is finished. (If the loop is in a function, the loop variable is local; otherwise, it is global).

Example

iterating_over_arrays.py

```
#!/usr/bin/env python

my_list = ["Idle", "Cleese", "Chapman", "Gilliam", "Palin", "Jones"]
my_tuple = "Roger", "Old Woman", "Prince Herbert", "Brother Maynard"
my_str = "She turned me into a newt"

for p in my_list:  ①
    print(p)
print()

for r in my_tuple:  ②
    print(r)
print()

for ch in my_str:  ③
    print(ch, end=' ')
print()
```

① Iterate over elements of list

② Iterate over elements of tuple

③ Iterate over characters of string

iterating_over_arrays.py

```
Idle
Cleese
Chapman
Gilliam
Palin
Jones

Roger
Old Woman
Prince Herbert
Brother Maynard

S h e   t u r n e d   m e   i n t o   a   n e w t
```

Tuples

- Designed for "records" or "structs"
- Immutable (read-only)
- Create with comma-separated list of objects
- Use for fixed-size collections of related objects
- Indexing, slicing, etc. are same as lists

Python has a second array type, the **tuple**. It is something like a list, but is immutable; that is, you cannot change values in a tuple after it has been created.

A tuple in Python is used for "records" or "structs" — collections of related items. You do not typically iterate over a tuple; it is more likely that you access elements individually, or *unpack* the tuple into variables.

Tuples are especially appropriate for functions that need to return multiple values; they can also be good for passing function arguments with multiple values.

While both tuples and lists can be used for any data, there are some conventions.

- Use a list when you have a collection of similar objects.
- Use a tuple when you have a collection of related, but dissimilar objects.

In a tuple, the position of elements is important; in a list, the position is not important.

For example, you might have a list of dates, where each date was contained in a month, day, year tuple.

To specify a one-element tuple, use a trailing comma; to specify an empty tuple, use empty parentheses.

```
result = 5,
result = ()
```

TIP Parentheses are not needed around a tuple unless the tuple is nested in a larger data structure.

Example

creating_tuples.py

```
#!/usr/bin/env python

birth_date = 1901, 5, 5

server_info = 'Linux', 'RHEL', 5.2, 'Melissa Jones'

latlon = 35.99, -72.390

print("birth_date:", birth_date)
print("server_info:", server_info)
print("latlon:", latlon)
```

creating_tuples.py

```
birth_date: (1901, 5, 5)
server_info: ('Linux', 'RHEL', 5.2, 'Melissa Jones')
latlon: (35.99, -72.39)
```

TIP

To specify a one-element tuple, use a trailing comma, otherwise it will be interpreted as a single object:

```
color = 'red',
```

Iterable Unpacking

- Copy elements to variables
- Works with any array-like object
- More readable than numeric indexing

If you have a tuple like this:

```
my_date = 8, 1, 2014
```

You can access the elements with

```
print(my_date[0], my_date[1], my_date[2])
```

It’s not very readable though. How do you know which is the month and which is the day?

A better approach is *unpacking*, which is simply copying a tuple (or any other iterable) to a list of variables:

```
month, day, year = my_date
```

Now you can use the variables and anyone reading the code will know what they mean. This is really how tuples were designed to be used.

Example

iterable_unpacking.py

```
#!/usr/bin/env python

values = ['a', 'b', 'c']

x, y, z = values  ①

print(x, y, z)
print()

people = [
    ('Bill', 'Gates', 'Microsoft'),
    ('Steve', 'Jobs', 'Apple'),
    ('Paul', 'Allen', 'Microsoft'),
    ('Larry', 'Ellison', 'Oracle'),
    ('Mark', 'Zuckerberg', 'Facebook'),
    ('Sergey', 'Brin', 'Google'),
    ('Larry', 'Page', 'Google'),
    ('Linux', 'Torvalds', 'Linux'),
]

for row in people:
    first_name, last_name, _ = row  ② ③
    print(first_name, last_name)
print()

for first_name, last_name, _ in people:  ④
    print(first_name, last_name)
print()

# extended unpacking
values = ['a', 'b', 'c', 'd', 'e', 'f']
x, y, *z = values
print(x, y, z)

x, *y, z = values
print(x, y, z)

*x, y, z = values
print(x, y, z)
```

① unpack values (which is an iterable) into individual variables

② unpack **row** into variables

③ _ is used as a "junk" variable that won’t be used

④ a **for** loop unpacks if there is more than one variable

iterable_unpacking.py

```
a b c

Bill Gates
Steve Jobs
Paul Allen
Larry Ellison
Mark Zuckerberg
Sergey Brin
Larry Page
Linux Torvalds

Bill Gates
Steve Jobs
Paul Allen
Larry Ellison
Mark Zuckerberg
Sergey Brin
Larry Page
Linux Torvalds

a b ['c', 'd', 'e', 'f']
a ['b', 'c', 'd', 'e'] f
['a', 'b', 'c', 'd'] e f
```

Nested sequences

- Lists and tuples may contain other lists and tuples
- Use multiple brackets to specify higher dimensions
- Depth of nesting limited only by memory

Lists and tuples can contain any type of data, so a two-dimensional array can be created using a list of lists. A typical real-life scenario consists of reading data into a list of tuples.

There are many combinations – lists of tuples, lists of lists, etc.

To initialize a nested data structure, use nested brackets and parentheses, as needed.

Example

nested_sequences.py

```
#!/usr/bin/env python

people = [
    ('Melinda', 'Gates', 'Gates Foundation'),
    ('Steve', 'Jobs', 'Apple'),
    ('Larry', 'Wall', 'Perl'),
    ('Paul', 'Allen', 'Microsoft'),
    ('Larry', 'Ellison', 'Oracle'),
    ('Bill', 'Gates', 'Microsoft'),
    ('Mark', 'Zuckerberg', 'Facebook'),
    ('Sergey', 'Brin', 'Google'),
    ('Larry', 'Page', 'Google'),
    ('Linus', 'Torvalds', 'Linux'),
]

for person in people:  ①
    print(person[0], person[1])
print('-' * 60)

for person in people:
    first_name, last_name, product = person  ②
    print(first_name, last_name)
print('-' * 60)

for first_name, last_name, product in people:  ③
    print(first_name, last_name)
print('-' * 60)
```

① person is a tuple

② unpack person into variables

③ if there is more than one variable in a for loop, each element is unpacked

nested_sequences.py

```
Melinda Gates
Steve Jobs
Larry Wall
Paul Allen
Larry Ellison
Bill Gates
Mark Zuckerberg
Sergey Brin
Larry Page
Linus Torvalds
------------------------------------------------------------
Melinda Gates
Steve Jobs
Larry Wall
Paul Allen
Larry Ellison
Bill Gates
Mark Zuckerberg
Sergey Brin
Larry Page
Linus Torvalds
------------------------------------------------------------
Melinda Gates
Steve Jobs
Larry Wall
Paul Allen
Larry Ellison
Bill Gates
Mark Zuckerberg
Sergey Brin
Larry Page
Linus Torvalds
------------------------------------------------------------
```

Functions for all sequences

- Many builtin functions expect a sequence
- Syntax

```
n = len(s)
n = min(s)
n = max(s)
n = sum(s)
s2 = sorted(s)
s2 = reversed(s)
s = zip(s1,s2,...)
```

Many builtin functions accept a sequence as the parameter. These functions can be applied to a list, tuple, dictionary, or set.

len(s) returns the number of elements in s (the number of characters in a string).

min(s) and **max(s)** return the smallest and largest values in s. Types in s must be similar — mixing strings and numbers will raise an error.

sorted(s) returns a sorted list of any sequence s.

NOTE min(), max(), and sorted() accept a named parameter **key**, which specifies a key function for converting each element of s to the value wanted for comparison. In other words, the key function could convert all strings to lower case, or provide one property of an object.

sum(s) returns the sum of all elements of s, which must all be numeric.

reversed(s) returns an iterator (not a list) that can loop through s in reverse order.

zip(s1,s2,...) returns an iterator consisting of (s1[0],s2[0]),(s1[1], s2[1]), ...). This can be used to "pivot" rows and columns of data.

Example

sequence_functions.py

```
#!/usr/bin/env python

colors = ["red", "blue", "green", "yellow", "brown", "black"]
months = (
    "Jan", "Feb", "Mar", "Apr", "May", "Jun",
    "Jul", "Aug", "Sep", "Oct", "Nov", "Dec",
)

print("colors: len is {}; min is {}; max is {}".format(len(colors), min(colors),
max(colors)))
print("months: len is {}; min is {}; max is {}".format(len(months), min(months),
max(months)))
print()

print("sorted:", end=' ')
for m in sorted(colors):   ①
    print(m, end=' ')
print()

phrase = ('dog', 'bites', 'man')
print(" ".join(reversed(phrase)))  ②
print()

first_names = "Bill Bill Dennis Steve Larry".split()
last_names = "Gates Joy Richie Jobs Ellison".split()

full_names = zip(first_names, last_names)  ③
print("full_names:", full_names)
print()

for first_name, last_name in full_names:
    print("{} {}".format(first_name, last_name))
```

① sorted() returns a sorted list

② reversed() returns a **reversed** iterator

③ zip() returns an iterator of tuples created from corresponding elements

sequence_functions.py

```
colors: len is 6; min is black; max is yellow
months: len is 12; min is Apr; max is Sep

sorted: black blue brown green red yellow
man bites dog

full_names: <zip object at 0x7faaf8177870>

Bill Gates
Bill Joy
Dennis Richie
Steve Jobs
Larry Ellison
```

Using enumerate()

- Numbers items beginning with 0 (or specified value)
- Returns enumerate object that provides a *virtual* list of tuples

To get the index of each list item, use the builtin function enumerate(s). It returns an **enumerate object**.

```
for t in enumerate(s):
    print(t[0],t[1])

for i,item in enumerate(s):
    print(i,item)

for i,item in enumerate(s,1)
    print(i,item)
```

When you iterate through the following list with enumerate():

```
    [x,y,z]
```

you get this (virtual) list of tuples:

```
    [(0,x),(1,y),(2,z)]
```

You can give enumerate() a second argument, which is added to the index. This way you can start numbering at 1, or any other place.

Example

enumerate.py

```
#!/usr/bin/env python

colors = "red blue green yellow brown black".split()

months = "Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec".split()

for i, color in enumerate(colors):  ①
    print(i, color)

print()


for num, month in enumerate(months, 1):  ②
    print("{} {}".format(num, month))
```

① enumerate() returns iterable of (index, value) tuples

② Second parameter to enumerate is added to index

enumerate.py

```
0 red
1 blue
2 green
3 yellow
4 brown
5 black

1 Jan
2 Feb
3 Mar
4 Apr
5 May
6 Jun
7 Jul
8 Aug
9 Sep
10 Oct
11 Nov
12 Dec
```

Operators and keywords for sequences

- Operators + *
- Keywords **del in not in**

del deletes an entire string, list, or tuple. It can also delete one element, or a slice, from a list. del cannot remove elements of strings and tuples, because they are immutable.

in returns True if the specified object is an element of the sequence.

not in returns True if the specified object is *not* an element of the sequence.

+ adds one sequence to another

***** multiplies a sequence (i.e., makes a bigger sequence by repeating the original).

```
x in s  #note ▯ x can be any Python object
s2 = s1 * 3
s3 = s1 + s2
```

Example

sequence_operators.py

```
#!/usr/bin/env python

colors = ["red", "blue", "green", "yellow", "brown", "black"]

months = (
    "Jan", "Feb", "Mar", "Apr", "May", "Jun",
    "Jul", "Aug", "Sep", "Oct", "Nov", "Dec",
)

print("yellow in colors: ", ("yellow" in colors))  ①
print("pink in colors: ", ("pink" in colors))

print("colors: ", ",".join(colors))  ②

del colors[4]  # remove brown   ③

print("removed 'brown':", ",".join(colors))

colors.remove('green')  ④

print("removed 'green':", ",".join(colors))

sum_of_lists = [True] + [True] + [False]  ⑤

print("sum of lists:", sum_of_lists)

product = [True] * 5  ⑥

print("product of lists:", product)
```

① Test for membership in list

② Concatenate iterable using ", " as delimiter

③ Permanently remove element with index 4

④ Remove element by value

⑤ Add 3 lists together; combines all elements

⑥ Multiply a list; replicates elements

sequence_operators.py

```
yellow in colors:  True
pink in colors:  False
colors:  red,blue,green,yellow,brown,black
removed 'brown': red,blue,green,yellow,black
removed 'green': red,blue,yellow,black
sum of lists: [True, True, False]
product of lists: [True, True, True, True, True]
```

The range() function

- Provides (virtual) list of numbers
- Slice-like parameters
- Syntax

```
    range(stop)
    range(start, stop)
    range(start, stop, step)
```

The range() function returns a **range object**, that provides a list of numbers when iterated over. The parameters to range() are similar to the parameters for slicing (start, stop, step).

This can be useful to execute some code a fixed number of times.

Example

using_ranges.py

```
#!/usr/bin/env python

print("range(1, 6): ", end=' ')
for x in range(1, 6):  ①
    print(x, end=' ')
print()

print("range(6): ", end=' ')
for x in range(6):  ②
    print(x, end=' ')
print()

print("range(3, 12): ", end=' ')
for x in range(3, 12):  ③
    print(x, end=' ')
print()

print("range(5, 30, 5): ", end=' ')
for x in range(5, 30, 5):  ④
    print(x, end=' ')
print()

print("range(10, 0, -1): ", end=' ')
for x in range(10, 0, -1):  ⑤
    print(x, end=' ')
print()
```

① Start=1, Stop=6 (1 through 5)

② Start=0, Stop=6 (0 through 5)

③ Start=3, Stop=12 (3 through 11)

④ Start=5, Stop=30, Step=5 (5 through 25 by 5)

⑤ Start=10, Stop=1, Step=-1 (10 through 1 by 1)

using_ranges.py

```
range(1, 6):  1 2 3 4 5
range(6):  0 1 2 3 4 5
range(3, 12):  3 4 5 6 7 8 9 10 11
range(5, 30, 5):  5 10 15 20 25
range(10, 0, -1):  10 9 8 7 6 5 4 3 2 1
```

List comprehensions

- Shortcut for a for loop
- Optional if clause
- Always returns list
- Syntax

```
[ EXPR for VAR in SEQUENCE if EXPR ]
```

A list comprehension is a Python idiom that creates a shortcut for a for loop. A loop like this:

```
results = []
for var in sequence:
    results.append(expr)   # where expr involves var
```

can be rewritten as

```
results = [ expr for var in sequence ]
```

A conditional if may be added:

```
results = [ expr for var in sequence if expr ]
```

The loop expression can be a tuple. You can nest two or more for loops.

Example

list_comprehensions.py

```
#!/usr/bin/env python

fruits = ['watermelon', 'apple', 'mango', 'kiwi', 'apricot', 'lemon', 'guava']

ufruits = [fruit.upper() for fruit in fruits]        ①
afruits = [fruit.title() for fruit in fruits if fruit.startswith('a')]  ②

print("ufruits:", ufruits)
print("afruits:", afruits)
print()

values = [2, 42, 18, 39.7, 92, '14', "boom", ['a', 'b', 'c']]

doubles = [v * 2 for v in values]   ③

print("doubles:", doubles, '\n')

nums = [x for x in values if isinstance(x, int)]   ④
print(nums, '\n')

dirty_strings = ['   Gronk    ', 'PULABA       ', '        floog']

clean = [d.strip().lower() for d in dirty_strings]
for c in clean:
    print(">{}<".format(c), end=' ')
print("\n")

suits = 'Clubs', 'Diamonds', 'Hearts', 'Spades'
ranks = '2 3 4 5 6 7 8 9 10 J Q K A'.split()

deck = [(rank, suit) for suit in suits for rank in ranks]   ⑤

for rank, suit in deck:
    print("{}-{}".format(rank, suit))
```

① Simple transformation of all elements

② Transformation of selected elements only

③ Any kind of data is OK

④ Select only integers from list

⑤ More than one **for** is OK

list_comprehensions.py

```
ufruits: ['WATERMELON', 'APPLE', 'MANGO', 'KIWI', 'APRICOT', 'LEMON', 'GUAVA']
afruits: ['Apple', 'Apricot']

doubles: [4, 84, 36, 79.4, 184, '1414', 'boomboom', ['a', 'b', 'c', 'a', 'b', 'c']]

[2, 42, 18, 92]

>gronk< >pulaba< >floog<

2-Clubs
3-Clubs
4-Clubs
5-Clubs
6-Clubs
7-Clubs
8-Clubs
9-Clubs
10-Clubs
J-Clubs
Q-Clubs
K-Clubs
A-Clubs
2-Diamonds
3-Diamonds
4-Diamonds
5-Diamonds
6-Diamonds
7-Diamonds
8-Diamonds
9-Diamonds
```

etc etc

Generator Expressions

- Similar to list comprehensions
- Lazy evaluations – only execute as needed
- Syntax

```
( EXPR for VAR in SEQUENCE if EXPR )
```

A generator expression is very similar to a list comprehension. There are two major differences, one visible and one invisible.

The visible difference is that generator expressions are created with parentheses rather than square brackets. The invisible difference is that instead of returning a list, they return an iterable object.

The object only fetches each item as requested, and if you stop partway through the sequence; it never fetches the remaining items. Generator expressions are thus frugal with memory.

Example

generator_expressions.py

```
#!/usr/bin/env python

fruits = ['watermelon', 'apple', 'mango', 'kiwi', 'apricot', 'lemon', 'guava']

ufruits = (fruit.upper() for fruit in fruits)  ①
afruits = (fruit.title() for fruit in fruits if fruit.startswith('a'))

print("ufruits:", " ".join(ufruits))
print("afruits:", " ".join(afruits))
print()

values = [2, 42, 18, 92, "boom", ['a', 'b', 'c']]
doubles = (v * 2 for v in values)

print("doubles:", end=' ')
for d in doubles:
    print(d, end=' ')
print("\n")

nums = (int(s) for s in values if isinstance(s, int))
for n in nums:
    print(n, end=' ')
print("\n")

dirty_strings = ['   Gronk    ', 'PULABA       ', '        floog']

clean = (d.strip().lower() for d in dirty_strings)
for c in clean:
    print(">{}<".format(c), end=' ')
print("\n")

powers = ((i, i ** 2, i ** 3) for i in range(1, 11))
for num, square, cube in powers:
    print("{:2d} {:3d} {:4d}".format(num, square, cube))
print()
```

① These are all exactly like the list comprehension example, but return generators rather than lists *generator_expressions.py*

```
ufruits: WATERMELON APPLE MANGO KIWI APRICOT LEMON GUAVA
afruits: Apple Apricot

doubles: 4 84 36 184 boomboom ['a', 'b', 'c', 'a', 'b', 'c']

2 42 18 92

>gronk< >pulaba< >floog<

 1   1    1
 2   4    8
 3   9   27
 4  16   64
 5  25  125
 6  36  216
 7  49  343
 8  64  512
 9  81  729
10 100 1000
```

Chapter 4 Exercises

Exercise 4-1 (pow2.py)

Print out all the powers of 2 from 2^0 through 2^{31}.

Use the ** operator, which raises a number to a power.

NOTE For exercises 4-2 and 4-3, start with the file sequences.py, which has the lists ctemps and fruits already typed in. You can put all the answers in sequences.py

Exercise 4-2 (sequences.py)

ctemps is a list of Celsius temperatures. Loop through ctemps, convert each temperature to Fahrenheit, and print out both temperatures.

Exercise 4-3 (sequences.py)

Use a list comprehension to copy the list **fruits** to a new list named **clean_fruits**, with all fruits in lower case and leading/trailing white space removed. Print out the new list.

HINT: Use chained methods (x.spam().ham())

Exercise 4-4 (sieve.py)

FOR ADVANCED STUDENTS

The "Sieve of Eratosthenes" is an ancient algorithm for finding prime numbers. It works by starting at 2 and checking each number up to a specified limit. If the number has been marked as non-prime, it is skipped. Otherwise, it is prime, so it is output, and all its multiples are marked as non-prime.

Write a program to implement this algorithm. Specify the limit (the highest number to check) on the script's command line. Supply a default if no limit is specified.

Initialize a list (maybe named **is_prime**) to the size of the limit plus one (use * to multiply a single-item list). All elements should be set to **True**.

Use two *nested* loops.

The outer loop will check each value (element of the array) from 2 to the upper limit. (use the `range()`) function.

If the element has a **True** value (is prime), print out its value. Then, execute a second loop iterates through all the multiples of the number, and marks them as **False** (i.e., non-prime).

No action is needed if the value is False. This will skip the non-prime numbers.

TIP Use range() to generate the multiples of the current number.

NOTE In this exercise, the *value* of the element is either **True** or **False** — the *index* is the number be checked for primeness.

See next page for the pseudocode for this program:

Pseudocode for sieve.py

```
if # command line args == 1
    get LIMIT from command line
else
    set LIMIT to 50

Initialize IS_PRIMES list to size LIMIT+1, with all TRUE values

for NUM  from 2 to LIMIT+1
    if IS_PRIME[NUM]
        output NUM
        for M from NUM to LIMIT+1, counting by NUM
            IS_PRIME[M] = FALSE
```

Chapter 5: Working with Files

Objectives

- Reading a text file line-by-line
- Reading an entire text files
- Reading all lines of a text file into an array
- Writing to a text file

Text file I/O

- Create a file object with open
- Specify modes: read/write, text/binary
- Read or write from file object
- Close file object (or use **with** block)

Python provides a file object that is created by the built-in open() function. From this file object you can read or write data in several different ways. When opening a file, you specify the file name and the mode, which says whether you want to read, write, or append to the file, and whether you want text or binary (raw) processing.

NOTE This chapter is about working with generic files. For files in standard formats, such as XML, CSV, YAML, JSON, and many others, Python has format-specific modules to read them.

Opening a text file

- Specify the file name and the mode
- Returns a file object
- Mode can be read or write
- Specify "b" for binary (raw) mode
- Omit mode for reading

Open a text file with the open() command. Arguments are the file name, which may be specified as a relative or absolute path, and the mode. The mode consists of "r" for read, "w" for write, or "a" for append. To open a file in binary mode, add "b" to the mode, as in "rb", "wb", or "ab".

If you omit the mode, "r" is the default.

Example

```
ty = open("tyger.txt","r")  open for reading in text mode
ty = open("tyger.txt")      open for reading in text mode (default mode)
junk = open("junk.dat","rb")    open for reading in raw mode
stf = open("stuff.txt","w") open for writing in text mode
stf = open("stuff.txt","x") open for writing in text mode, fail if file exists
moju = open("morejunk.dat","wb")    open for writing in raw mode
config = open("spam.cfg","a")   open for append in text mode
```

TIP The **fileinput** module in the standard library makes it easy to loop over each line in all files specified on the command line, or STDIN if no files are specified. This avoids having to open and close each file.

The *with* block

- Provides "execution context"
- Automagically closes file object
- Not specific to file objects

Because it is easy to forget to close a file object, you can use a **with** block to open your file. This will automatically close the file object when the block is finished. The syntax is

```
with open(filename, mode) as fileobject:
    # process fileobject
```

Reading a text file

- Iterate through file with for/in

```
    for line in file_in
```

- Use methods of the file object

```
    file_in.readlines()   read all lines from file_in
    file_in.read()        read all of file_in
    file_in.read(n)       read n characters from file in text mode; n bytes from
file_in in binary mode
    file_in.readline()    read next line from file_in
```

The easiest way to read a file is by looping through the file object with a for/in loop. This is possible because the file object is an iterator, which means the object knows how to provide a sequence of values.

You can also read a text file one line or multiple lines at a time. **readline()** reads the next available line; **readlines()** reads all lines into a list.

read() will read the entire file; **read(n)** will read n bytes from the file (n *characters* if in text mode).

readline() will read the next line from the file.

Example

read_tyger.py

```
#!/usr/bin/env python

with open("../DATA/tyger.txt", "r") as tyger_in:  ①
    for line in tyger_in:  ②
        print(line, end='')  ③
```

① **tyger_in** is return value of **open(…)**

② **tyger_in** is a *generator*, returning one line at a time

③ the line already has a newline, so **print()** does not need one

read_tyger.py

```
           The Tyger

Tyger! Tyger! burning bright
In the forests of the night,
What immortal hand or eye
Could frame thy fearful symmetry?

In what distant deeps or skies
Burnt the fire of thine eyes?
On what wings dare he aspire?
What the hand dare seize the fire?

And what shoulder, & what art,
Could twist the sinews of thy heart?
And when thy heart began to beat,
What dread hand? & what dread feet?

What the hammer? what the chain?
In what furnace was thy brain?
What the anvil? what dread grasp
Dare its deadly terrors clasp?

When the stars threw down their spears
And water'd heaven with their tears,
Did he smile his work to see?
Did he who made the Lamb make thee?

Tyger! Tyger! burning bright
In the forests of the night,
What immortal hand or eye
Dare frame thy fearful symmetry?

                    by William Blake
```

Example

reading_files.py

```
#!/usr/bin/env python

FILE_NAME = '../DATA/mary.txt'

mary_in = open(FILE_NAME)  ①
# read file...
mary_in.close()  ②

with open(FILE_NAME) as mary_in:  ③
    for raw_line in mary_in:  ④
        line = raw_line.rstrip()  ⑤
        print(line)
print('-' * 60)

with open(FILE_NAME) as mary_in:
    contents = mary_in.read()  ⑥
    print("NORMAL:")
    print(contents)
    print("=" * 20)
    print("RAW:")
    print(repr(contents))  ⑦
print('-' * 60)

with open(FILE_NAME) as mary_in:
    lines_with_nl = mary_in.readlines()  ⑧
    print(lines_with_nl)
print('-' * 60)

with open(FILE_NAME) as mary_in:
    lines_without_nl = mary_in.read().splitlines()  ⑨
    print(lines_without_nl)
```

① open file for reading

② close file (easy to forget to do this!)

③ open file for reading

④ iterate over lines in file (line retains \n)

⑤ rstrip('\n\r') removes whitespace (including \r or \n) from end of string

⑥ read entire file into one string

⑦ print string in "raw" mode

⑧ readlines() reads all lines into an array

⑨ splitlines() splits string on '\n' into lines

reading_files.py

```
Mary had a little lamb,
Its fleece was white as snow,
And everywhere that Mary went
The lamb was sure to go
------------------------------------------------------------
NORMAL:
Mary had a little lamb,
Its fleece was white as snow,
And everywhere that Mary went
The lamb was sure to go

====================
RAW:
'Mary had a little lamb,\nIts fleece was white as snow,\nAnd everywhere that Mary
went\nThe lamb was sure to go\n'
------------------------------------------------------------
['Mary had a little lamb,\n', 'Its fleece was white as snow,\n', 'And everywhere that
Mary went\n', 'The lamb was sure to go\n']
------------------------------------------------------------
['Mary had a little lamb,', 'Its fleece was white as snow,', 'And everywhere that Mary
went', 'The lamb was sure to go']
```

Writing to a text file

- Use write() or writelines()
- Add \n manually

To write to a text file, use the write() function to write a single string; or writelines() to write a list of strings.

writelines() will not add newline characters, so make sure the items in your list already have them.

Example

write_file.py

```
#!/usr/bin/env python

states = (
    'Virginia',
    'North Carolina',
    'Washington',
    'New York',
    'Florida',
    'Ohio',
)

with open("states.txt", "w") as states_out: ①
    for state in states:
        states_out.write(state + "\n")  ②
```

① "w" opens for writing, "a" for append

② write() does not add \n automatically

write_file.py

cat states.txt (Windows: type states.txt)

```
Virginia
North Carolina
Washington
New York
Florida
Ohio
```

"writelines" should have been called "writestrings"

Table 10. File Methods

Function	**Description**
f.close()	close file f
f.flush()	write out buffered data to file f

s = f.read(n)
s = f.read()
	read size bytes from file f into string s; if n is ⇐ 0, or omitted, reads entire file

s = f.readline()
s = f.readline(n)
	read one line from file f into string s. If n is specified, read no more than n characters

m = f.readlines()	read all lines from file f into list m

f.seek(n)
f.seek(n,w)
	position file f at offset n for next read or write; if argument w (whence) is omitted or 0, offset is from beginning; if 1, from current file position, if 2, from end of file

f.tell()	return current offset from beginning of file
f.write(s)	write string s to file f
f.writelines(m)	write list of strings m to file f; does not add line terminators

Chapter 5 Exercises

Exercise 5-1 (line_no.py)

Write a program to display each line of a file preceded by the line number. Allow your program to process one or more files specified on the command line. Be sure to reset the line number for each file.

TIP Use enumerate().

Test with the following commands:

```
python line_no.py DATA/tyger.txt
python line_no.py DATA/parrot.txt DATA/tyger.txt
```

Test with other files, as desired

Exercise 5-2 (alt_lines.py)

Write a program to create two files, a.txt and b.txt from the file alt.txt. Lines that start with 'a' go in a.txt; the other lines (which all start with 'b') go in b.txt. Compare the original to the two new files.

Exercise 5-3 (count_alice.py, count_words.py)

A. Write a program to count how many lines of alice.txt contain the word "Alice". (There should be 392).

TIP Use the **in** operator to test whether a line contains the word "Alice"

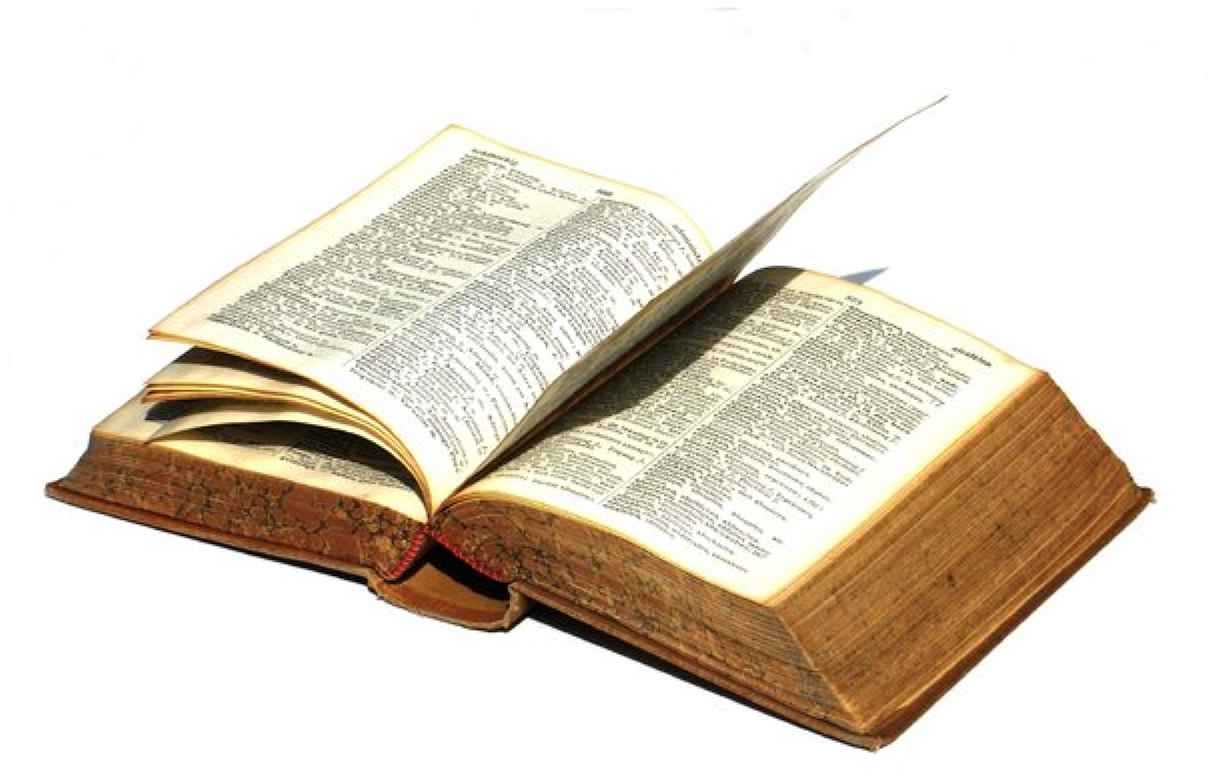
B. Modify count_alice.py to take the first command line parameter as a word to find, and the remaining parameters as filenames. For each file, print out the file name and the number of lines that contain the specified word. Test thoroughly

FOR ADVANCED STUDENTS (icount_words.py) Modify count_words.py to make the search case-insensitive.

Chapter 6: Dictionaries and Sets

Objectives

- Creating dictionaries
- Using dictionaries for mapping and counting
- Iterating through key-value pairs
- Reading a file into a dictionary
- Counting with a dictionary
- Using sets



About dictionaries

- A collection
- Associates keys with values
- called "hashes", "hash tables" or "associative arrays" in other languages
- Rich set of functions available

A dictionary is a collection that contains key-value pairs. Dictionaries are not sequential like lists, tuples, and strings; they function more as a lookup table. They map one value to another.

The keys must be immutable – lists and dictionaries may not be used as keys. Any immutable type may be a key, although typically keys are strings.

Prior to version 3.6, the elements of a dictionary are in no particular order. Starting with 3.6, elements are stored in the order added. If you iterate over *dictionary*.items(), it will iterate in the order that the elements were added.

Values can be any Python object – strings, numbers, tuples, lists, dates, or anything else.

For instance, a dictionary might

- map column names in a database table to their corresponding values
- map almost any group of related items to a unique identifier
- map screen names to real names
- map zip codes to a count of customers per zip code
- count error codes in a log file
- count image tags in an HTML file

When to use dictionaries?

- Mapping
- Counting

Dictionaries are very useful for mapping a set of keys to a corresponding set of values. You could have a dictionary where the key is a candidate for office, and value is the state in which the candidate is running, or the value could be an object containing many pieces of information about the candidate.

Dictionaries are also handy for counting. The keys could be candidates and the values could be the number of votes each candidate received.

Creating dictionaries

- Create dictionaries with { } or dict()
- Create from (nearly) any sequence
- Add additional keys by assignment

To create a dictionary, use the dict() function or {}. The dictionary can be created empty, or you can initialize it with one or more key/value pairs, separated by colons.

To add more keys, assign to the dictionary using square brackets.

Remember, braces are only used to create a dictionary; indexing uses brackets like all the other container types. To get the value for a given key, specify the key with square brackets or use the get() method.

Example

creating_dicts.py

```
#!/usr/bin/env python

d1 = dict()  ①

airports = {'IAD': 'Dulles', 'SEA': 'Seattle-Tacoma',  ②
            'RDU': 'Raleigh-Durham', 'LAX': 'Los Angeles'}

d2 = {}
d3 = dict(red=5, blue=10, yellow=1, brown=5, black=12)  ③

pairs = [('Washington', 'Olympia'), ('Virginia', 'Richmond'),
         ('Oregon', 'Salem'), ('California', 'Sacramento')]

state_caps = dict(pairs)  ④

print(d3['red'])  ⑤
print(airports['LAX'])

airports['SLC'] = 'Salt Lake City'  ⑥
airports['LAX'] = 'Lost Angels'  ⑦
print(airports['SLC'])
```

① create new empty dict

② initialize dict with literal key/value pairs (keys can be any string, number or tuple)

③ initialize dict with named parameters; keys must be valid identifier names

④ initialize dict with an iterable of pairs

⑤ print value for given key

⑥ assign to new key

⑦ overwrite existing key

creating_dicts.py

```
5
Los Angeles
Salt Lake City
```

Table 11. Frequently used dictionary functions and operators

Function	Description
len(D)	the number of elements in D
D[k]	the element of D with key k
D[k] = v	set D[k] to v
del D[k]	remove element from D whose key is k
D.clear()	remove all items from a dictionary
k in D	True if key k exists in D
k not in D	True if key k does not exist in D
D.get(k[, x])	D[k] if k in a, else x
D.items()	return an iterator over (key, value) pairs
D.update([b])	updates (and overwrites) key/value pairs from b
D.setdefault(k[, x])	a[k] if k in D, else x (also setting it)

Table 12. Less frequently used dictionary functions

Function	Description
D.keys()	return an iterator over the mapping's keys
D.values()	return an iterator over the mapping's values
D.copy()	a (shallow) copy of D
D.has_key(k)	True if a has D key k, else False (but use in)
D.fromkeys(seq[, value])	Creates a new dictionary with keys from seq and values set to value
D.pop(k[, x])	a[k] if k in D, else x (and remove k)
D.popitem()	remove and return an arbitrary (key, value) pair

Getting dictionary values

- d[key]
- d.get(key,default-value)
- d.setdefault(key, default-value)

There are three main ways to get the value of a dictionary element, given the key.

Using the key as an index retrieves the corresponding value, or raises a KeyError.

The get() method returns the value, or a default value if the key does not exist. If no default value is specified, and the key does not exist, get() returns None.

The setdefault() method is like get(), but if the key does not exist, adds the key and the default value to the dictionary.

Use the **in** operator to test whether a dictionary contains a given key.

Example

getting_dict_values.py

```
#!/usr/bin/env python

d1 = dict()

airports = {'IAD': 'Dulles', 'SEA': 'Seattle-Tacoma',
            'RDU': 'Raleigh-Durham', 'LAX': 'Los Angeles'}

d2 = {}
d3 = dict(red=5, blue=10, yellow=1, brown=5, black=12)

pairs = [('Washington', 'Olympia'), ('Virginia', 'Richmond'),
         ('Oregon', 'Salem'), ('California', 'Sacramento')]

state_caps = dict(pairs)

print(d3['red'])
print(airports['LAX'])

airports['SLC'] = 'Salt Lake City'
airports['LAX'] = 'Lost Angels'
print(airports['SLC'])  ①

key = 'PSP'
if key in airports:
    print(airports[key])  ②

print(airports.get(key))  ③
print(airports.get(key, 'NO SUCH AIRPORT'))  ④

print(airports.setdefault(key, 'Palm Springs'))  ⑤
print(key in airports)  ⑥
```

① print value where key is 'SLC'

② print key if key is in dictionary

③ get value if key in dict, otherwise get None

④ get value if key in dict, otherwise get 'NO SUCH AIRPORT'

⑤ get value if key in dict, otherwise get 'Palm Springs' AND set key

⑥ check for key in dict

getting_dict_values.py

```
5
Los Angeles
Salt Lake City
None
NO SUCH AIRPORT
Palm Springs
True
```

Iterating through a dictionary

- d.items() generates key/value tuples
- Key order
  - before 3.6: not predictable
  - 3.6 and later: insertion order

To iterate through tuples containing the key and the value, use the method DICT.items(). It generates tuples in the form (KEY,VALUE).

Before 3.6, elements are retrieved in arbitrary order; beginning with 3.6, elements are retrieved in the order they were added.

To do something with the elements in a particular order, the usual approach is to pass ***DICT*.items()** to the **sorted()** function and loop over the result.

TIP If you iterate through the dictionary itself (as opposed to *dictionary*.items()), you get just the keys.

Example

iterating_over_dicts.py

```
#!/usr/bin/env python

airports = {'IAD': 'Dulles', 'SEA': 'Seattle-Tacoma',
            'RDU': 'Raleigh-Durham', 'LAX': 'Los Angeles'}

for abbr, airport in airports.items():  ①
    print(abbr, airport)
```

① items() returns a virtual list of key:value pairs

iterating_over_dicts.py

```
IAD Dulles
SEA Seattle-Tacoma
RDU Raleigh-Durham
LAX Los Angeles
```

Reading file data into a dictionary

- Data must have unique key
- Key is one column, value can be string, number, list, or tuple (or anything else!)

To read a file into a dictionary, read the file one line at a time, splitting the line into fields as necessary. Use a unique field for the key. The value can be either some other field, or a group of fields, as stored in a list or tuple. Remember that the value can be any Python object.

Example

read_into_dict_of_tuples.py

```
#!/usr/bin/env python

from pprint import pprint

knight_info = {}  ①

with open("../DATA/knights.txt") as knights_in:
    for line in knights_in:
        name, title, color, quest, comment = line.rstrip('\n\r').split(":")
        knight_info[name] = title, color, quest, comment  ②

pprint(knight_info)
print()

for name, info in knight_info.items():
    print(info[0], name)

print()
print(knight_info['Robin'][2])
```

① create empty dict

② create new dict element with **name** as key and a tuple of the other fields as the value

read_into_dict_of_tuples.py

```
{'Arthur': ('King', 'blue', 'The Grail', 'King of the Britons'),
 'Bedevere': ('Sir', 'red, no blue!', 'The Grail', 'AARRRRRRRGGGGHH'),
 'Galahad': ('Sir', 'red', 'The Grail', "'I could handle some more peril'"),
 'Gawain': ('Sir', 'blue', 'The Grail', 'none'),
 'Lancelot': ('Sir', 'blue', 'The Grail', '"It\'s too perilous!"'),
 'Robin': ('Sir', 'yellow', 'Not Sure', 'He boldly ran away')}

King Arthur
Sir Galahad
Sir Lancelot
Sir Robin
Sir Bedevere
Sir Gawain

Not Sure
```

TIP See also **read_into_dict_of_dicts.py** and **read_into_dict_of_named_tuples.py** in the EXAMPLES folder.

Counting with dictionaries

- Use dictionary where key is item to be counted
- Value is number of times item has been seen.

To count items, use a dictionary where the key is the item to be counted, and the value is the number of times it has been seen (i.e., the count).

The get() method is useful for this. The first time an item is seen, get can return 0; thereafter, it returns the current count. Each time, add 1 to this value.

TIP Check out the **Counter** class in the **collections** module

Example

count_with_dict.py

```
#!/usr/bin/env python

counts = {}  ①
with open("../DATA/breakfast.txt") as breakfast_in:
    for line in breakfast_in:
        breakfast_item = line.rstrip('\n\r')
        if breakfast_item in counts:   ②
            counts[breakfast_item] = counts[breakfast_item] + 1   ③
        else:
            counts[breakfast_item] = 1 ④

for item, count in counts.items():
    print(item, count)
```

① create empty dict

② create new dict element with **name** as key and a tuple of the other fields as the value

count_with_dict.py

```
spam 10
eggs 3
crumpets 1
```

As a short cut, you could check for the key and increment with a one-liner:

```
counts[breakfast_item] = counts.get(breakfast_item,0) + 1
```

About sets

- Find unique values
- Check for membership
- Find union or intersection
- Like a dictionary where all values are True
- Two kinds of sets
    - set (mutable)
    - frozenset (immutable)

A set is useful when you just want to keep track of a group of values, but there is no particular value associated with them .

The easy way to think of a set is that it’s like a dictionary where the value of every element is True. That is, the important thing is whether the key is in the set or not.

There are methods to compute the union, intersection, and difference of sets, along with some more esoteric functionality.

As with dictionary keys, the values in a set must be unique. If you add a key that already exists, it doesn’t change the set.

You could use a set to keep track of all the different error codes in a file, for instance.

Creating Sets

- Literal set: {item1, item2, …}
- Use set() or frozenset()
- Add members with SET.add()

To create a set, use the set() constructor, which can be initialized with any iterable. It returns a set object, to which you can then add elements with the add() method.

Create a literal set with curly braces containing a comma-separated list of the members. This won't be confused with a literal dictionary, because dictionary elements contain a colon separating the key and value.

To create an immutable set, use frozenset(). Once created, you my not add or delete items from a frozenset. This is useful for quick lookup of valid values.

Working with sets

- Common set operations
    - adding an element
    - deleting an element
    - checking for membership
    - computing
        - union
        - intersection
        - symmetric difference (xor)

The most common thing to do with a set is to check for membership. This is accomplished with the **in** operator. New elements are added with the **add()** method, and elements are deleted with the **del** operator.

Intersection (**&**) of two sets returns a new set with members common to both sets.

Union (|) of two sets returns a new set with all members from both sets.

Xor (^) of two sets returns a new set with members that are one one set or the other, but not both. (AKA symmetric difference)

Difference (**-**) of two sets returns a new set with members on the right removed from the set on the left.

Example

set_examples.py

```
#!/usr/bin/env python

set1 = {'red', 'blue', 'green', 'purple', 'green'}  ①
set2 = {'green', 'blue', 'yellow', 'orange'}

set1.add('taupe')  ②

print(set1)
print(set2)
print(set1 & set2)  ③
print(set1 | set2)  ④
print(set1 ^ set2)  ⑤
print(set1 - set2)  ⑥
print(set2 - set1)
print()

food = 'spam ham ham spam spam spam ham spam spam eggs cheese spam'.split()
food_set = set(food)  ⑦
print(food_set)
```

① create literal set

② add element to set (ignored if already in set)

③ intersection of two sets

④ union of two sets

⑤ XOR (symmetric difference); items in one set but not both

⑥ Remove items in right set from left set

⑦ Create set from iterable (e.g., list)

set_examples.py

```
{'red', 'blue', 'green', 'taupe', 'purple'}
{'blue', 'orange', 'green', 'yellow'}
{'blue', 'green'}
{'red', 'blue', 'orange', 'green', 'taupe', 'yellow', 'purple'}
{'orange', 'red', 'taupe', 'yellow', 'purple'}
{'red', 'taupe', 'purple'}
{'orange', 'yellow'}

{'ham', 'cheese', 'spam', 'eggs'}
```

Table 13. Set functions and methods

Function	Description
m in S	True if s contains member m
m not in S	True if S does not contain member m
len(s)	the number of items in S
S.add(m)	Add member m to S (if S already contains m do nothing)
S.clear()	remove all members from S
S.copy()	a (shallow) copy of S
S - S2 S.difference(S2)	Return the set of all elements in S that are not in S2
S.difference_update(S2)	Remove all members of S2 from S
S.discard(m)	Remove member m from S if it is a member. If m is not a member, do nothing.
S & S2 S.intersection(S2)	Return new set with all unique members of S and S2
S.isdisjoint(S2)	Return True if S and S2 have no members in common
S.issubset(S2)	Return True is S is a subset of S2
S.issuperset(S2)	Return True is S2 is a subset of S
S.pop()	Remove and return an arbitrary set element. Raises KeyError if the set is empty.
S.remove(m)	Remove member m from a set; it must be a member.
S ^ S2 S.symmetric_difference(S2)	Return all members in S or S2 but not both.
S.symmetric_difference_update(S2)	Update a set with the symmetric difference of itself and another.
S | S2 S.union(S2)	Return all members that are in S or S2
S.update(S2)	Update a set with the union of itself and S2

Chapter 6 Exercises

Exercise 6-1 (scores.py)

A class of students has taken a test. Their scores have been stored in **testscores.dat**. Write a program named **scores.py** to read in the data (read it into a dictionary where the keys are the student names and the values are the test scores). Print out the student names, one per line, sorted, and with the numeric score and letter grade. After printing all the scores, print the average score.

```
Grading Scale
95-100
A
89-94
B
83-88
C
75-82
D
< 75
F
```

Exercise 6-2 (shell_users.py)

Using the file named **passwd**, write a program to count the number of users using each shell. To do this, read **passwd** one line at a time. Split each line into its seven (colon-delimited) fields. The shell is the last field. For each entry, add one to the dictionary element whose key is the shell.

When finished reading the password file, loop through the keys of the dictionary, printing out the shell and the count.

Exercise 6-3 (common_fruit.py)

Using sets, compute which fruits are in both **fruit1.txt** and **fruit2.txt**. To do this, read the files into sets (the files contain one fruit per line) and find the intersection of the sets.

What if fruits are in both files, but one is capitalized and the other isn’t?

Exercise 6-4 (set_sieve.py)

FOR ADVANCED STUDENTS Rewrite **sieve.py** to use a set rather than a list to keep track of which numbers are non-prime. This turns out to be easier – you don't have to initialize the set, as you did with the list.

Chapter 7: Functions Modules Packages

Objectives

- Define functions
- Learn the four kinds of function parameters
- Create new modules
- Load modules with **import**
- Set module search locations
- Organize modules into packages
- Alias module and package names

Functions

- Defined with **def**
- Accept parameters
- Return a value

Functions are a way of isolating code that is needed in more than one place, refactoring code to make it more modular. They are defined with the **def** statement.

Functions can take various types of parameters, as described on the following page. Parameter types are dynamic.

Functions can return one object of any type, using the **return** statement. If there is no return statement, the function returns **None**.

TIP Be sure to separate your business logic (data and calculations) from your presentation logic (the user interface).

Example

function_basics.py

```
#!/usr/bin/env python


def say_hello():  ①
    print("Hello, world")
    print()
    ②


say_hello()  ③


def get_hello():
    return "Hello, world"  ④


h = get_hello()  ⑤
print(h)
print()


def sqrt(num):  ⑥
    return num ** .5


m = sqrt(1234)  ⑦
n = sqrt(2)

print("m is {:.3f} n is {:.3f}".format(m, n))
```

① Function takes no parameters

② If no **return** statement, return None

③ Call function (arguments, if any, in ())

④ Function returns value

⑤ Store return value in h

⑥ Function takes exactly one argument

⑦ Call function with one argument

function_basics.py

```
Hello, world

Hello, world

m is 35.128 n is 1.414
```

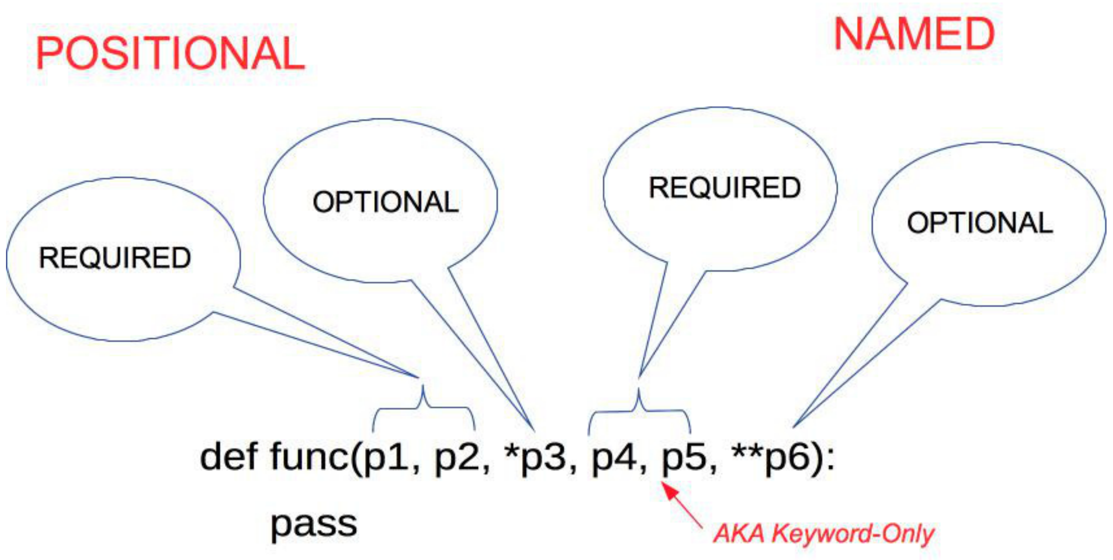
Function parameters

- Positional or named
- Required or optional
- Can have default values

Functions can accept both positional and named parameters. Furthermore, parameters can be required or optional. They must be specified in the order presented here.

The first set of parameters, if any, is a set of comma-separated names. These are all required. Next you can specify a variable preceded by an asterisk — this will accept any optional parameters.

After the optional positional parameters you can specify required named parameters. These must come after the optional parameters. If there are no optional parameters, you can use a plain asterisk as a placeholder. Finally, you can specify a variable preceded by two asterisks to accept optional named parameters.



```
def func(p1, p2, *p3, p4, p5, **p6):
    pass
```

Example

function_parameters.py

```
#!/usr/bin/env python

def fun_one():  ①
    print("Hello, world")


print("fun_one():", end=' ')
fun_one()
print()


def fun_two(n):  ②
    return n ** 2


x = fun_two(5)
print("fun_two(5) is {}\n".format(x))


def fun_three(count=3):  ③
    for _ in range(count):
        print("spam", end=' ')
    print()


fun_three()
fun_three(10)
print()


def fun_four(n, *opt):  ④
    print("fun_four():")
    print("n is ", n)
    print("opt is", opt)
    print('-' * 20)


fun_four('apple')
fun_four('apple', "blueberry", "peach", "cherry")


def fun_five(*, spam=0, eggs=0):  ⑤
    print("fun_five():")
    print("spam is:", spam)
    print("eggs is:", eggs)
    print()


fun_five(spam=1, eggs=2)
fun_five(eggs=2, spam=2)
fun_five(spam=1)
fun_five(eggs=2)
fun_five()


def fun_six(**named_args):  ⑥
    print("fun_six():")
    for name in named_args:
        print(name, "==> ", named_args[name])


fun_six(name="Lancelot", quest="Grail", color="red")
```

① no parameters

② one required parameter

③ one required parameter with default value

④ one fixed, plus optional parameters

⑤ keyword-only parameters

⑥ keyword (named) parameters

function_parameters.py

```
fun_one(): Hello, world

fun_two(5) is 25

spam spam spam
spam spam spam spam spam spam spam spam spam spam

fun_four():
n is  apple
opt is ()
--------------------
fun_four():
n is  apple
opt is ('blueberry', 'peach', 'cherry')
--------------------
fun_five():
spam is: 1
eggs is: 2

fun_five():
spam is: 2
eggs is: 2

fun_five():
spam is: 1
eggs is: 0

fun_five():
spam is: 0
eggs is: 2

fun_five():
spam is: 0
eggs is: 0

fun_six():
name ==>  Lancelot
quest ==>  Grail
color ==>  red
```

Default parameters

- Assigned with equals sign
- Used if no values passed to function

Required parameters can have default values. They are assigned to parameters with the equals sign. Parameters without defaults cannot be specified after parameters with defaults.

Example

default_parameters.py

```
#!/usr/bin/env python

def spam(greeting, whom='world'):  ①
    print("{}, {}".format(greeting, whom))


spam("Hello", "Mom")  ②
spam("Hello")  ③
print()

def ham(*, file_name, file_format='txt'):  ④
    print("Processing {} as {}".format(file_name, file_format))

ham(file_name='eggs')  ⑤
ham(file_name='toast', file_format='csv')
```

① 'world' is default value for positional parameter **whom**

② parameter supplied; default not used

③ parameter not supplied; default is used

④ 'world' is default value for named parameter **format**

⑤ parameter **format** not supplied; default is used *default_parameters.py*

```
Hello, Mom
Hello, world

Processing eggs as txt
Processing toast as csv
```

Python Function parameter behavior (from PEP 3102)

For each formal parameter, there is a slot which will be used to contain the value of the argument assigned to that parameter.

- Slots which have had values assigned to them are marked as 'filled'. Slots which have no value assigned to them yet are considered 'empty'.
- Initially, all slots are marked as empty.
- Positional arguments are assigned first, followed by keyword arguments.
- For each positional argument:
    - Attempt to bind the argument to the first unfilled parameter slot. If the slot is not a vararg slot, then mark the slot as 'filled'.
    - If the next unfilled slot is a vararg slot, and it does not have a name, then it is an error.
    - Otherwise, if the next unfilled slot is a vararg slot then all remaining non-keyword arguments are placed into the vararg slot.
- For each keyword argument:
    - If there is a parameter with the same name as the keyword, then the argument value is assigned to that parameter slot. However, if the parameter slot is already filled, then that is an error.
    - Otherwise, if there is a 'keyword dictionary' argument, the argument is added to the dictionary using the keyword name as the dictionary key, unless there is already an entry with that key, in which case it is an error.
    - Otherwise, if there is no keyword dictionary, and no matching named parameter, then it is an error.
- Finally:
    - If the vararg slot is not yet filled, assign an empty tuple as its value.
    - For each remaining empty slot: if there is a default value for that slot, then fill the slot with the default value. If there is no default value, then it is an error.
- In accordance with the current Python implementation, any errors encountered will be signaled by raising TypeError.

Name resolution (AKA Scope)

- What is "scope"?
- Scopes used dynamically
- Four levels of scope
- Assignments always go into the innermost scope (starting with local)

A scope is the area of a Python program where an unqualified (not preceded by a module name) name can be looked up.

Scopes are used dynamically. There are four nested scopes that are searched for names in the following order:

local	local names bound within a function
nonlocal	local names plus local names of outer function(s)
global	the current module’s global names
builtin	built-in functions (contents of _***builtins***_ module)

Within a function, all assignments and declarations create local names. All variables found outside of local scope (that is, outside of the function) are read-only.

Inside functions, local scope references the local names of the current function. Outside functions, local scope is the same as the global scope – the module’s namespace. Class definitions also create a local scope.

Nested functions provide another scope. Code in function B which is defined inside function A has read-only access to all of A’s variables. This is called **nonlocal** scope.

Example

scope_examples.py

```
#!/usr/bin/env python

x = 42  ①


def function_a():
    y = 5  ②

    def function_b():
        z = 32  ③
        print("function_b(): z is", z)  ④
        print("function_b(): y is", y)  ⑤
        print("function_b(): x is", x)  ⑥
        print("function_b(): type(x) is", type(x))  ⑦

    return function_b


f = function_a()  ⑧
f()  ⑨
```

① global variable

② local variable to function_a(), or nonlocal to function_b()

③ local variable

④ local scope

⑤ nested (nonlocal) scope

⑥ global scope

⑦ builtin scope

⑧ calling function_a, which returns function_b

⑨ calling function_b

scope_examples.py

```
function_b(): z is 32
function_b(): y is 5
function_b(): x is 42
function_b(): type(x) is <class 'int'>
```

The global statement

- global statement allows function to change globals
- nonlocal statement allows function to change nonlocals

The **global** keyword allows a function to modify a global variable. This is universally acknowledged as a BAD IDEA. Mutating global data can lead to all sorts of hard-to-diagnose bugs, because a function might change a global that affects some other part of the program. It's better to pass data into functions as parameters and return data as needed. Mutable objects, such as lists, sets, and dictionaries can be modified in-place.

The **nonlocal** keyword can be used like **global** to make nonlocal variables in an outer function writable.

Modules

- Files containing python code
- End with .py
- No real difference from scripts

A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module's name (as a string) is available as the value of the global variable *name*.

To use a module named spam.py, say `import spam`

This does not enter the names of the functions defined in spam directly into the symbol table; it only adds the module name **spam**. Use the module name to access the functions or other attributes.

Python uses modules to contain functions that can be loaded as needed by scripts. A simple module contains one or more functions; more complex modules can contain initialization code as well. Python classes are also implemented as modules.

A module is only loaded once, even there are multiple places in an application that import it.

Modules and packages should be documented with *docstrings*.

Using import

- import statement loads modules
- Three variations
  - import module
  - from module import function-list
  - from module import * use with caution!

There are three variations on the **import** statement:

Variation 1

import module
loads the module so its data and functions can be used, but does not put its attributes (names of classes, functions, and variables) into the current namespace.

Variation 2

from module import function, ...
imports only the function(s) specified into the current namespace. Other functions are not available (even though they are loaded into memory).

Variation 3

from module import *
loads the module, and imports all functions that do not start with an underscore into the current namespace. This should be used with caution, as it can pollute the current namespace and possibly overwrite builtin attributes or attributes from a different module.

NOTE The first time a module is loaded, the interpreter creates a version compiled for faster loading. This version has platform information embedded in the name, and has the extension .pyc. These .pyc files are put in a folder named **__pycache__**.

Example

samplelib.py

```
#!/usr/bin/env python

# sample Python module


def spam():
    print("Hello from spam()")

def ham():
    print("Hello from ham()")

def _eggs():
    print("Hello from _eggs()")
```

use_samplelib1.py

```
#!/usr/bin/env python
import samplelib  ①

samplelib.spam()  ②
samplelib.ham()
```

① import samplelib module (samplelib.py) — creates object named **samplelib** of type "Module"

② call function spam() in module samplelib

use_samplelib1.py

```
Hello from spam()
Hello from ham()
```

use_samplelib2.py

```
#!/usr/bin/env python
from samplelib import spam, ham  ①

spam()  ②
ham()
```

① import functions spam and ham from samplelib module into current namespace — does not create the module object

② module name not needed to call function spam()

use_samplelib2.py

```
Hello from spam()
Hello from ham()
```

use_samplelib3.py

```
#!/usr/bin/env python
from samplelib import *  ①

spam()  ②
ham()
```

① import all functions (that do not start with _) from samplelib module into current namespace

② module name not needed to call function spam()

use_samplelib3.py

```
Hello from spam()
Hello from ham()
```

use_samplelib4.py

```
#!/usr/bin/env python
from samplelib import spam as pig, ham as hog  ①

pig()
hog()
```

① import functions spam and ham, aliased to pig and hog

use_samplelib4.py

```
Hello from spam()
Hello from ham()
```

How *import* * can be dangerous

- Imported names may overwrite existing names
- Be careful to read the documentation

Using `import *` to import all public names from a module has a bit of a risk. While generally harmless, there is the chance that you will unknowingly import a module that overwrites some previously-imported module.

To be 100% certain, always import the entire module, or else import names explicitly.

Examples

electrical.py

```
#!/usr/bin/env python

default_amps = 10
default_voltage = 110
default_current = 'AC'

def amps():
    return default_amps

def voltage():
    return default_voltage

def current():
    return default_current
```

navigation.py

```
#!/usr/bin/env python

current_types = 'slow medium fast'.split()

def current():
    return current_types[0]
```

why_import_star_is_bad.py

```
#!/usr/bin/env python

from electrical import *  ①
from navigation import *  ②

print(current())  ③
print(voltage())
print(amps())
```

① import current *explicitly* from electrical

② import current *implicitly* from navigation

③ calls navigation.current(), not electrical.current()

why_import_star_is_bad.py

```
slow
110
10
```

how_to_avoid_import_star.py

```
#!/usr/bin/env python
import electrical as e  ①
import navigation as n  ②

print(e.current())  ③
print(n.current())  ④
```

how_to_avoid_import_star.py

```
AC
slow
```

Module search path

- Searches current folder first, then predefined locations
- Add custom locations to PYTHONPATH
- Paths stored in sys.path

When you specify a module to load with the import statement, it first looks in the current directory, and then searches the directories listed in sys.path.

```
>>> import sys
>>> sys.path
```

To add locations, put one or more directories to search in the PYTHONPATH environment variable. Separate multiple paths by semicolons for Windows, or colons for Unix/Linux. This will add them to **sys.path**, after the current folder, but before the predefined locations.

Windows

set PYTHONPATH=C:\Users\bob\Documents and settings\Python

Linux/OS X

export PYTHONPATH="/home/bob/python"

You can also append to sys.path in your scripts, but this can result in non-portable scripts, and scripts that will fail if the location of the imported modules changes.

```
import sys
sys.path.extend("/usr/dev/python/libs","/home/bob/pylib")
import module1
import module2
```

Executing modules as scripts

- `name` is current module.
  - set to `__main__` if run as script
  - set to *module_name* if imported
- test with `if name == "__main__"`
- Module can be both run directly and imported

It is sometimes convenient to have a module also be a runnable script. This is handy for testing and debugging, and for providing modules that also can be used as standalone utilities.

Since the interpreter defines its own name as '__main__', you can test the current namespace's *name* attribute. If it is '__main__', then you are at the main (top) level of the interpreter, and your file is being run as a script; it was not loaded as a module.

Any code in a module that is not contained in function or method is executed when the module is imported.

This can include data assignments and other startup tasks, for example connecting to a database or opening a file.

Many modules do not need any initialization code.

Example

using_main.py

```
#!/usr/bin/env python
import sys


# other imports  (standard library, standard non-library, local)

# constants (AKA global variables)

# main function
def main(args):  ①
    function1()
    function2()


# other functions
def function1():
    print("hello from function1()")


def function2():
    print("hello from function2()")


if __name__ == '__main__':
    main(sys.argv[1:])  ②
```

① Program entry point. While **main** is not a reserved word, it is a strong convention

② Call main() with the command line parameters (omitting the script itself)

Packages

- Package is folder containing modules or packages
- Startup code goes in __init__.py (optional)

A package is a group of related modules or subpackages. The grouping is physical – a package is a folder that contains one or more modules. It is a way of giving a hierarchical structure to the module namespace so that all modules do not live in the same folder.

A package may have an initialization script named **__init__.py**. If present, this script is executed when the package or any of its contents are loaded. (In Python 2, **__init__.py** was required).

Modules in packages are accessed by prefixing the module with the package name, using the dot notation used to access module attributes.

Thus, if Module **eggs** is in package **spam**, to call the **scramble()** function in **eggs**, you would say `spam.eggs.scramble()`.

By default, importing a package name by itself has no effect; you must explicitly load the modules in the packages. You should usually import the module using its package name, like `from spam import eggs`, to import the eggs module from the spam package.

Packages can be nested.

Example

```
sound/                  Top-level package
    __init__.py         Initialize the sound package (optional)
    formats/            Subpackage for file formats
        __init__.py     Initialize the formats package (optional)
        wavread.py
        wavwrite.py
        aiffread.py
        aiffwrite.py
        auread.py
        auwrite.py
        ...
    effects/            Subpackage for sound effects
        __init__.py     Initialize the formats package (optional)
        echo.py
        surround.py
        reverse.py
        ...
    filters/            Subpackage for filters
        __init__.py     Initialize the formats package (optional)
        equalizer.py
```

```
from sound.formats import aiffread
from sound.effects.surround import dolby
import sound.filters.equalizer as eq
```

Example: Core Django packages

django	django.contrib.postgres.indexes
django.apps	django.contrib.postgres.validators
django.conf.urls	django.contrib.redirects
django.conf.urls.i18n	django.contrib.sessions
django.contrib.admin	django.contrib.sessions.middleware
django.contrib.admindocs	django.contrib.sitemaps
django.contrib.auth	django.contrib.sites
django.contrib.auth.backends	django.contrib.sites.middleware
django.contrib.auth.forms	django.contrib.staticfiles
django.contrib.auth.hashers	django.contrib.syndication
django.contrib.auth.middleware	django.core.checks
django.contrib.auth.password_validation	django.core.exceptions
django.contrib.auth.signals	django.core.files
django.contrib.auth.views	django.core.files.storage
django.contrib.contenttypes	django.core.files.uploadedfile
django.contrib.contenttypes.admin	django.core.files.uploadhandler
django.contrib.contenttypes.fields	django.core.mail
django.contrib.contenttypes.forms	django.core.management
django.contrib.flatpages	django.core.paginator
django.contrib.gis	django.core.signals
django.contrib.gis.admin	django.core.signing
django.contrib.gis.db.backends	django.core.validators
django.contrib.gis.db.models	django.db
django.contrib.gis.db.models.functions	django.db.backends
django.contrib.gis.feeds	django.db.backends.base.schema
django.contrib.gis.forms	django.db.migrations
django.contrib.gis.forms.widgets	django.db.migrations.operations
django.contrib.gis.gdal	django.db.models
django.contrib.gis.geoip2	django.db.models.constraints
django.contrib.gis.geos	django.db.models.fields
django.contrib.gis.measure	django.db.models.fields.related
django.contrib.gis.serializers.geojson	django.db.models.functions
django.contrib.gis.utils	django.db.models.indexes
django.contrib.gis.utils.layermapping	django.db.models.lookups
django.contrib.gis.utils.ogrinspect	django.db.models.options
django.contrib.humanize	django.db.models.signals
django.contrib.messages	django.db.transaction
django.contrib.messages.middleware	django.dispatch
django.contrib.postgres	django.forms
django.contrib.postgres.aggregates	django.forms.fields
django.contrib.postgres.constraints	django.forms.formsets

django.forms.models	django.urls.conf
django.forms.renderers	django.utils
django.forms.widgets	django.utils.cache
django.http	django.utils.dateparse
django.middleware	django.utils.decorators
django.middleware.cache	django.utils.encoding
django.middleware.clickjacking	django.utils.feedgenerator
django.middleware.common	django.utils.functional
django.middleware.csrf	django.utils.html
django.middleware.gzip	django.utils.http
django.middleware.http	django.utils.log
django.middleware.locale	django.utils.module_loading
django.middleware.security	django.utils.safestring
django.shortcuts	django.utils.text
django.template	django.utils.timezone
django.template.backends	django.utils.translation
django.template.backends.django	django.views
django.template.backends.jinja2	django.views.decorators.cache
django.template.loader	django.views.decorators.csrf
django.template.response	django.views.decorators.gzip
django.test	django.views.decorators.http
django.test.signals	django.views.decorators.vary
django.test.utils	django.views.generic.dates
django.urls	django.views.i18n

Configuring import with __init__.py

- Provide package documentation
- Load modules into package's namespace for convenience
  - Specify modules to load when * is used
- Execute startup code

The docstring in **__init__.py** is used to document the package itself. This is used by IDEs as well as **pydoc**.

For convenience, you can put import statements in a package's **__init__.py** to autoload the modules into the package namespace, so that import PKG imports all the (or just selected) modules in the package.

If the variable **__all__** in **__init__.py** is set to a list of module names, then only these modules will be loaded when the import is

__init__.py can also be used to setup data or other resources that will be used by multiple modules within a package.

```
from PKG import *
```

Given the following package and module layout, the table on the next page describes how **__init__.py** affects imports.

```
my_package
    |------__init__.py
    |------module_a.py
    |          function_a()
    |------module_b.py
    |          function_b()
    |------module_c.py
               function_c()
```

Import statement	**What it does**
If **__init__.py** is empty	
`import my_package`	Imports **my_package** only, but not contents. No modules are imported. This is not useful.
`import my_package.module_a`	Imports **module_a** into **my_package** namespace. Objects in **module_a** must be prefixed with **my_package.module_a**
`from my_package import module_a`	Imports **module_a** into main namespace. Objects in **module_a** must be prefixed with **module_a**

`from my_package import module_a,`
`module_b`
	Imports **module_a** and **module_b** into main namespace.

`from my_package import *`	Does not import anything!
`from my_package.module_a import *`	Imports all contents of **module_a** (that do not start with an underscore) into main namespace. Not generally recommended.
If **__init__.py** contains: `all = ['module_a', 'module_b']`	
`import my_package`	Imports my_package only, but not contents. No modules are imported. This is still not useful.
`from my_package import module_a`	As before, imports **module_a** into main namespace. Objects in **module_a** must be prefixed with **module_a**
`from my_package import *`	Imports **module_a** and **module_b**, but not **module_c** into main namespace.

If **__init__.py** contains:
`all = ['module_a', 'module_b'] import`
`module_a`
`import module_b`	

`import my_package`	Imports **module_a** and **module_b** into the my_package namespace. Objects in **module_a** must be prefixed with **my_package.module_a**. *Now this is useful.*
`from my_package import module_a`	Imports **module_a** into main namespace. Objects in **module_a** must be prefixed with **module_a**
`from my_package import *`	Only imports **module_a** and **module_b** into main namespace.
`from my_package import module_c`	Imports **module_c** into the main namespace.

Documenting modules and packages

- Use docstrings
- Described in PEP 257
- Generate docs with Sphinx (optional)

In addition to comments, which are for the *maintainer* of your code, you should add docstrings, which provide documentation for the *user* of your code.

If the first statement in a module, function, or class is an unassigned string, it is assigned as the *docstring* of that object. It is stored in the special attribute *_doc_*, and so is available to code.

The docstring can use any form of literal string, but triple double quotes are preferred, for consistency.

See **PEP 257** for a detailed guide on docstring conventions.

Tools such as pydoc, and many IDEs will use the information in docstrings. In addition, the Sphinx tool will gather docstrings from an entire project and format them as a single HTML, PDF, or EPUB document.

Python style

- Code is read more often than it is written!
- Style guides enforce consistency and readability

- Indent 4 spaces (do not use tabs)
- Keep lines ⇐ 79 characters
- Imports at top of script, and on separate lines
- Surround operators with space
- Comment thoroughly to explain why and how code works when not obvious
- Use docstrings to explain how to use modules, classes, methods, and functions
- Use lower_case_with_underscores for functions, methods, and attributes
- Use UPPER_CASE_WITH_UNDERSCORES for globals
- Use StudlyCaps (mixed-case) for class names
- Use _leading_underscore for internal (non-API) attributes

Guido van Rossum, Python's BDFL (Benevolent Dictator For Life), once said that code is read much more often than it is written. This means that once code is written, it may be read by the original developer, users, subsequent developers who inherit your code. Do them a favor and make your code readable. This in turn makes your code more maintainable.

To make your code readable, it is import to write your code in a consistent manner. There are several Python style guides available, including PEP (Python Enhancement Proposal) 8, Style Guide for Python Code, and PEP 257, Docstring Conventions.

If you are part of a development team, it is a good practice to put together a style guide for the team. The team will save time not having to figure out each other's style.

Chapter 7 Exercises

Exercise 7-1 (potus.py, potus_main.py)

Create a module named **potus** (potus.py) to provide information from the presidents.txt file. It should provide the following function:

```
get_info(term#) -> dict  provide dictionary of info for a specified president
```

Write a script to use the module.

For the ambitious (potus_amb.py, potus_amb_main.py)

Add the following functions to the module

```
get_oldest() -> string   return the name of oldest president
get_youngest()-> string  return the name of youngest president
```

'youngest' and 'oldest' refer to age at beginning of first term and age at end of last term.

Chapter 8: Errors and Exception Handling

Objectives

- Understanding syntax errors
- Handling exceptions with try-except-else-finally
- Learning the standard exception objects

Syntax errors

- Generated by the parser
- Cannot be trapped

Syntax errors are generated by the Python parser, and cause execution to stop (your script exits). They display the file name and line number where the error occurred, as well as an indication of where in the line the error occurred.

Because they are generated as soon as they are encountered, syntax errors may not be handled.

Example

```
  File "<stdin>", line 1
    for x in bargle
                  ^
SyntaxError: invalid syntax
```

TIP When running in interactive mode, the filename is <stdin>.

Exceptions

- Generated when runtime errors occur
- Usually fatal if not handled

Even if code is syntactically correct, errors can occur. A common run-time error is to attempt to open a non-existent file. Such errors are called exceptions, and cause the interpreter to stop with an error message.

Python has a hierarchy of builtin exceptions; handling an exception higher in the tree will handle any children of that exception.

TIP Custom exceptions can be created by sub-classing the Exception object.

Example

exception_unhandled.py

```
#!/usr/bin/env python

x = 5
y = "cheese"

z = x + y  ①
```

① Adding a string to an int raises **TypeError**

exception_unhandled.py

```
Traceback (most recent call last):
  File "exception_unhandled.py", line 6, in <module>
    z = x + y  ①
TypeError: unsupported operand type(s) for +: 'int' and 'str'
```

Handling exceptions with try

- Use try/except clauses
- Specify expected exception

To handle an exception, put the code which might generate an exception in a try block. After the try block, you must specify a except block with the expected exception. If an exception is raised in the try block, execution stops and the interpreter looks for the exception in the except block. If found, it executes the except block and execution continues; otherwise, the exception is treated as fatal and the interpreter exits.

Example

exception_simple.py

```
#!/usr/bin/env python

try:  ①
    x = 5
    y = "cheese"
    z = x + y
    print("Bottom of try")

except TypeError as err:    ②
    print("Naughty programmer! ", err)

print("After try-except")  ③
```

① Execute code that might have a problem

② Catch the expected error; assign error object to **err**

③ Get here whether or not exception occurred

exception_simple.py

```
Naughty programmer!  unsupported operand type(s) for +: 'int' and 'str'
After try-except
```

Handling multiple exceptions

- Use a tuple of exception names, but with single argument

If your try clause might generate more than one kind of exception, you can specify a tuple of exception types, then the variable which will hold the exception object.

Example

exception_multiple.py

```
#!/usr/bin/env python

try:
    x = 5
    y = "cheese"
    z = x + y
    f = open("sesame.txt")
    print("Bottom of try")

except (IOError, TypeError) as err:  ①
    print("Naughty programmer! ", err)
```

① Use a tuple of 2 or more exception types

exception_multiple.py

```
Naughty programmer!  unsupported operand type(s) for +: 'int' and 'str'
```

Handling generic exceptions

- Use **Exception**
- Specify except with no exception list
- Clean up any uncaught exceptions

As a shortcut, you can specify **Exception** or an empty exception list. This will handle any exception that occurs in the try block.

Example

exception_generic.py

```
#!/usr/bin/env python

try:
    x = 5
    y = "cheese"
    z = x + y
    f = open("sesame.txt")
    print("Bottom of try")

except Exception as err: ①
    print("Naughty programmer! ", err)
```

① Will catch *any* exception

exception_generic.py

```
Naughty programmer!  unsupported operand type(s) for +: 'int' and 'str'
```

Ignoring exceptions

- Use the **pass** statement

Use the **pass** statement to do nothing when an exception occurs

Because the except clause must contain some code, the pass statement fulfills the syntax without doing anything.

Example

exception_ignore.py

```
#!/usr/bin/env python

try:
    x = 5
    y = "cheese"
    z = x + y
    f = open("sesame.txt")
    print("Bottom of try")

except(TypeError, IOError): ①
    pass
```

① Catch exceptions, and do nothing

exception_ignore.py

```
_no output_
```

This is probably a bad idea…

Using else

- executed if no exceptions were raised
- not required
- can make code easier to read

The last except block can be followed by an else block. The code in the else block is executed only if there were no exceptions raised in the try block. Exceptions in the else block are not handled by the preceding except blocks.

The else lets you make sure that some code related to the try clause (and before the finally clause) is only run if there's no exception, without trapping the exception specified in the except clause.

```
try:
    something_that_can_throw_ioerror()
except IOError as e:
    handle_the_IO_exception()
else:
# we don't want to catch this IOError if it's raised
    something_else_that_throws_ioerror()
finally:
    something_we_always_need_to_do()
```

Example

exception_else.py

```
#!/usr/bin/env python

numpairs = [(5, 1), (1, 5), (5, 0), (0, 5)]

total = 0

for x, y in numpairs:
    try:
        quotient = x / y
    except Exception as err:
        print("uh-oh, when y = {}, {}".format(y, err))
    else:
        total += quotient  ①
print(total)
```

① Only if no exceptions were raised

exception_else.py

```
uh-oh, when y = 0, division by zero
5.2
```

Cleaning up with finally

- Executed whether or not exception occurs
- Code executed whether or not exception raised
- Code runs even if **exit()** called
- For cleanup

A **finally** block can be used in addition to, or instead of, an **except** block. The code in a **finally** block is executed whether or not an exception occurs. The **finally** block is executed after the **try**, **except**, and **else** blocks.

What makes **finally** different from just putting statements after try-except-else is that the **finally** block will execute even if there is a **return()** or **exit()** in the **except** block.

The purpose of a **finally** block is to clean up any resources left over from the **try** block. Examples include closing network connections and removing temporary files.

Example

exception_finally.py

```
#!/usr/bin/env python

try:
    x = 5
    y = 37
    z = x + y
    print("z is", z)
except TypeError as err:    ①
    print("Caught exception:", err)
finally:
    print("Don't care whether we had an exception")  ②

print()

try:
    x = 5
    y = "cheese"
    z = x + y
    print("Bottom of try")
except TypeError as err:
    print("Caught exception:", err)
finally:
    print("Still don't care whether we had an exception")
```

① Catch **TypeError**

② Print whether **TypeError** is caught or not

exception_finally.py

```
z is 42
Don't care whether we had an exception

Caught exception: unsupported operand type(s) for +: 'int' and 'str'
Still don't care whether we had an exception
```

The Standard Exception Hierarchy (Python 3.7)

```
BaseException
 +-- SystemExit
 +-- KeyboardInterrupt
 +-- GeneratorExit
 +-- Exception
      +-- StopIteration
      +-- StopAsyncIteration
      +-- ArithmeticError
      |    +-- FloatingPointError
      |    +-- OverflowError
      |    +-- ZeroDivisionError
      +-- AssertionError
      +-- AttributeError
      +-- BufferError
      +-- EOFError
      +-- ImportError
      |    +-- ModuleNotFoundError
      +-- LookupError
      |    +-- IndexError
      |    +-- KeyError
      +-- MemoryError
      +-- NameError
      |    +-- UnboundLocalError
      +-- OSError
      |    +-- BlockingIOError
      |    +-- ChildProcessError
      |    +-- ConnectionError
      |    |    +-- BrokenPipeError
      |    |    +-- ConnectionAbortedError
      |    |    +-- ConnectionRefusedError
      |    |    +-- ConnectionResetError
      |    +-- FileExistsError
      |    +-- FileNotFoundError
      |    +-- InterruptedError
      |    +-- IsADirectoryError
      |    +-- NotADirectoryError
      |    +-- PermissionError
      |    +-- ProcessLookupError
      |    +-- TimeoutError
      +-- ReferenceError
      +-- RuntimeError
      |    +-- NotImplementedError
      |    +-- RecursionError
      +-- SyntaxError
      |    +-- IndentationError
      |         +-- TabError
      +-- SystemError
      +-- TypeError
      +-- ValueError
      |    +-- UnicodeError
      |         +-- UnicodeDecodeError
      |         +-- UnicodeEncodeError
      |         +-- UnicodeTranslateError
```

Chapter 8 Exercises

Exercise 8-1 (c2f_loop_safe.py)

Rewrite c2f_loop.py to handle the error that occurs if the user enters non-numeric data. The script should print a message and keep going if an error occurs.

Exercise 8-2 (c2f_batch_safe.py)

Rewrite c2f_batch.py to handle the ValueError that occurs if sys.argv[1] is not a valid number.

Chapter 9: Using the Standard Library

Objectives

- Overview of the standard library
- Getting information on the Python interpreter’s environment
- Running external programs
- Walking through a directory tree
- Working with path names
- Calculating dates and times
- Fetching data from a URL
- Generating random values

The sys module

- Import the sys module to provide access to the interpreter and its environment
- Get interpreter attributes
- Interact with the operating system

The sys module provides access to some objects used or maintained by the interpreter and to functions that interact strongly with the interpreter.

This module provides details of the current Python interpreter; it also provides objects and methods to interact with the operating system.

Even though the sys module is built into the Python interpreter, it must be imported like any other module.

Interpreter Information

- sys provides details of interpreter

To get the folder where Python is installed, use **sys.prefix**.

To get the path to the Python executable, use **sys.executable**.

To get a version string, use **sys.version**.

To get the details of the interpreter as a tuple, use **sys.version_info**.

To get the list of directories that will be searched for modules, examine **sys.path**.

To get a list of currently loaded modules, use **sys.modules**.

To find out what platform (OS/architecture) the script is running on, use **sys.platform**.

STDIO

- stdin
- stdout
- stderr

The sys object defines three file objects representing the three streams of STDIO, or "standard I/O".

Unless they have been redirected, sys.stdin is the keyboard, and sys.stdout and sys.stderr are the console screen. You should use sys.stderr for error messages.

Example

stdio.py

```
#!/usr/bin/env python

import sys
sys.stdout.write("Hello, world\n")
sys.stderr.write("Error message here...\n")
```

stdio.py 2>spam.txt

```
Hello, world
```

type spam.txt *windows*

cat spam.txt *non-windows*

```
Error message here...
```

Launching external programs

- Different ways to launch programs
    - Just launch (use system())
    - Capture output (use popen())
- import os module
- Use system() or popen() methods

In Python, you can launch an external command using the os module functions os.system() and os.popen().

os.system() launches any external command, as though you had typed it at a command prompt. popen() opens a pipe to a command so you can read the output of the command one line at a time. popen() is very similar to the open() function; it returns an iterable object.

For more control over external processes, use the **subprocess** module (part of the standard library), or check out the sh module (not part of the standard library).

Example

external_programs.py

```
#!/usr/bin/env python
import os

os.system("hostname")  ①

with os.popen('netstat -an') as netstat_in:  ②
    for entry in netstat_in:  ③
        if 'ESTAB' in entry:  ④
            print(entry, end='')
print()
```

① Just run "hostname"

② Open command line "netstat -an" as a file-like object

③ Iterate over lines in output of "netstat -an"

④ Check to see if line contains "ESTAB"

external_programs.py

```
Johns-Macbook.attlocal.net
tcp4       0      0  192.168.1.242.63446    104.89.0.50.443        ESTABLISHED
tcp4       0      0  192.168.1.242.63443    104.89.0.50.443        ESTABLISHED
tcp4       0      0  192.168.1.242.63442    199.244.49.16.443      ESTABLISHED
tcp4       0      0  192.168.1.242.63434    104.96.220.131.443     ESTABLISHED
tcp4       0      0  192.168.1.242.63428    52.54.188.195.443      ESTABLISHED
tcp6       0      0  2600:1700:3901:6.63425 2600:1f16:b8a:8e.443   ESTABLISHED
tcp4       0      0  192.168.1.242.63424    23.212.144.208.443     ESTABLISHED
tcp4       0      0  192.168.1.242.63423    44.194.225.67.443      ESTABLISHED
tcp4       0      0  192.168.1.242.63415    65.8.56.105.443        ESTABLISHED
tcp4       0      0  192.168.1.242.63410    185.167.164.39.443     ESTABLISHED
tcp4       0      0  192.168.1.242.63406    13.248.242.197.443     ESTABLISHED
tcp4       0      0  192.168.1.242.63405    18.214.14.231.443      ESTABLISHED
tcp4       0      0  192.168.1.242.63400    23.21.249.91.443       ESTABLISHED
tcp4       0      0  192.168.1.242.63394    54.208.242.84.443      ESTABLISHED
```

Paths, directories and filenames

- import os.path module
- path is mapped to appropriate package for current os
- The os.path module provides many functions for working with paths.
- Some of the more common methods:
    - os.path.exists()
    - os.path.dirname()
    - os.path.basename
    - os.path.split()

os.path is the primary module for working with filenames and paths. There are many methods for getting and modifying a file or folder’s path.

Also provide are methods for getting information about a file.

Example

paths.py

```
#!/usr/bin/env python
import sys
import os.path

unix_p1 = "bin/spam.txt"  ①
unix_p2 = "/usr/local/bin/ham"  ②

win_p1 = r"spam\ham.doc"  ③
win_p2 = r"\\spam\ham\eggs\toast\jam.doc"  ④

if sys.platform == 'win32':  ⑤
    print("win_p1:", win_p1)
    print("win_p2:", win_p2)
    print("dirname(win_p1):", os.path.dirname(win_p1))  ⑥
    print("dirname(win_p2):", os.path.dirname(win_p2))
    print("basename(win_p1):", os.path.basename(win_p1))  ⑦
    print("basename(win_p2):", os.path.basename(win_p2))
    print("isabs(win_p1):", os.path.isabs(win_p1))  ⑧
    print("isabs(win_p2):", os.path.isabs(win_p2))
else:
    print("unix_p1:", unix_p1)
    print("unix_p2:", unix_p2)
    print("dirname(unix_p1):", os.path.dirname(unix_p1))  ⑥
    print("dirname(unix_p2):", os.path.dirname(unix_p2))
    print("basename(unix_p1):", os.path.basename(unix_p1))  ⑦
    print("basename(unix_p2):", os.path.basename(unix_p2))
    print("isabs(unix_p1):", os.path.isabs(unix_p1))  ⑧
    print("isabs(unix_p2):", os.path.isabs(unix_p2))
    print(
        'format("cp spam.txt {}".format(os.path.expanduser("~"))):',  ⑨
        format("cp spam.txt {}".format(os.path.expanduser("~"))),
    )
    print(
        'format("cd {}".format(os.path.expanduser("~root"))):',  ⑩
        format("cd {}".format(os.path.expanduser("~root"))),
    )
```

① Unix relative path

② Unix absolute path

③ Windows relative path

④ Windows UNC path

⑤ What platform are we on?

⑥ Just the folder name

⑦ Just the file (or folder) name

⑧ Is it an absolute path?

⑨ ~ is current user’s home

⑩ ~NAME is NAME’s home

paths.py

```
unix_p1: bin/spam.txt
unix_p2: /usr/local/bin/ham
dirname(unix_p1): bin
dirname(unix_p2): /usr/local/bin
basename(unix_p1): spam.txt
basename(unix_p2): ham
isabs(unix_p1): False
isabs(unix_p2): True
format("cp spam.txt {}".format(os.path.expanduser("~"))): cp spam.txt /Users/jstrick
format("cd {}".format(os.path.expanduser("~root"))): cd /var/root
```

paths.py (windows)

```
dirname(win_p1):  \\marmoset\sharing\technology\docs\bonsai
dirname(win_p2):  \\marmoset\sharing\technology\docs\bonsai
basename(win_p1):  foo.doc
basename(win_p2):  foo.doc
os.path.split(win_p1) Head: \\marmoset\sharing\technology\docs\bonsai Tail: foo.doc
os.path.split(win_p1) Head: bonsai Tail: foo.doc
os.path.splitunc(win_p1) Head: \\marmoset\sharing Tail: \technology\docs\bonsai\foo.doc
os.path.splitunc(win_p1) Head:  Tail: bonsai\foo.doc
```

Walking directory trees

- Import os module
- Use the os.walk() iterator
- Returns tuple for each directory starting with the specified top directory
- Tuple contains full path to directory, list of subdirectories, and list of files *syntax:

```
for currdir,subdirs,files in os.walk("start-dir"):
      pass
```

The os.walk() method provides a way to easily walk a directory tree. It provides an iterator for a directory and all its subdirectories. For each directory, it returns a tuple with three values.

The first element is the full (absolute) path to the directory; the second element is a list of the directory’s subdirectories (relative names); the third element is a list of the non-directory files in the subdirectory (also relative names).

TIP Remember to not use "dir" or "file" as variables when looping through the iterator, because they will overwrite builtins.

Example

os_walk.py

```
#!/usr/bin/env python

# count number of files and dirs in  a directory tree
# note "files" includes devices, symbolic links, and pipes
import os
import sys

if sys.platform == 'win32':  ①
    target = 'C:/Users'
else:
    target = '/etc'

total_files = 0  ②
total_dirs = 0

for currdir, subdirs, files in os.walk(target):  ③
    total_dirs += 1  # increment number of directories seen
    total_files += len(files)  # add the number of files in this dir

print("{} contains {} dirs and {} files".format(target, total_dirs, total_files))  ④
```

os_walk.py

```
/etc contains 38 dirs and 343 files
```

os_walk2.py

```
#!/usr/bin/env python
"""
    find files whose size is greater than or equal to specified number of bytes
"""
import sys
import os

MINIMUM_SIZE = 1000

if len(sys.argv) < 2: ①
    print('Syntax: walk2.py START-DIR')
    sys.exit(1)

for currdir, subdirs, files in os.walk(sys.argv[1]):
    for file in files: ②
        fullpath = os.path.join(currdir, file) ③
        if os.path.isfile(fullpath): ④
            fsize = os.path.getsize(fullpath) ⑤
            if fsize >= MINIMUM_SIZE: ⑥
                print("{:40s} {:8d}".format(fullpath, fsize))
```

os_walk2.py

```
./xml_from_presidents.py                     2458
./boto3_create_folders.py                    1324
./dc_carddeck.py                             1595
./paramiko_remote_cmd.py                     1217
./sa_movie_models.py                         1349
./xml_create_knights.py                      1396
./.pylintrc                                 14755
./db_mysql_metadata.py                       1431
./new_magic.py                               1387
./iterable_recipes.py                        8359
```

…

Grabbing data from the web

- import module urllib
- urlopen() similar to open()
- Iterate through (or read from) URL object
- Use info() method for metadata

Python makes grabbing web pages easy with the urllib module. The urllib.request.urlopen() method returns an HTTP response object (which also acts like a file object).

Iterating through this object returns the lines in the specified web page (the same lines you would see with "view source" in a browser).

Since the URL is opened in binary mode; you can use *response*.read() to download any kind of file which a URL represents – PDF, MP3, JPG, and so forth.

NOTE Grabbing web pages is even easier with the **requests** modules. See **read_html_requests.py** and **read_pdf_requests.py** in the EXAMPLES folder.

Example

read_html_urllib.py

```
#!/usr/bin/env python

import urllib.request

u = urllib.request.urlopen("https://www.python.org")

print(u.info())  ①
print()

print(u.read(500).decode())   ②
```

① .info() returns a dictionary of HTTP headers

② The text is returned as a bytes object, so it needs to be decoded to a string

read_html_urllib.py

```
Connection: close
Content-Length: 49735
Server: nginx
Content-Type: text/html; charset=utf-8
X-Frame-Options: DENY
Via: 1.1 vegur, 1.1 varnish, 1.1 varnish
Accept-Ranges: bytes
Date: Wed, 18 Aug 2021 17:43:52 GMT
Age: 2958
X-Served-By: cache-bwi5172-BWI, cache-stp9222-STP
X-Cache: HIT, HIT
X-Cache-Hits: 1, 9
X-Timer: S1629308632.095654,VS0,VE0
Vary: Cookie
Strict-Transport-Security: max-age=63072000; includeSubDomains



<!doctype html>
<!--[if lt IE 7]>   <html class="no-js ie6 lt-ie7 lt-ie8 lt-ie9">   <![endif]-->
<!--[if IE 7]>      <html class="no-js ie7 lt-ie8 lt-ie9">          <![endif]-->
<!--[if IE 8]>      <html class="no-js ie8 lt-ie9">                 <![endif]-->
<!--[if gt IE 8]><!--><html class="no-js" lang="en" dir="ltr">  <!--<![endif]-->

<head>
    <meta charset="utf-8">
    <meta http-equiv="X-UA-Compatible" content="IE=edge">

    <link rel="prefetch" href="//ajax.googleapis.com/ajax/libs/jqu
```

…

Example

read_pdf_urllib.py

```
#!/usr/bin/env python

import sys
import os
from urllib.request import urlopen
from urllib.error import HTTPError

# url to download a PDF file of a NASA ISS brochure

url = 'https://www.nasa.gov/pdf/739318main_ISS%20Utilization%20Brochure
%202012%20Screenres%203-8-13.pdf'  ①

saved_pdf_file = 'nasa_iss.pdf'  ②

try:
    URL = urlopen(url)  ③
except HTTPError as e:  ④
    print("Unable to open URL:", e)
    sys.exit(1)

pdf_contents = URL.read()  ⑤
URL.close()

with open(saved_pdf_file, 'wb') as pdf_in:
    pdf_in.write(pdf_contents)  ⑥

if sys.platform == 'win32':  ⑦
    cmd = saved_pdf_file
elif sys.platform == 'darwin':
    cmd = 'open ' + saved_pdf_file
else:
    cmd = 'acroread ' + saved_pdf_file

os.system(cmd)  ⑧
```

Sending email

- use smtplib
- For attachments, use email.mime.*
- Can provide authentication
- Can work with proxies

It is easy to send a simple email message with Python. The smtplib module allows you to create and send the message.

To send an attachment, use smptlib plus one or more of the submodules of email.mime, which are needed to put the message and attachments in proper MIME format.

TIP When sending attachments, be sure to use the .as_string() method on the MIME message object. Otherwise you will be sending binary gibberish to your recipient.

Example

email_simple.py

```
#!/usr/bin/env python
from getpass import getpass  ①
import smtplib  ②
from email.message import EmailMessage  ③
from datetime import datetime

TIMESTAMP = datetime.now().ctime()  ④

SENDER = 'jstrick@mindspring.com'
RECIPIENTS = ['jstrickler@gmail.com']
MESSAGE_SUBJECT = 'Python SMTP example'

MESSAGE_BODY = """
Hello at {}.

Testing email from Python
""".format(TIMESTAMP)

SMTP_USER = 'pythonclass'
SMTP_PASSWORD = getpass("Enter SMTP server password:")  ⑤

smtpserver = smtplib.SMTP("smtp2go.com", 2525)  ⑥
smtpserver.login(SMTP_USER, SMTP_PASSWORD)  ⑦

msg = EmailMessage()  ⑧
msg.set_content(MESSAGE_BODY)  ⑨
msg['Subject'] = MESSAGE_SUBJECT  ⑩
msg['from'] = SENDER  ⑪
msg['to'] = RECIPIENTS  ⑫

try:
    smtpserver.send_message(msg)  ⑬
except smtplib.SMTPException as err:
    print("Unable to send mail:", err)
finally:
    smtpserver.quit()  ⑭
```

① module for hiding password

② module for sending email

③ module for creating message

④ get a time string for the current date/time

⑤ get password (not echoed to screen)

⑥ connect to SMTP server

⑦ log into SMTP server

⑧ create empty email message

⑨ add the message body

⑩ add the message subject

⑪ add the sender address

⑫ add a list of recipients

⑬ send the message

⑭ disconnect from SMTP server

email_attach.py

```
#!/usr/bin/env python
import smtplib
from datetime import datetime
from imghdr import what  ①
from email.message import EmailMessage ②
from getpass import getpass ③


SMTP_SERVER = "smtp2go.com"  ④
SMTP_PORT = 2525

SMTP_USER = 'pythonclass'

SENDER = 'jstrick@mindspring.com'
RECIPIENTS = ['jstrickler@gmail.com']


def main():
    smtp_server = create_smtp_server()
    now = datetime.now()
    msg = create_message(
        SENDER,
        RECIPIENTS,
        'Here is your attachment',
        'Testing email attachments from python class at {}\n\n'.format(now),
    )
    add_text_attachment('../DATA/parrot.txt', msg)
    add_image_attachment('../DATA/felix_auto.jpeg', msg)
    send_message(smtp_server, msg)


def create_message(sender, recipients, subject, body):
    msg = EmailMessage()  ⑤
    msg.set_content(body)  ⑥
    msg['From'] = sender
    msg['To'] = recipients
    msg['Subject'] = subject
    return msg


def add_text_attachment(file_name, message):
    with open(file_name) as file_in:  ⑦
        attachment_data = file_in.read()
    message.add_attachment(attachment_data)  ⑧
```

```
def add_image_attachment(file_name, message):
    with open(file_name, 'rb') as file_in:  ⑨
        attachment_data = file_in.read()
    image_type = what(None, h=attachment_data)  ⑩
    message.add_attachment(attachment_data, maintype='image', subtype=image_type)  ⑪


def create_smtp_server():
    password = getpass("Enter SMTP server password:")  ⑫
    smtpserver = smtplib.SMTP(SMTP_SERVER, SMTP_PORT)  ⑬
    smtpserver.login(SMTP_USER, password)  ⑭

    return smtpserver


def send_message(server, message):
    try:
        server.send_message(message)  ⑮
    finally:
        server.quit()


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

① module to determine image type

② module for creating email message

③ module for reading password privately

④ global variables for external information (IRL should be from environment — command line, config file, etc.)

⑤ create instance of EmailMessage to hold message

⑥ set content (message text) and various headers

⑦ read data for text attachment

⑧ add text attachment to message

⑨ read data for binary attachment

⑩ get type of binary data

⑪ add binary attachment to message, including type and subtype (e.g., "image/jpg)"

⑫ get password from user (don’t hardcode sensitive data in script)

⑬ create SMTP server connection

⑭ log into SMTP connection

⑮ send message

math functions

- use the math module
- Provides functions and constants

Python provides many math functions. It also provides constants pi and e.

Table 14. Math functions

sqrt(x)	Returns the square root of x
exp(x)	Return ex
log(x)	Returns the natural log, i.e. lnx
log10(x)	Returns the log to the base 10 of x
sin(x)	Returns the sine of x
cos(x)	Return the cosine of x
tan(x)	Returns the tangent of x
asin(x)	Return the arc sine of x
acos(x)	Return the arc cosine of x
atan(x)	Return the arc tangent of x
fabs(x)	Return the absolute value, i.e. the modulus, of x
ceil(x)	Rounds x (which is a float) up to next highest integer1
floor(x)	Rounds x (which is a float) down to next lowest integer
degrees(x)	converts angle x from radians to degrees
radians(x)	converts angle x from degrees to radians

TIP This table is not comprehensive – see docs for math module for some more functions.

For more math and engineering functions, see the external modules numpy and scipy.

Random values

- Use the random module
- Useful methods
  - random()
  - randint(start,stop)
  - randrange(start,limit)
  - choice(seq)
  - sample(seq,count)
  - shuffle(seq)

The random module provides methods based on selected a random number. In addition to random(), which returns a fractional number between 0 and 1, there are a number of convenience functions.

randint() and randrange() return a random integer within a range of numbers; the difference is that randint() includes the endpoint of the specified range, and randrange() does not.

choice() returns one element from any of Python’s sequence types; sample() is the same, but returns a specified number of elements.

shuffle() randomizes a sequence.

Example

random_ex.py

```
#!/usr/bin/env python

import random

fruits = ["pomegranate", "cherry", "apricot", "date", "apple",
"lemon", "kiwi", "orange", "lime", "watermelon", "guava",
"papaya", "fig", "pear", "banana", "tamarind", "persimmon",
"elderberry", "peach", "blueberry", "lychee", "grape"]


for i in range(10):
    print("random():", random.random())
    print("randint(1, 2000):", random.randint(1, 2000))
    print("randrange(1, 5):", random.randrange(1, 10))
    print("choice(fruit):", random.choice(fruits))
    print("sample(fruit, 3):", random.sample(fruits, 3))
    print()
```

random_ex.py

```
random(): 0.43926416208393115
randint(1, 2000): 631
randrange(1, 5): 9
choice(fruit): fig
sample(fruit, 3): ['date', 'kiwi', 'elderberry']

random(): 0.4962584006816043
randint(1, 2000): 266
randrange(1, 5): 5
choice(fruit): persimmon
sample(fruit, 3): ['apricot', 'kiwi', 'fig']

random(): 0.8207483236032811
randint(1, 2000): 190
randrange(1, 5): 9
choice(fruit): pomegranate
sample(fruit, 3): ['persimmon', 'pear', 'grape']

random(): 0.837287492184198
randint(1, 2000): 421
randrange(1, 5): 2
choice(fruit): apricot
sample(fruit, 3): ['apricot', 'lemon', 'banana']

random(): 0.20005621377992688
randint(1, 2000): 1488
randrange(1, 5): 2
choice(fruit): lime
sample(fruit, 3): ['kiwi', 'guava', 'blueberry']
```

Dates and times

- Use the datetime module
- Provides several classes
    - datetime
    - date
    - time
    - timedelta

Python provides the datetime module for manipulating dates and times. Once you have created date or time objects, you can combines them and extract the time units you need.

Example

datetime_ex.py

```
#!/usr/bin/env python

from datetime import datetime, date, timedelta

print("date.today():", date.today())  ①

now = datetime.now()  ②
print("now.day:", now.day)  ③
print("now.month:", now.month)
print("now.year:", now.year)
print("now.hour:", now.hour)
print("now.minute:", now.minute)
print("now.second:", now.second)

d1 = datetime(2018, 6, 13)  ④
d2 = datetime(2018, 8, 24)

d3 = d2 - d1  ⑤

print("raw time delta:", d3)
print("time delta days:", d3.days)  ⑥

interval = timedelta(10)  ⑦
print("interval:", interval)

d4 = d2 + interval  ⑧
d5 = d2 - interval
print("d2 + interval:", d4)
print("d2 - interval:", d5)
print()

t1 = datetime(2016, 8, 24, 10, 4, 34)  ⑨
t2 = datetime(2018, 8, 24, 22, 8, 1)
t3 = t2 - t1

print("datetime(2016, 8, 24, 10, 4, 34):", t1)
print("datetime(2018, 8, 24, 22, 8, 1):", t2)
print("time diff (t2 - t1):", t3)
```

datetime_ex.py

```
date.today(): 2021-08-18
now.day: 18
now.month: 8
now.year: 2021
now.hour: 13
now.minute: 43
now.second: 52
raw time delta: 72 days, 0:00:00
time delta days: 72
interval: 10 days, 0:00:00
d2 + interval: 2018-09-03 00:00:00
d2 - interval: 2018-08-14 00:00:00

datetime(2016, 8, 24, 10, 4, 34): 2016-08-24 10:04:34
datetime(2018, 8, 24, 22, 8, 1): 2018-08-24 22:08:01
time diff (t2 - t1): 730 days, 12:03:27
```

Zipped archives

- import zipfile for (PK)zipped files
- Get a list of files
- Extract files

The zipfile module allows you to read and write to zipped archives. In either case you first create a zipfile object; specifying a mode of "w" if you want to create an archive, and a mode of "r" (or nothing) if you want to read an existing zip file.

There are also modules for gzipped, bzipped, and compressed archives.

Example

zipfile_ex.py

```
#!/usr/bin/env python

from zipfile import ZipFile, ZIP_DEFLATED
import os.path

# reading & extracting
rzip = ZipFile("../DATA/textfiles.zip")  ①
print(rzip.namelist())  ②
ty = rzip.read('tyger.txt').decode()  ③
print(ty[:50])
rzip.extract('parrot.txt')  ④

# creating a zip file
wzip = ZipFile("example.zip", mode="w", compression=ZIP_DEFLATED)  ⑤
for base in "parrot tyger knights alice poe_sonnet spam".split():
    filename = os.path.join("../DATA", base + '.txt')
    print("adding {} as {}".format(filename, base + '.txt'))
    wzip.write(filename, base + '.txt')  ⑥
```

① Open zip file for reading

② Print list of members in zip file

③ Read (raw binary) data from member and convert from bytes to string

④ Extract member

⑤ Create new zip file

⑥ Add member to zip file

zipfile_ex.py

```
['fruit.txt', 'parrot.txt', 'tyger.txt', 'spam.txt']
           The Tyger

Tyger! Tyger! burning bright
adding ../DATA/parrot.txt as parrot.txt
adding ../DATA/tyger.txt as tyger.txt
adding ../DATA/knights.txt as knights.txt
adding ../DATA/alice.txt as alice.txt
adding ../DATA/poe_sonnet.txt as poe_sonnet.txt
adding ../DATA/spam.txt as spam.txt
```

Chapter 9 Exercises

Exercise 9-1 (print_sys_info.py)

Use the module os to print out the pathname separator, the PATH variable separator, and the extension separator for your OS.

Exercise 9-2 (file_size.py)

Write a script that accepts one or more files on the command line, and prints out the size, one file per line. If any argument is not a file, print out an error message.

TIP You will need the os.path module.

Chapter 10: Pythonic Programming

Objectives

- Learn what makes code "Pythonic"
- Understand some Python-specific idioms
- Create lambda functions
- Perform advanced slicing operations on sequences
- Distinguish between collections and generators

The Zen of Python

> Beautiful is better than ugly.
> Explicit is better than implicit.
> Simple is better than complex.
> Complex is better than complicated.
> Flat is better than nested.
> Sparse is better than dense.
> Readability counts.
> Special cases aren’t special enough to break the rules.
> Although practicality beats purity.
> Errors should never pass silently.
> Unless explicitly silenced.
> In the face of ambiguity, refuse the temptation to guess.
> There should be one-- and preferably only one --obvious way to do it.
> Although that way may not be obvious at first unless you’re Dutch.
> Now is better than never.
> Although never is often better than **right** now.
> If the implementation is hard to explain, it’s a bad idea.
> If the implementation is easy to explain, it may be a good idea.
> Namespaces are one honking great idea — let’s do more of those!
>
> — Tim Peters, from PEP 20

Tim Peters is a longtime contributor to Python. He wrote the standard sorting routine, known as **timsort**.

The above text is printed out when you execute the code `import this`. Generally speaking, if code follows the guidelines in the Zen of Python, then it’s Pythonic.

Tuples

- Fixed-size, read-only
- Collection of related items
- Supports some sequence operations
- Think 'struct' or 'record'

A **tuple** is a collection of related data. While on the surface it seems like just a read-only list, it is used when you need to pass multiple values to or from a function, but the values are not all the same type

To create a tuple, use a comma-separated list of objects. Parentheses are not needed around a tuple unless the tuple is nested in a larger data structure.

A tuple in Python might be represented by a struct or a "record" in other languages.

While both tuples and lists can be used for any data:

- Use a list when you have a collection of similar objects.
- Use a tuple when you have a collection of related objects, which may or may not be similar.

TIP To specify a one-element tuple, use a trailing comma, otherwise it will be interpreted as a single object: color = 'red',

Example

```
hostinfo = ( 'gemini','linux','ubuntu','hardy','Bob Smith' )

birthday = ( 'April',5,1978 )
```

Iterable unpacking

- Copy iterable to list of variables
- Frequently used with list of tuples
- Make code more readable

When you have an iterable such as a tuple or list, you access individual elements by index. However, `spam[0]` and `spam[1]` are not so readable compared to `first_name` and `company`. To copy an iterable to a list of variable names, just assign the iterable to a comma-separated list of names:

```
birthday = ( 'April',5,1978 )
month, day, year = birthday
```

You may be thinking "why not just assign to the variables in the first place?". For a single tuple or list, this would be true. The power of unpacking comes in the following areas:

- Looping over a sequence of tuples
- Passing tuples (or other iterables) into a function

Example

unpacking_people.py

```
#!/usr/bin/env python
#


people = [  ①
    ('Melinda', 'Gates', 'Gates Foundation'),
    ('Steve', 'Jobs', 'Apple'),
    ('Larry', 'Wall', 'Perl'),
    ('Paul', 'Allen', 'Microsoft'),
    ('Larry', 'Ellison', 'Oracle'),
    ('Bill', 'Gates', 'Microsoft'),
    ('Mark', 'Zuckerberg', 'Facebook'),
    ('Sergey', 'Brin', 'Google'),
    ('Larry', 'Page', 'Google'),
    ('Linus', 'Torvalds', 'Linux'),
]

for first_name, last_name, org in people:  ②
    print("{} {}".format(first_name, last_name))
```

① A list of 3-element tuples

② The for loop unpacks each tuple into the three variables.

unpacking_people.py

```
Melinda Gates
Steve Jobs
Larry Wall
Paul Allen
Larry Ellison
Bill Gates
Mark Zuckerberg
Sergey Brin
Larry Page
Linus Torvalds
```

Extended iterable unpacking

- Allows for one "wild card"
- Allows common "first, rest" unpacking

When unpacking iterables, sometimes you want to grab parts of the iterable as a group. This is provided by extended iterable unpacking.

One (and only one) variable in the result of unpacking can have a star prepended. This variable will be a list of all values not assigned to other variables.

Example

extended_iterable_unpacking.py

```
#!/usr/bin/env python

values = ['a', 'b', 'c', 'd', 'e']  ①

x, y, *z = values  ②
print("x: {}    y: {}    z: {}".format(x, y, z))
print()

x, *y, z = values  ②
print("x: {}    y: {}    z: {}".format(x, y, z))
print()

*x, y, z = values  ②
print("x: {}    y: {}    z: {}".format(x, y, z))
print()

people = [
    ('Bill', 'Gates', 'Microsoft'),
    ('Steve', 'Jobs', 'Apple'),
    ('Paul', 'Allen', 'Microsoft'),
    ('Larry', 'Ellison', 'Oracle'),
    ('Mark', 'Zuckerberg', 'Facebook'),
    ('Sergey', 'Brin', 'Google'),
    ('Larry', 'Page', 'Google'),
    ('Linux', 'Torvalds', 'Linux'),
]

for *name, _ in people:  ③
    print(name)
print()
```

① **values** has 6 elements

② * takes all extra elements from iterable

③ **name** gets all but the last field

extended_iterable_unpacking.py

```
x: a    y: b    z: ['c', 'd', 'e']

x: a    y: ['b', 'c', 'd']    z: e

x: ['a', 'b', 'c']    y: d    z: e

['Bill', 'Gates']
['Steve', 'Jobs']
['Paul', 'Allen']
['Larry', 'Ellison']
['Mark', 'Zuckerberg']
['Sergey', 'Brin']
['Larry', 'Page']
['Linux', 'Torvalds']
```

Unpacking function arguments

- Go from iterable to list of items
- Use * or **

Sometimes you need the other end of iterable unpacking. What do you do if you have a list of three values, and you want to pass them to a method that expects three positional arguments? One approach is to use the individual items by index. A more Pythonic approach is to use * to *unpack* the iterable into individual items:

Use a single asterisk to unpack a list or tuple (or similar iterable); use two asterisks to unpack a dictionary or similar.

In the example, see how the list **HEADINGS** is passed to .format(), which expects individual parameters, not *one parameter* containing multiple values.

Example

unpacking_function_args.py

```
#!/usr/bin/env python
#

people = [ ①
    ('Joe', 'Schmoe', 'Burbank', 'CA'),
    ('Mary', 'Rattburger', 'Madison', 'WI'),
    ('Jose', 'Ramirez', 'Ames', 'IA'),
]

def person_record(first_name, last_name, city, state): ②
    print("{} {} lives in {}, {}".format(first_name, last_name, city, state))

for person in people:  ③
    person_record(*person)  ④
```

① list of 4-element tuples

② function that takes 4 parameters

③ person is a tuple (one element of people list)

④ ***person** unpacks the tuple into four individual parameters

unpacking_function_args.py

```
Joe Schmoe lives in Burbank, CA
Mary Rattburger lives in Madison, WI
Jose Ramirez lives in Ames, IA
```

Example

shoe_sizes.py

```
#!/usr/bin/env python
#
BARLEYCORN = 1 / 3.0
CM_TO_INCH = 2.54
MENS_START_SIZE = 12
WOMENS_START_SIZE = 10.5

FMT = '{:6.1f} {:8.2f} {:8.2f}'
HEADFMT = '{:>6s} {:>8s} {:>8s}'

HEADINGS = ['Size', 'Inches', 'CM']

SIZE_RANGE = []
for i in range(6, 14):
    SIZE_RANGE.extend([i, i + .5])

def main():
    for heading, flag in [("MEN'S", True), ("WOMEN'S", False)]:
        print(heading)
        print((HEADFMT.format(*HEADINGS)))  ①
        for size in SIZE_RANGE:
            inches, cm = get_length(size, flag)
            print(FMT.format(size, inches, cm))

        print()

def get_length(size, mens=True):
    if mens:
        start_size = MENS_START_SIZE
    else:
        start_size = WOMENS_START_SIZE

    inches = start_size - ((start_size - size) * BARLEYCORN)
    cm = inches * CM_TO_INCH
    return inches, cm

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

① format expects individual arguments for each placeholder; the asterisk unpacks HEADINGS into individual strings

shoe_sizes.py

```
MEN'S
  Size   Inches       CM
   6.0    10.00    25.40
   6.5    10.17    25.82
   7.0    10.33    26.25
   7.5    10.50    26.67
   8.0    10.67    27.09
   8.5    10.83    27.52
```

…

The sorted() function

- Returns a sorted copy of any collection
- Customize with named keyword parameters

```
key=
reverse=
```

The sorted() builtin function returns a sorted copy of its argument, which can be any iterable.

You can customize sorted with the **key** parameter.

Example

basic_sorting.py

```
#!/usr/bin/env python

"""Basic sorting example"""

fruits = ["pomegranate", "cherry", "apricot", "date", "Apple", "lemon", "Kiwi",
          "ORANGE", "lime", "Watermelon", "guava", "papaya", "FIG", "pear", "banana",
          "Tamarind", "persimmon", "elderberry", "peach", "BLUEberry", "lychee",
          "grape"]

sorted_fruit = sorted(fruits)  ①

print(sorted_fruit)
```

① sorted() returns a list

basic_sorting.py

```
['Apple', 'BLUEberry', 'FIG', 'Kiwi', 'ORANGE', 'Tamarind', 'Watermelon', 'apricot',
'banana', 'cherry', 'date', 'elderberry', 'grape', 'guava', 'lemon', 'lime', 'lychee',
'papaya', 'peach', 'pear', 'persimmon', 'pomegranate']
```

Custom sort keys

- Use **key** parameter
- Specify name of function to use
- Key function takes exactly one parameter
- Useful for case-insensitive sorting, sorting by external data, etc.

You can specify a function with the **key** parameter of the sorted() function. This function will be used once for each element of the list being sorted, to provide the comparison value. Thus, you can sort a list of strings case-insensitively, or sort a list of zip codes by the number of Starbucks within the zip code.

The function must take exactly one parameter (which is one element of the sequence being sorted) and return either a single value or a tuple of values. The returned values will be compared in order.

You can use any builtin Python function or method that meets these requirements, or you can write your own function.

TIP The lower() method can be called directly from the builtin object str. It takes one string argument and returns a lower case copy.

```
sorted_strings = sorted(unsorted_strings, key=str.lower)
```

Example

custom_sort_keys.py

```
#!/usr/bin/env python

fruit = ["pomegranate", "cherry", "apricot", "date", "Apple", "lemon",
         "Kiwi", "ORANGE", "lime", "Watermelon", "guava", "papaya", "FIG",
         "pear", "banana", "Tamarind", "persimmon", "elderberry", "peach",
         "BLUEberry", "lychee", "grape"]

def ignore_case(item):  ①
    return item.lower()  ②

fs1 = sorted(fruit, key=ignore_case)  ③
print("Ignoring case:")
print(" ".join(fs1), end="\n\n")

def by_length_then_name(item):
    return (len(item), item.lower())  ④

fs2 = sorted(fruit, key=by_length_then_name)
print("By length, then name:")
print(" ".join(fs2))
print()

nums = [800, 80, 1000, 32, 255, 400, 5, 5000]

n1 = sorted(nums)  ⑤
print("Numbers sorted numerically:")
for n in n1:
    print(n, end=' ')
print("\n")

n2 = sorted(nums, key=str)  ⑥
print("Numbers sorted as strings:")
for n in n2:
    print(n, end=' ')
print()
```

① Parameter is *one* element of iterable to be sorted

② Return value to sort on

③ Specify function with named parameter **key**

④ Key functions can return tuple of values to compare, in order

⑤ Numbers sort numerically by default

⑥ Sort numbers as strings

custom_sort_keys.py

```
Ignoring case:
Apple apricot banana BLUEberry cherry date elderberry FIG grape guava Kiwi lemon lime
lychee ORANGE papaya peach pear persimmon pomegranate Tamarind Watermelon

By length, then name:
FIG date Kiwi lime pear Apple grape guava lemon peach banana cherry lychee ORANGE papaya
apricot Tamarind BLUEberry persimmon elderberry Watermelon pomegranate

Numbers sorted numerically:
5 32 80 255 400 800 1000 5000

Numbers sorted as strings:
1000 255 32 400 5 5000 80 800
```

Example

sort_holmes.py

```
#!/usr/bin/env python
"""Sort titles, ignoring leading articles"""
books = [
    "A Study in Scarlet",
    "The Sign of the Four",
    "The Hound of the Baskervilles",
    "The Valley of Fear",
    "The Adventures of Sherlock Holmes",
    "The Memoirs of Sherlock Holmes",
    "The Return of Sherlock Holmes",
    "His Last Bow",
    "The Case-Book of Sherlock Holmes",
]


def strip_articles(title):  ①
    title = title.lower()
    for article in 'a ', 'an ', 'the ':
        if title.startswith(article):
            title = title[len(article):]  ②
            break
    return title


for book in sorted(books, key=strip_articles):  ③
    print(book)
```

① create function which takes element to compare and returns comparison key

② remove article by using a slice that starts after article + space`

③ sort using custom function

sort_holmes.py

```
The Adventures of Sherlock Holmes
The Case-Book of Sherlock Holmes
His Last Bow
The Hound of the Baskervilles
The Memoirs of Sherlock Holmes
The Return of Sherlock Holmes
The Sign of the Four
A Study in Scarlet
The Valley of Fear
```

Lambda functions

- Short cut function definition
- Useful for functions only used in one place
- Frequently passed as parameter to other functions
- Function body is an expression; it cannot contain other code

A **lambda function** is a brief function definition that makes it easy to create a function on the fly. This can be useful for passing functions into other functions, to be called later. Functions passed in this way are referred to as "callbacks". Normal functions can be callbacks as well. The advantage of a lambda function is solely the programmer's convenience. There is no speed or other advantage.

One important use of lambda functions is for providing sort keys; another is to provide event handlers in GUI programming.

The basic syntax for creating a lambda function is

```
lambda parameter-list: expression
```

where parameter-list is a list of function parameters, and expression is an expression involving the parameters. The expression is the return value of the function.

A lambda function could also be defined in the normal manner

```
    def function-name(param-list):
        return expr
```

But it is not possible to use the normal syntax as a function parameter, or as an element in a list.

Example

lambda_examples.py

```
#!/usr/bin/env python

fruits = ['watermelon', 'Apple', 'Mango', 'KIWI', 'apricot', 'LEMON', 'guava']

sfruits = sorted(fruits, key=lambda e: e.lower())  ①

print(" ".join(sfruits))
```

① The lambda function takes one fruit and returns it in lower case

lambda_examples.py

```
Apple apricot guava KIWI LEMON Mango watermelon
```

List comprehensions

- Filters or modifies elements
- Creates new list
- Shortcut for a for loop

A list comprehension is a Python idiom that creates a shortcut for a for loop. It returns a copy of a list with every element transformed via an expression. Functional programmers refer to this as a mapping function.

A loop like this:

```
results = []
for var in sequence:
    results.append(expr)   # where expr involves var
```

can be rewritten as

```
results = [ expr for var in sequence ]
```

A conditional if may be added to filter values:

```
results = [ expr for var in sequence if expr ]
```

Example

listcomp.py

```
#!/usr/bin/env python

fruits = ['watermelon', 'apple', 'mango', 'kiwi', 'apricot', 'lemon', 'guava']

values = [2, 42, 18, 92, "boom", ['a', 'b', 'c']]

ufruits = [fruit.upper() for fruit in fruits]  ①

afruits = [fruit for fruit in fruits if fruit.startswith('a')]  ②

doubles = [v * 2 for v in values]  ③

print("ufruits:", " ".join(ufruits))
print("afruits:", " ".join(afruits))
print("doubles:", end=' ')
for d in doubles:
    print(d, end=' ')
print()
```

① Copy each fruit to upper case

② Select each fruit if it starts with 'a'

③ Copy each number, doubling it

listcomp.py

```
ufruits: WATERMELON APPLE MANGO KIWI APRICOT LEMON GUAVA
afruits: apple apricot
doubles: 4 84 36 184 boomboom ['a', 'b', 'c', 'a', 'b', 'c']
```

Dictionary comprehensions

- Expression is key/value pair
- Transform iterable to dictionary

A dictionary comprehension has syntax similar to a list comprehension. The expression is a key:value pair, and is added to the resulting dictionary. If a key is used more than once, it overrides any previous keys. This can be handy for building a dictionary from a sequence of values.

Example

dict_comprehension.py

```
#!/usr/bin/env python


animals = ['OWL', 'Badger', 'bushbaby', 'Tiger', 'Wombat', 'GORILLA', 'AARDVARK']

# {KEY: VALUE for VAR ... in ITERABLE if CONDITION}
d = {a.lower(): len(a) for a in animals}  ①

print(d, '\n')

words = ['unicorn', 'stigmata', 'barley', 'bookkeeper']

d = {w:{c:w.count(c) for c in sorted(w)} for w in words} ②

for word, word_signature in d.items():
    print(word, word_signature)
```

① Create a dictionary with key/value pairs derived from an iterable

② Use a nested dictionary comprehension to create a dictionary mapping words to dictionaries which map letters to their counts (could be useful for anagrams)

dict_comprehension.py

```
{'owl': 3, 'badger': 6, 'bushbaby': 8, 'tiger': 5, 'wombat': 6, 'gorilla': 7, 'aardvark':
8}

unicorn {'c': 1, 'i': 1, 'n': 2, 'o': 1, 'r': 1, 'u': 1}
stigmata {'a': 2, 'g': 1, 'i': 1, 'm': 1, 's': 1, 't': 2}
barley {'a': 1, 'b': 1, 'e': 1, 'l': 1, 'r': 1, 'y': 1}
bookkeeper {'b': 1, 'e': 3, 'k': 2, 'o': 2, 'p': 1, 'r': 1}
```

Set comprehensions

- Expression is added to set
- Transform iterable to set — with modifications

A set comprehension is useful for turning any sequence into a set. Items can be modified or skipped as the set is built.

If you don’t need to modify the items, it’s probably easier to just past the sequence to the **set()** constructor.

Example

set_comprehension.py

```
#!/usr/bin/env python

import re

with open("../DATA/mary.txt") as mary_in:
    s = {w.lower()  for ln in mary_in  for w in re.split(r'\W+', ln) if w} ①
print(s)
```

① Get unique words from file. Only one line is in memory at a time. Skip "empty" words.

set_comprehension.py

```
{'sure', 'to', 'fleece', 'the', 'as', 'went', 'a', 'that', 'little', 'had', 'everywhere',
'its', 'go', 'mary', 'snow', 'was', 'and', 'lamb', 'white'}
```

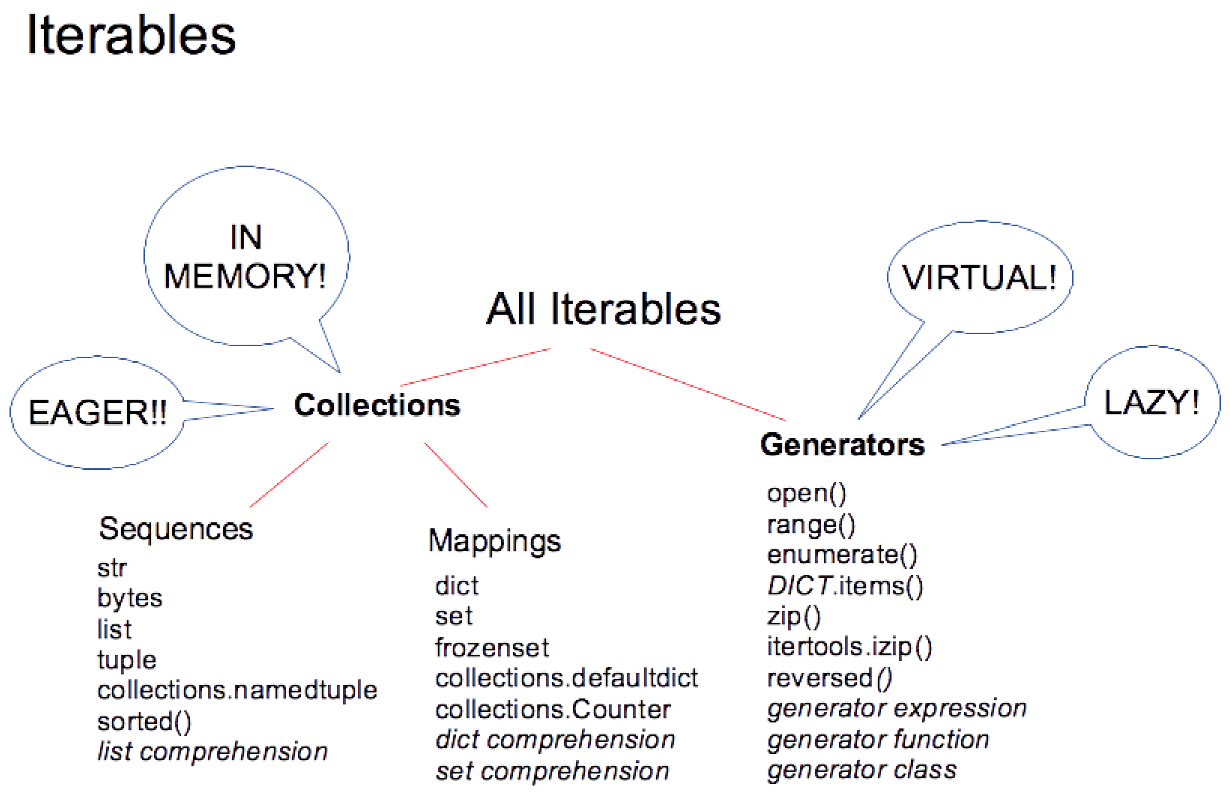
Iterables

- Expression that can be looped over
- Can be collections *e.g.* list, tuple, str, bytes
- Can be generators *e.g.* range(), file objects, enumerate(), zip(), reversed()

Python has many builtin iterables – a file object, for instance, which allows iterating through the lines in a file.

All builtin collections (list, tuple, str, bytes) are iterables. They keep all their values in memory. Many other builtin iterables are *generators*.

A generator does not keep all its values in memory – it creates them one at a time as needed, and feeds them to the for-in loop. This is a Good Thing, because it saves memory.



Generator Expressions

- Like list comprehensions, but create a generator object
- More efficient
- Use parentheses rather than brackets

A generator expression is similar to a list comprehension, but it provides a generator instead of a list. That is, while a list comprehension returns a complete list, the generator expression returns one item at a time.

The main difference in syntax is that the generator expression uses parentheses rather than brackets.

Generator expressions are especially useful with functions like sum(), min(), and max() that reduce an iterable input to a single value:

NOTE There is an implied **yield** statement at the beginning of the expression.

Example

gen_ex.py

```
#!/usr/bin/env python

# sum the squares of a list of numbers
# using list comprehension, entire list is stored in memory
s1 = sum([x * x for x in range(10)])  ①

# only one square is in memory at a time with generator expression
s2 = sum(x * x for x in range(10))  ②
print(s1, s2)
print()

with open("../DATA/mary.txt") as page:
    m = max(len(line) for line in page)  ③
print(m)
```

① using list comprehension, entire list is stored in memory

② with generator expression, only one square is in memory at a time

③ only one line in memory at a time. max() iterates over generated values

gen_ex.py

```
285 285

30
```

Generator functions

- Mostly like a normal function
- Use yield rather than return
- Maintains state

A generator is like a normal function, but instead of a return statement, it has a yield statement. Each time the yield statement is reached, it provides the next value in the sequence. When there are no more values, the function calls return, and the loop stops. A generator function maintains state between calls, unlike a normal function.

Example

sieve_generator.py

```
#!/usr/bin/env python

def next_prime(limit):
    flags = set()  ①

    for i in range(2, limit):
        if i in flags:
            continue
        for j in range(2 * i, limit + 1, i):
            flags.add(j)  ②
        yield i  ③


np = next_prime(200)  ④
for prime in np:  ⑤
    print(prime, end=' ')
```

① initialize empty set (to be used for "is-prime" flags

② add non-prime elements to set

③ execution stops here until next value is requested by for-in loop

④ next_prime() returns a generator object

⑤ iterate over **yielded** primes

sieve_generator.py

```
2 3 5 7 11 13 17 19 23 29 31 37 41 43 47 53 59 61 67 71 73 79 83 89 97 101 103 107 109
113 127 131 137 139 149 151 157 163 167 173 179 181 191 193 197 199
```

Example

line_trimmer.py

```
#!/usr/bin/env python

def trimmed(file_name):
    with open(file_name) as file_in:
        for line in file_in:
            yield line.rstrip('\n\r')  ①


for trimmed_line in trimmed('../DATA/mary.txt'):  ②
    print(trimmed_line)
```

① 'yield' causes this function to return a generator object

② looping over the a generator object returned by trimmed()

line_trimmer.py

```
Mary had a little lamb,
Its fleece was white as snow,
And everywhere that Mary went
The lamb was sure to go
```

String formatting

- Numbered placeholders
- Add width, padding
- Access elements of sequences and dictionaries
- Access object attributes

The traditional (i.e., old) way to format strings in Python was with the % operator and a format string containing fields designated with percent signs. The new, improved method of string formatting uses the format() method. It takes a format string and one or more arguments. The format strings contains placeholders which consist of curly braces, which may contain formatting details. This new method has much more flexibility.

By default, the placeholders are numbered from left to right, starting at 0. This corresponds to the order of arguments to format().

Formatting information can be added, preceded by a colon.

```
{:d}     format the argument as an integer
{:03d}   format as an integer, 3 columns wide, zero padded
{:>25s}  same, but right-justified
{:.3f}   format as a float, with 3 decimal places
```

Placeholders can be manually numbered. This is handy when you want to use a format() parameter more than once.

```
"Try one of these: {0}.jpg {0}.png {0}.bmp {0}.pdf".format('penguin')
```

Example

stringformat_ex.py

```
#!/usr/bin/env python

from datetime import date

color = 'blue'
animal = 'iguana'

print('{} {}'.format(color, animal))  ①

fahr = 98.6839832
print('{:.1f}'.format(fahr))  ②

value = 12345
print('{0:d} {0:04x} {0:08o} {0:016b}'.format(value))  ③

data = {'A': 38, 'B': 127, 'C': 9}

for letter, number in sorted(data.items()):
    print("{} {:4d}".format(letter, number))  ④
```

① {} placeholders are autonumbered, starting at 0; this corresponds to the parameters to format()

② Formatting directives start with ':'; .1f means format floating point with one decimal place

③ {} placeholders can be manually numbered to reuse parameters

④ :4d means format decimal integer in a field 4 characters wide

stringformat_ex.py

```
blue iguana
98.7
12345 3039 00030071 0011000000111001
A   38
B  127
C    9
```

f-strings

- Shorter syntax for string formatting
- Only available Python 3.6 and later
- Put **f** in front of string

A great new feature, f-strings, was added to Python 3.6. These are strings that contain placeholders, as used with normal string formatting, but the expression to be formatted is also placed in the placeholder. This makes formatting strings more readable, with less typing. As with formatted strings, any expression can be formatted.

Other than putting the value to be formatted directly in the placeholder, the formatting directives are the same as normal Python 3 string formatting.

In normal 3.x formatting:

```
x = 24
y = 32.2345
name = 'Bill Gates'
company = 'Bill Gates'
print("{} founded {}.format(name, company)"
print("{:10s} {:.2f}".format(x, y)
```

f-strings let you do this:

```
x = 24
y = 32.2345
name = 'Bill Gates'
company = 'Bill Gates'
print(f"{name} founded {company})"
print(f"{x:10s} {y:.2f})"
```

Example

f_strings.py

```
#!/usr/bin/env python

import sys

if sys.version_info.major == 3 and sys.version_info.minor >= 6:

    name = "Tim"
    count = 5
    avg = 3.456
    info = 2093
    result = 38293892

    print(f"Name is [{name:<10s}]")  ①
    print(f"Name is [{name:>10s}]")  ②
    print(f"count is {count:03d} avg is {avg:.2f}")  ③

    print(f"info is {info} {info:d} {info:o} {info:x}")  ④

    print(f"${result:,d}")  ⑤

    city = 'Orlando'
    temp = 85

    print(f"It is {temp} in {city}")  ⑥

else:
    print("Sorry -- f-strings are only supported by Python 3.6+")
```

① < means left justify (default for non-numbers), 10 is field width, s formats a string

② > means right justify

③ .2f means round a float to 2 decimal points

④ d is decimal, o is octal, x is hex

⑤ , means add commas to numeric value

⑥ parameters can be selected by name instead of position *f_strings.py*

```
Name is [Tim       ]
Name is [       Tim]
count is 005 avg is 3.46
info is 2093 2093 4055 82d
$38,293,892
It is 85 in Orlando
```

Chapter 10 Exercises

Exercise 10-1 (pres_upper.py)

Read the file **presidents.txt**, creating a list of of the presidents' last names. Then, use a list comprehension to make a copy of the list of names in upper case. Finally, loop through the list returned by the list comprehension and print out the names one per line.

Exercise 10-2 (pres_by_dob.py)

Print out all the presidents first and last names, date of birth, and their political affiliations, sorted by date of birth.

Read the **presidents.txt** file, putting the four fields into a list of tuples.

Loop through the list, sorting by date of birth, and printing the information for each president. Use **sorted()** and a lambda function.

Exercise 10-3 (pres_gen.py)

Write a generator function to provide a sequence of the names of presidents (in "FIRSTNAME MIDDLENAME LASTNAME" format) from the presidents.txt file. They should be provided in the same order they are in the file. You should not read the entire file into memory, but one-at-a-time from the file.

Then iterate over the the generator returned by your function and print the names.

Chapter 11: Introduction to Python Classes

Objectives

- Understanding the big picture of OO programming
- Defining a class and its constructor
- Creating object methods
- Adding attributes and properties to a class
- Using inheritance for code reuse
- Adding class data and methods

About object-oriented programming

- Definitions of objects
- Can be used directly as well
- Objects contain data and methods

Python is an object-oriented language. It supports the creation of classes, which define *objects* (AKA *instances*).

Objects contain both data and the methods (functions) that operate on the data. Each object created has its own personal data, called *instance data*. It can also have data that is shared with all the objects created from its class, called *class data*.

Each class defines a *constructor* , which initializes and returns an object.

Objects may inherit attributes (data and methods) from other objects.

Methods are not polymorphic; i.e., you can’t define multiple versions of a method, with different signatures, and have the corresponding method selected at runtime. However, because Python has dynamic typing, this is seldom needed.

Defining classes

- Use the **class** statement
- **Syntax**

```
class ClassName(baseclass):
    pass
```

To create a class, declare the class with the **class** statement. Any base classes may be specified in parentheses, but are not required.

Classes are conventionally named with Camel Case (i.e., all words, including the first, are capitalized). This is also known as CapWords, StudlyCaps, etc. Modules conventionally have lower-case names. Thus, it is usual to have module **rocketengine** containing class **RocketEngine**.

A method is a function defined in a class. All methods, including the constructor, are passed the object itself. This is conventionally named "self", and while this is not mandatory, most Python programmers expect it.

The basic layout is this:

```
class ClassName(baseclass):
    classvar = value

    def __init__:(self,...):
        self._attrib = instancevalue;
        ClassName.attrib = classvalue;

    def method1:(self,...):
        self._attrib = instancevalue

    def method2:(self,...):
        x = self.method1()
```

Example

simple_class.py

```
#!/usr/bin/env python

class Simple():  ①
    def __init__(self, message_text):  ②
        self._message_text = message_text  ③

    def text(self):  ④
        return self._message_text


if __name__ == "__main__":
    msg1 = Simple('hello')  ⑤
    print(msg1.text())  ⑥

    msg2 = Simple('hi there')  ⑦
    print(msg2.text())
```

① default base class is **object**

② constructor

③ message text stored in instance object

④ instance method

⑤ instantiate an instance of Simple

⑥ call instance method

⑦ create 2nd instance of Simple

simple_class.py

```
hello
hi there
```

Constructors

- Constructor is named **__init__**
- AKA initializer
- Passed *self* plus any parameters

A class's constructor (also known as the initializer) is named __init__. It receives the object being created, and any parameters passed into the initializer in the code as part of instantiation.

As with any Python function, the constructor's parameters can be fixed, optional, keyword-only, or keyword.

It is also normal to name data elements (variables) of a class with a leading underscore to indicate (in a non-mandatory way) that the variable is *private*. Access to private variables should be provided via public access methods (AKA getters) or properties.

Instance methods

- Expect the object as first parameter
- Object conventionally named *self*
- Otherwise like normal Python functions
- Use *self* to access instance attributes or methods
- Use class name to access class data

Instance methods are defined like normal functions, but like constructors, the object that the method is called from is passed in as the first parameter. As with the constructor, the parameter should be named *self*.

Example

animal.py

```
class Animal():
    count = 0  ①

    def __init__(self, species, name, sound):
        self._species = species
        self._name = name
        self._sound = sound
        Animal.count += 1

    @property
    def species(self):
        return self._species

    @classmethod
    def kill(cls):
        cls.count -= 1

    @property
    def name(self):
        return self._name

    def make_sound(self):
        print(self._sound)

    @classmethod
    def remove(cls):
        cls.count -= 1  ②

    @classmethod
    def zoo_size(cls):  ③
        return cls.count


if __name__ == "__main__":
    leo = Animal("African lion", "Leo", "Roarrrrrrr")
    garfield = Animal("cat", "Garfield", "Meowwwww")
    felix = Animal("cat", "Felix", "Meowwwww")

    for animal in leo, garfield, felix:
        print(animal.name, "is a", animal.species, "--", end=' ')
        animal.make_sound()
```

① class data

② update class data from instance

③ zoo_size gets class object when called from instance or class

animal.py

```
Leo is a African lion -- Roarrrrrrr
Garfield is a cat -- Meowwwwww
Felix is a cat -- Meowwwwww
```

Properties

- Properties are managed attributes
- Create with @property decorator
- Create getter, setter, deleter, docstring
- Specify getter only for read-only property

An object can have properties, or managed attributes. When a property is evaluated, its corresponding getter method is invoked; when a property is assigned to, its corresponding setter method is invoked.

Properties can be created with the @property decorator and its derivatives. @property applied to a method causes it to be a "getter" method for a property with the same name as the method.

Using @name.setter on a method with the same name as the property creates a setter method, and @name .deleter on a method with the same name creates a deleter method.

Why properties? Consider that you had a

Example

properties.py

```
#!/usr/bin/env python

class Person():

    def __init__(self, firstname=None, lastname=None):
        self._first_name = None
        self._last_name = None
        self.first_name = firstname  ①
        self.last_name = lastname

    @property
    def first_name(self):  ②
        return self._first_name

    @first_name.setter  ③
    def first_name(self, value):  ④
        if value is None or value.isalpha():
            self._first_name = value
        else:
            raise ValueError("First name may only contain letters")

    @property
    def last_name(self):
        return self._last_name

    @last_name.setter
    def last_name(self, value):
        if value is None or value.isalpha():
            self._last_name = value
        else:
            raise ValueError("Last name may only contain letters")


if __name__ == '__main__':
    person1 = Person('Ferneater', 'Eulalia')

    person2 = Person()
    person2.last_name = 'Pepperpot'  ⑤
    person2.first_name = 'Hortense'

    print("{} {}".format(person1.first_name, person1.last_name))
    print("{} {}".format(person2.first_name, person2.last_name))
    try:
        person3 = Person("R2D2")
    except ValueError as err:
        print(err)
    else:
        print("{} {}".format(person3.first_name, person3.last_name))
```

① calls property

② getter property

③ decorator comes from getter property

④ setter property

⑤ access property

properties.py

```
Ferneater Eulalia
Hortense Pepperpot
First name may only contain letters
```

Class methods and data

- Defined in the class, but outside of methods
- Defined as attribute of class name (similar to self)
- Define class methods with @classmethod
- Class methods get the class object as 1st parameter

Most classes need to store some data that is common to all objects created in the class. This is generally called class data.

Class attributes can be created by using the class name directly, or via class methods.

A class method is created by using the @classmethod decorator. Class methods are implicitly passed the class object.

Class methods can be called from the class object or from an instance of the class; in either case the method is passed the class object.

Example

class_methods_and_data.py

```
#!/usr/bin/env python

class Rabbit:
    LOCATION = "the Cave of Caerbannog"  ①

    def __init__(self, weapon):
        self.weapon = weapon

    def display(self):
        print("This rabbit guarding {} uses {} as a weapon".
              format(self.LOCATION, self.weapon))  ②

    @classmethod  ③
    def get_location(cls):  ④
        return cls.LOCATION  ⑤


r = Rabbit("a nice cup of tea")
print(Rabbit.get_location())  ⑥
print(r.get_location())  ⑦
```

① class data (not duplicated in instances)

② instance method

③ the **@classmethod** decorator makes a function receive the class object, not the instance object

④ *get_location() is a *class* method

⑤ class methods can access class data via **cls**

⑥ call class method from class

⑦ call class method from instance

class_methods_and_data.py

```
the Cave of Caerbannog
the Cave of Caerbannog
```

Static Methods

- Define with @staticmethod

A static method is a utility method that is included in the API of a class, but does not require either an instance or a class object. Static methods are not passed any implicit parameters.

Many classes do not need any static methods.

Define static methods with the @staticmethod decorator.

Example

```
class Spam():

    @staticmethod
    def format_as_title(s):   # no implicit parameters
        return s.strip().title()
```

Private methods

- Called by other methods in the class
- Not visible to users of the class
- Conventionally named with leading underscore

Private methods are those that are called only within the class. They are not part of the API – they are not visible to users of the class. Private methods may be instance, class, or static methods.

Name private methods with a leading underscore. This does not protect it from use, but gives programmers a hint that it's for internal use only.

Inheritance

- Specify base classes after class name
- Multiple inheritance OK
- Depth-first, left-to-right search for methods not in derived class

Classes may inherit methods and data. Specify a parenthesized list of base classes after the class name in the class definition.

If a method or attribute is not found in the derived class, it is first sought in the first base class in the list. If not found, it is sought in the base class of that class, if any, and so on. This is usually called a depth-first search.

The derived class inherits all attributes of the base class. If the base class initializer takes the same arguments as the derived class, then no extra coding is needed. Otherwise, to explicitly call the initializer in the base class, use super().__init__(args).

The simplest derived class would be:

```
class Mammal(Animal):
    pass
```

A Mammal object will have all the attributes and methods of an Animal object.

Example

mammal.py

```
#!/usr/bin/env python

from animal import Animal


class Mammal(Animal):  ①
    def __init__(self, species, name, sound, gestation):
        super(Mammal, self).__init__(species, name, sound)
        self._gestation = gestation

    @property
    def gestation(self):  ②
        """Length of gestation period in days"""
        return self._gestation


if __name__ == "__main__":
    mammal1 = Mammal("African lion", "Bob", "Roarrrr", 120)
    print(mammal1.name, "is a", mammal1.species, "--", end=' ')
    mammal1.make_sound()

    print("Number of animals", mammal1.zoo_size())

    mammal2 = Mammal("Fruit bat", "Freddie", "Squeak!!", 180)
    print(mammal2.name, "is a", mammal2.species, "--", end=' ')
    mammal2.make_sound()

    print("Number of animals", mammal2.zoo_size())
    print("Number of animals", Mammal.zoo_size())

    mammal1.kill()
    print("Number of animals", Mammal.zoo_size())

    print("Gestation period of the", mammal1.species, "is", mammal1.gestation, "days")
    print("Gestation period of the", mammal2.species, "is", mammal2.gestation, "days")
```

① inherit from Animal

② add property to existing Animal properties

mammal.py

```
Bob is a African lion -- Roarrrr
Number of animals 1
Freddie is a Fruit bat -- Squeak!!
Number of animals 2
Number of animals 2
Number of animals 1
Gestation period of the African lion is 120 days
Gestation period of the Fruit bat is 180 days
```

Untangling the nomenclature

There are many terms to distinguish the various parts of a Python program. This chart is an attempt to help you sort out what is what:

Table 15. Objected-oriented Nomenclature

attribute	A variable or method that is part of a class or object
base class	A class from which other classes inherit
child class	Same as derived class
class	A Python module from which objects may be created
class method	A function that expects the class object as its first parameter. Such a function can be called from either the class itself or an instance of the class. Created with @classmethod decorator.
derived class	A class which inherits from some other class
function	An executable subprogram.
instance method	A function that expects the instance object, conventionally named self, as its first parameter. See "method".
method	A function defined inside a class.
module	A file containing python code, and which is designed to be imported into Python scripts or other modules.
package	A folder containing one or more modules. Packages may be imported. There must be a file named __init__.py in the package folder.
parent class	Same as base class
property	A managed attribute (variable) of an instance of a class
script	A Python program. A script is an executable file containing Python commands.
static method	A function in a class that does not automatically receive any parameters; typically used for private utility functions. Created with @staticmethod decorator.
superclass	Same as base class

Chapter 11 Exercises

Exercise 11-1 (knight.py, knight_info.py)

Part 1:

Create a module which defines a class named **Knight**.

The initializer for the class should expect the knight's name as a parameter. Get the information from the file **knights.txt** to initialize the object.

The object should have these (read-only) properties:

name
title
favorite_color
quest
comment

Example

```
from knight import Knight
k = Knight('Arthur')
print k.favorite_color
```

Part 2:

Create an application to use the **Knight** class created in part one. For each knight specified on the command line, create a **knight** object and print out the knight's name, favorite color, quest, and comment. Precede the name with the knight's title.

Example output:

```
Arthur Bedevere
Name: King Arthur
Favorite Color: blue
Quest: The Grail
Comment: King of the Britons

Name: Sir Bedevere
Favorite Color: red, no, blue!
Quest: The Grail
Comment: AARRRRRRRGGGGHH
```

Chapter 12: Effective Scripts

Objectives

- Launch external programs
- Check permissions on files
- Get system configuration information
- Store data offline
- Create Unix-style filters
- Parse command line options
- Configure application logging

Using glob

- Expands wildcards
- Windows and non-windows
- Useful with **subprocess** module

When executing external programs, sometimes you want to specify a list of files using a wildcard. The **glob** function in the **glob** module will do this. Pass one string containing a wildcard (such as `*.txt`) to glob(), and it returns a sorted list of the matching files. If no files match, it returns an empty list.

Example

glob_example.py

```
#!/usr/bin/env python

from glob import glob

files = glob('../DATA/*.txt') ①
print(files, '\n')

no_files = glob('../JUNK/*.avi')
print(no_files, '\n')
```

① expand file name wildcard into sorted list of matching names *glob_example.py*

```
['../DATA/presidents_plus_biden.txt', '../DATA/columns_of_numbers.txt',
'../DATA/poe_sonnet.txt', '../DATA/computer_people.txt', '../DATA/owl.txt',
'../DATA/eggs.txt', '../DATA/world_airport_codes.txt', '../DATA/stateinfo.txt',
'../DATA/fruit2.txt', '../DATA/us_airport_codes.txt', '../DATA/parrot.txt',
'../DATA/http_status_codes.txt', '../DATA/fruit1.txt', '../DATA/alice.txt',
'../DATA/littlewomen.txt', '../DATA/spam.txt', '../DATA/world_median_ages.txt',
'../DATA/phone_numbers.txt', '../DATA/sales_by_month.txt', '../DATA/engineers.txt',
'../DATA/underrated.txt', '../DATA/tolkien.txt', '../DATA/tyger.txt',
'../DATA/example_data.txt', '../DATA/states.txt', '../DATA/kjv.txt', '../DATA/fruit.txt',
'../DATA/areacodes.txt', '../DATA/float_values.txt', '../DATA/unabom.txt',
'../DATA/chaos.txt', '../DATA/noisewords.txt', '../DATA/presidents.txt',
'../DATA/bible.txt', '../DATA/breakfast.txt', '../DATA/Pride_and_Prejudice.txt',
'../DATA/nsfw_words.txt', '../DATA/mary.txt',
'../DATA/2017FullMembersMontanaLegislators.txt', '../DATA/badger.txt',
'../DATA/README.txt', '../DATA/words.txt', '../DATA/primeministers.txt',
'../DATA/grail.txt', '../DATA/alt.txt', '../DATA/knights.txt',
'../DATA/world_airports_codes_raw.txt', '../DATA/correspondence.txt']

[]
```

Using shlex.split()

- Splits string
- Preserves white space

If you have an external command you want to execute, you should split it into individual words. If your command has quoted whitespace, the normal **split()** method of a string won't work.

For this you can use **shlex.split()**, which preserves quoted whitespace within a string.

Example

shlex_split.py

```
#!/usr/bin/env python
#
import shlex

cmd = 'herp derp "fuzzy bear" "wanga tanga" pop'  ①

print(cmd.split())  ②
print()

print(shlex.split(cmd))  ③
```

① Command line with quoted whitespace

② Normal split does the wrong thing

③ shlex.split() does the right thing

shlex_split.py

```
['herp', 'derp', '"fuzzy', 'bear"', '"wanga', 'tanga"', 'pop']

['herp', 'derp', 'fuzzy bear', 'wanga tanga', 'pop']
```

The subprocess module

- Spawns new processes
- works on Windows and non-Windows systems
- Convenience methods
    - **run()**
    - **call()**, **check_call()**

The **subprocess** module spawns and manages new processes. You can use this to run local non-Python programs, to log into remote systems, and generally to execute command lines.

subprocess implements a low-level class named Popen; However, the convenience methods **run()**, **check_call()**, and check_output()**, which are built on top of Popen(), are commonly used, as they have a simpler interface. You can capture *stdout** and **stderr**, separately. If you don't capture them, they will go to the console.

In all cases, you pass in an iterable containing the command split into individual words, including any file names. This is why this chapter starts with glob.glob() and shlex.split().

Table 16. CalledProcessError attributes

Attribute	Description
args	The arguments used to launch the process. This may be a list or a string.
returncode	Exit status of the child process. Typically, an exit status of 0 indicates that it ran successfully. A negative value -N indicates that the child was terminated by signal N (POSIX only).
stdout	Captured stdout from the child process. A bytes sequence, or a string if run() was called with an encoding or errors. None if stdout was not captured. If you ran the process with stderr=subprocess.STDOUT, stdout and stderr will be combined in this attribute, and stderr will be None. stderr

subprocess convenience functions

- run(), check_call() , check_output()
- Simpler to use than Popen

subprocess defines convenience functions, **call()**, **check_call()**, and **check_output()**.

```
proc subprocess.run(cmd, ...)
```

Run command with arguments. Wait for command to complete, then return a **CompletedProcess** instance.

```
subprocess.check_call(cmd, ...)
```

Run command with arguments. Wait for command to complete. If the exit code was zero then return, otherwise raise CalledProcessError. The CalledProcessError object will have the return code in the returncode attribute.

```
check_output(cmd, ...)
```

Run command with arguments and return its output as a byte string. If the exit code was non-zero it raises a CalledProcessError. The CalledProcessError object will have the return code in the returncode attribute and output in the output attribute.

NOTE run() is only implemented in Python 3.5 and later.

Example

subprocess_conv.py

```python
#!/usr/bin/env python

import sys
from subprocess import check_call, check_output, CalledProcessError
from glob import glob
import shlex

if sys.platform == 'win32':
    CMD = 'cmd /c dir'
    FILES = r'..\DATA\t*'
else:
    CMD = 'ls -ld'
    FILES = '../DATA/t*'

cmd_words = shlex.split(CMD)
cmd_files = glob(FILES)

full_cmd = cmd_words + cmd_files

try:
    check_call(full_cmd)
except CalledProcessError as err:
    print("Command failed with return code", err.returncode)

print('-' * 60)

try:
    output = check_output(full_cmd)
    print("Output:", output.decode(), sep='\n')
except CalledProcessError as e:
    print("Process failed with return code", e.returncode)

print('-' * 50)
```

subprocess_conv.py

```
-rw-r--r--  1 jstrick  staff  3178541 Nov  2  2020 ../DATA/tate_data.zip
-rwxr-xr-x  1 jstrick  staff      297 Nov 17  2016 ../DATA/testscores.dat
-rwxr-xr-x  1 jstrick  staff     2198 Feb 14  2016 ../DATA/textfiles.zip
-rw-r--r--  1 jstrick  staff   106960 Jul 26  2017 ../DATA/titanic3.csv
-rw-r--r--@ 1 jstrick  staff   284160 Jul 26  2017 ../DATA/titanic3.xls
-rwxr-xr-x  1 jstrick  staff    73808 Feb 14  2016 ../DATA/tolkien.txt
-rwxr-xr-x  1 jstrick  staff      834 Feb 14  2016 ../DATA/tyger.txt
------------------------------------------------------------
Output:
-rw-r--r--  1 jstrick  staff  3178541 Nov  2  2020 ../DATA/tate_data.zip
-rwxr-xr-x  1 jstrick  staff      297 Nov 17  2016 ../DATA/testscores.dat
-rwxr-xr-x  1 jstrick  staff     2198 Feb 14  2016 ../DATA/textfiles.zip
-rw-r--r--  1 jstrick  staff   106960 Jul 26  2017 ../DATA/titanic3.csv
-rw-r--r--@ 1 jstrick  staff   284160 Jul 26  2017 ../DATA/titanic3.xls
-rwxr-xr-x  1 jstrick  staff    73808 Feb 14  2016 ../DATA/tolkien.txt
-rwxr-xr-x  1 jstrick  staff      834 Feb 14  2016 ../DATA/tyger.txt

--------------------------------------------------
```

NOTE showing Unix/Linux/Mac output – Windows will be similar

TIP (Windows only) The following commands are *internal* to CMD.EXE, and must be preceded by `cmd /c` or they will not work: ASSOC, BREAK, CALL ,CD/CHDIR, CLS, COLOR, COPY, DATE, DEL, DIR, DPATH, ECHO, ENDLOCAL, ERASE, EXIT, FOR, FTYPE, GOTO, IF, KEYS, MD/MKDIR, MKLINK (vista and above), MOVE, PATH, PAUSE, POPD, PROMPT, PUSHD, REM, REN/RENAME, RD/RMDIR, SET, SETLOCAL, SHIFT, START, TIME, TITLE, TYPE, VER, VERIFY, VOL

Capturing stdout and stderr

- Add stdout, stderr args
- Assign subprocess.PIPE

To capture stdout and stderr with the subprocess module, import **PIPE** from subprocess and assign it to the stdout and stderr parameters to run(), check_call(), or check_output(), as needed.

For check_output(), the return value is the standard output; for run(), you can access the **stdout** and **stderr** attributes of the CompletedProcess instance returned by run().

NOTE output is returned as a bytes object; call decode() to turn it into a normal Python string.

Example

subprocess_capture.py

```
#!/usr/bin/env python

import sys
from subprocess import check_output, Popen, CalledProcessError, STDOUT, PIPE ①
from glob import glob
import shlex

if sys.platform == 'win32':
    CMD = 'cmd /c dir'
    FILES = r'..\DATA\t*'
else:
    CMD = 'ls -ld'
    FILES = '../DATA/t*'

cmd_words = shlex.split(CMD)
cmd_files = glob(FILES)

full_cmd = cmd_words + cmd_files

②
try:
    output = check_output(full_cmd) ③
    print("Output:", output.decode(), sep='\n') ④
except CalledProcessError as e:
    print("Process failed with return code", e.returncode)

print('-' * 50)
```

```
⑤
try:
    cmd = cmd_words + cmd_files + ['spam.txt']
    proc = Popen(cmd, stdout=PIPE, stderr=STDOUT) ⑥
    stdout, stderr = proc.communicate() ⑦
    print("Output:", stdout.decode()) ⑧
except CalledProcessError as e:
    print("Process failed with return code", e.returncode)

print('-' * 50)

try:
    cmd = cmd_words + cmd_files + ['spam.txt']
    proc = Popen(cmd, stdout=PIPE, stderr=PIPE) ⑨
    stdout, stderr = proc.communicate() ⑩
    print("Output:", stdout.decode()) ⑪
    print("Error:", stderr.decode()) ⑪
except CalledProcessError as e:
    print("Process failed with return code", e.returncode)

print('-' * 50)
```

① need to import PIPE and STDOUT

② capture only stdout

③ check_output() returns stdout

④ stdout is returned as bytes (decode to str)

⑤ capture stdout and stderr together

⑥ assign PIPE to stdout, so it is captured; assign STDOUT to stderr, so both are captured together

⑦ call communicate to get the input streams of the process; it returns two bytes objects representing stdout and stderr

⑧ decode the stdout object to a string

⑨ assign PIPE to stdout and PIPE to stderr, so both are captured individually

⑩ now stdout and stderr each have data

⑪ decode from bytes and output

subprocess_capture.py

```
Output:
-rw-r--r--  1 jstrick  staff  3178541 Nov  2  2020 ../DATA/tate_data.zip
-rwxr-xr-x  1 jstrick  staff      297 Nov 17  2016 ../DATA/testscores.dat
-rwxr-xr-x  1 jstrick  staff     2198 Feb 14  2016 ../DATA/textfiles.zip
-rw-r--r--  1 jstrick  staff   106960 Jul 26  2017 ../DATA/titanic3.csv
-rw-r--r--@ 1 jstrick  staff   284160 Jul 26  2017 ../DATA/titanic3.xls
-rwxr-xr-x  1 jstrick  staff    73808 Feb 14  2016 ../DATA/tolkien.txt
-rwxr-xr-x  1 jstrick  staff      834 Feb 14  2016 ../DATA/tyger.txt

--------------------------------------------------
Output: -rw-r--r--  1 jstrick  staff     3178541 Nov  2  2020 ../DATA/tate_data.zip
-rwxr-xr-x  1 jstrick  staff         297 Nov 17  2016 ../DATA/testscores.dat
-rwxr-xr-x  1 jstrick  staff        2198 Feb 14  2016 ../DATA/textfiles.zip
-rw-r--r--  1 jstrick  staff      106960 Jul 26  2017 ../DATA/titanic3.csv
-rw-r--r--@ 1 jstrick  staff      284160 Jul 26  2017 ../DATA/titanic3.xls
-rwxr-xr-x  1 jstrick  staff       73808 Feb 14  2016 ../DATA/tolkien.txt
-rwxr-xr-x  1 jstrick  staff         834 Feb 14  2016 ../DATA/tyger.txt
-rw-r--r--  1 jstrick  students       22 Aug 18 13:43 spam.txt

--------------------------------------------------
Output: -rw-r--r--  1 jstrick  staff     3178541 Nov  2  2020 ../DATA/tate_data.zip
-rwxr-xr-x  1 jstrick  staff         297 Nov 17  2016 ../DATA/testscores.dat
-rwxr-xr-x  1 jstrick  staff        2198 Feb 14  2016 ../DATA/textfiles.zip
-rw-r--r--  1 jstrick  staff      106960 Jul 26  2017 ../DATA/titanic3.csv
-rw-r--r--@ 1 jstrick  staff      284160 Jul 26  2017 ../DATA/titanic3.xls
-rwxr-xr-x  1 jstrick  staff       73808 Feb 14  2016 ../DATA/tolkien.txt
-rwxr-xr-x  1 jstrick  staff         834 Feb 14  2016 ../DATA/tyger.txt
-rw-r--r--  1 jstrick  students       22 Aug 18 13:43 spam.txt

Error:
--------------------------------------------------
```

Permissions

- Simplest is os.access()
- Get mode from os.lstat()
- Use binary AND with permission constants

Each entry in a Unix filesystem has a inode. The inode contains low-level information for the file, directory, or other filesystem entity. Permissions are stored in the 'mode', which is a 16-bit unsigned integer. The first 4 bits indicate what kind of entry it is, and the last 12 bits are the permissions.

To see if a file or directory is readable, writable, or executable use os.access(). To test for specific permissions, use the os.lstat() method to return a tuple of inode data, and use the S_IMODE () method to get the mode information as a number. Then use predefined constants such as stat.S_IRUSR, stat.S_IWGRP, etc. to test for permissions.

Example

file_access.py

```
#!/usr/bin/env python

import sys
import os

if len(sys.argv) < 2:
    start_dir = "."
else:
    start_dir = sys.argv[1]

for base_name in os.listdir(start_dir):  ①
    file_name = os.path.join(start_dir, base_name)
    if os.access(file_name, os.W_OK):  ②
        print(file_name, "is writable")
```

① os.listdir() lists the contents of a directory

② os.access() returns True if file has specified permissions (can be os.W_OK, os.R_OK, or os.X_OK, combined with | (OR))

file_access.py ../DATA

```
../DATA/hyper.xlsx is writable
../DATA/presidents.csv is writable
../DATA/Bicycle_Counts.csv is writable
../DATA/wetprf is writable
../DATA/uri-schemes-1.csv is writable
../DATA/presidents.html is writable
../DATA/presidents.xlsx is writable
../DATA/presidents_plus_biden.txt is writable
../DATA/baby_names is writable
../DATA/WindowsEvents.evtx is writable
```

…

Using shutil

- Portable ways to copy, move, and delete files
- Create archives
- Misc utilities

The **shutil** module provides portable functions for copying, moving, renaming, and deleting files. There are several variations of each command, depending on whether you need to copy all the attributes of a file, for instance.

The module also provides an easy way to create a zip file or compressed **tar** archive of a folder.

In addition, there are some miscellaneous convenience routines.

Example

shutil_ex.py

```
#!/usr/bin/env python
#
import shutil
import os

shutil.copy('../DATA/alice.txt', 'betsy.txt') ①

print("betsy.txt exists:", os.path.exists('betsy.txt'))

shutil.move('betsy.txt', 'fred.txt') ②
print("betsy.txt exists:", os.path.exists('betsy.txt'))
print("fred.txt exists:", os.path.exists('fred.txt'))

new_folder = 'remove_me'

os.mkdir(new_folder) ③
shutil.move('fred.txt', new_folder)

shutil.make_archive(new_folder, 'zip', new_folder) ④

print("{}.zip exists:".format(new_folder), os.path.exists(new_folder + '.zip'))

print("{} exists:".format(new_folder), os.path.exists(new_folder))

shutil.rmtree(new_folder) ⑤

print("{} exists:".format(new_folder), os.path.exists(new_folder))
```

① copy file

② rename file

③ create new folder

④ make a zip archive of new folder

⑤ recursively remove folder

shutil_ex.py

```
betsy.txt exists: True
betsy.txt exists: False
fred.txt exists: True
remove_me.zip exists: True
remove_me exists: True
remove_me exists: False
```

Creating a useful command line script

- More than just some lines of code
- Input + Business Logic + Output
- Process files for input, or STDIN
- Allow options for customizing execution
- Log results

A good system administration script is more than just some lines of code hacked together. It needs to gather data, apply the appropriate business logic, and, if necessary, output the results of the business logic to the desired destination.

Python has two tools in the standard library to help create professional command line scripts. One of these is the **argparse** module, for parsing options and parameters on the script's command line. The other is fileinput, which simplifies processing a list of files specified on the command line.

We will also look at the logging module, which can be used in any application to output to a variety of log destinations, including a plain file, syslog on Unix-like systems or the NTLog service on Windows, or even email.

Creating filters

- Filter reads files or STDIN and writes to STDOUT

> Common on Unix systems Well-known filters: awk, sed, grep, head, tail, cat Reads command line arguments as files, otherwise STDIN use fileinput.input()

A common kind of script iterates over all lines in all files specified on the command line. The algorithm is

```
for filename in sys.argv[1:]:
    with open(filename) as F:
       for line in F:
            # process line
```

Many Unix utilities are written to work this way – sed, grep, awk, head, tail, sort, and many more. They are called filters, because they filter their input in some way and output the modified text. Such filters read STDIN if no files are specified, so that they can be piped into.

The fileinput.input() class provides a shortcut for this kind of file processing. It implicitly loops through sys.argv[1:], opening and closing each file as needed, and then loops through the lines of each file. If sys.argv[1:] is empty, it reads sys.stdin. If a filename in the list is '-', it also reads sys.stdin.

fileinput works on Windows as well as Unix and Unix-like platforms.

To loop through a different list of files, pass an iterable object as the argument to fileinput.input().

There are several methods that you can call from fileinput to get the name of the current file, e.g.

Table 17. fileinput Methods

Method	**Description**
filename()	Name of current file being readable
lineno()	Cumulative line number from all files read so far
filelineno()	Line number of current file
isfirstline()	True if current line is first line of a file
isstdin()	True if current file is sys.stdin
close()	Close fileinput

Example

file_input.py

```
#!/usr/bin/env python

import fileinput

for line in fileinput.input():  ①
    if 'bird' in line:
        print('{}: {}'.format(fileinput.filename(), line), end=' ')  ②
```

① fileinput.input() is a generator of all lines in all files in sys.argv[1:]

② fileinput.filename() has the name of the current file

file_input.py ../DATA/parrot.txt ../DATA/alice.txt

```
../DATA/parrot.txt: At that point, the guy is so mad that he throws the bird into the
../DATA/parrot.txt: For the first few seconds there is a terrible din. The bird kicks
../DATA/parrot.txt: bird may be hurt. After a couple of minutes of silence, he's so
../DATA/parrot.txt: The bird calmly climbs onto the man's out-stretched arm and says,
../DATA/alice.txt: with the birds and animals that had fallen into it:  there were a
../DATA/alice.txt: bank--the birds with draggled feathers, the animals with their
../DATA/alice.txt: some of the other birds tittered audibly.
../DATA/alice.txt: and confusion, as the large birds complained that they could not
```

Parsing the command line

- Parse and analyze **sys.argv**
- Use **argparse**
    - Parses entire command line
    - Flexible
    - Validates options and arguments

Many command line scripts need to accept options and arguments. In general, options control the behavior of the script, while arguments provide input. Arguments are frequently file names, but can be anything. All arguments are available in Python via sys.argv

There are at least three modules in the standard library to parse command line options. The oldest module is **getopt** (earlier than v1.3), then **optparse** (introduced 2.3, now deprecated), and now, **argparse** is the latest and greatest. (Note: **argparse** is only available in 2.7 and 3.0+).

To get started with **argparse**, create an ArgumentParser object. Then, for each option or argument, call the parser's add_argument() method.

The add_argument() method accepts the name of the option (e.g. '-count') or the argument (e.g. 'filename'), plus named parameters to configure the option.

Once all arguments have been described, call the parser's parse_args() method. (By default, it will process sys.argv, but you can pass in any list or tuple instead.) parse_args() returns an object containing the arguments. You can access the arguments using either the name of the argument or the name specified with dest.

One useful feature of **argparse** is that it will convert command line arguments for you to the type specified by the type parameter. You can write your own function to do the conversion, as well.

Another feature is that **argparse** will automatically create a help option, -h, for your application, using the help strings provided with each option or parameter.

argparse parses the entire command line, not just arguments

Table 18. add_argument() named parameters

parameter	description
dest	Name of attribute (defaults to argument name)
nargs	Number of arguments Default: one argument, returns string '*': 0 or more arguments, returns list '+': 1 or more arguments, returns list '?': 0 or 1 arguments, returns list N: exactly N arguments, returns list
const	Value for options that do not take a user-specified value
default	Value if option not specified
type	type which the command-line arguments should be converted ; one of 'string', 'int', 'float', 'complex' or a function that accepts a single string argument and returns the desired object. (Default: 'string')
choices	A list of valid choices for the option
required	Set to true for required options
metavar	A name to use in the help string (default: same as dest)
help	Help text for option or argument

Example

parsing_args.py

```
#!/usr/bin/env python
import re
import fileinput
import argparse
from glob import glob  ①
from itertools import chain  ②

arg_parser = argparse.ArgumentParser(description="Emulate grep with python")  ③

arg_parser.add_argument(
    '-i',
    dest='ignore_case', action='store_true',
    help='ignore case'
)  ④

arg_parser.add_argument(
    'pattern', help='Pattern to find (required)'
)  ⑤

arg_parser.add_argument(
    'filenames', nargs='*',
    help='filename(s) (if no files specified, read STDIN)'
)  ⑥

args = arg_parser.parse_args()  ⑦

print('-' * 40)
print(args)
print('-' * 40)

regex = re.compile(args.pattern, re.I if args.ignore_case else 0)  ⑧

filename_gen = (glob(f) for f in args.filenames)  ⑨
filenames = chain.from_iterable(filename_gen)  ⑩

for line in fileinput.input(filenames):  ⑪
    if regex.search(line):
        print(line.rstrip())
```

① needed on Windows to parse filename wildcards

② needed on Windows to flatten list of filename lists

③ create argument parser

④ add option to the parser; dest is name of option attribute

⑤ add required argument to the parser

⑥ add optional arguments to the parser

⑦ actually parse the arguments

⑧ compile the pattern for searching; set re.IGNORECASE if -i option

⑨ for each filename argument, expand any wildcards; this returns list of lists

⑩ flatten list of lists into a single list of files to process (note: both filename_gen and filenames are generators; these two lines are only needed on Windows — non-Windows systems automatically expand wildcards)

⑪ loop over list of file names and read them one line at a time

parsing_args.py

```
usage: parsing_args.py [-h] [-i] pattern [filenames [filenames ...]]
parsing_args.py: error: the following arguments are required: pattern, filenames
```

parsing_args.py -i '\bbil' ../DATA/alice.txt ../DATA/presidents.txt

```
----------------------------------------
Namespace(filenames=['../DATA/alice.txt', '../DATA/presidents.txt'], ignore_case=True,
pattern='\\bbil')
----------------------------------------
                The Rabbit Sends in a Little Bill
Bill's got the other--Bill! fetch it here, lad!--Here, put 'em up
Here, Bill! catch hold of this rope--Will the roof bear?--Mind
crash)--`Now, who did that?--It was Bill, I fancy--Who's to go
then!--Bill's to go down--Here, Bill! the master says you're to
  `Oh! So Bill's got to come down the chimney, has he?' said
Alice to herself.  `Shy, they seem to put everything upon Bill!
I wouldn't be in Bill's place for a good deal:  this fireplace is
above her:  then, saying to herself `This is Bill,' she gave one
Bill!' then the Rabbit's voice along--`Catch him, you by the
  Last came a little feeble, squeaking voice, (`That's Bill,'
The poor little Lizard, Bill, was in the middle, being held up by
end of the bill, "French, music, AND WASHING--extra."'
Bill, the Lizard) could not make out at all what had become of
Lizard as she spoke.  (The unfortunate little Bill had left off
42:Clinton:William Jefferson 'Bill':1946-08-19:NONE:Hope:Arkansas:1993-01-20:2001-01-
20:Democratic
```

parsing_args.py -h

```
usage: parsing_args.py [-h] [-i] pattern [filenames [filenames ...]]

Emulate grep with python

positional arguments:
  pattern     Pattern to find (required)
  filenames   filename(s) (if no files specified, read STDIN)

optional arguments:
  -h, --help  show this help message and exit
  -i          ignore case
```

Simple Logging

- Specify file name
- Configure the minimum logging level
- Messages added at different levels
- Call methods on logging

For simple logging, just configure the log file name and minimum logging level with the basicConfig() method. Then call one of the per-level methods, such as logging.debug or logging.error, to output a log message for that level. If the message is at or above the minimal level, it will be added to the log file.

The file will continue to grow, and must be manually removed or truncated. If the file does not exist, it will be created.

The logger module provides 5 levels of logging messages, from DEBUG to CRITICAL. When you set up a logger, you specify the minimum level of messages to be logged. If you set up the logger with the minimum level set to ERROR, then only messages at ERROR and CRITICAL levels will be logged. Setting the minimum level to DEBUG allows all messages to be logged.

Table 19. Logging Levels

Level	Value
CRITICAL FATAL	50
ERROR	40
WARN WARNING	30
INFO	20
DEBUG	10
UNSET	0

Example

logging_simple.py

```
#!/usr/bin/env python

import logging

logging.basicConfig(
    filename='../TEMP/simple.log',
    level=logging.WARNING,
) ①

logging.warning('This is a warning') ②
logging.debug('This message is for debugging') ③
logging.error('This is an ERROR') ④
logging.critical('This is ***CRITICAL***') ⑤
logging.info('The capital of North Dakota is Bismark') ⑥
```

① setup logging; minimal level is WARN

② message will be output

③ message will NOT be output

④ message will be output

⑤ message will be output

⑥ message will not be output

simple.log

```
WARNING:root:This is a warning
ERROR:root:This is an ERROR
CRITICAL:root:This is ***CRITICAL***
```

Formatting log entries

- Add format=format to basicConfig() parameters
- Format is a string containing directives and (optionally) other text
- Use directives in the form of %(item)type
- Other text is left as-is

To format log entries, provide a format parameter to the basicConfig() method. This format will be a string contain special directives (i.e. Placeholders) and, optionally, other text. The directives are replaced with logging information; other data is left as-is.

Directives are in the form %(item)type, where item is the data field, and type is the data type.

Example

logging_formatted.py

```
#!/usr/bin/env python

import logging

logging.basicConfig(
    format='%(name)s %(asctime)s %(levelname)s %(message)s', ①
    filename='../TEMP/formatted.log',
    level=logging.INFO,
)

logging.info("this is information")
logging.warning("this is a warning")
logging.info("this is information")
logging.critical("this is critical")
```

① set the format for log entries

formatted.log

```
root 2021-08-18 13:43:53,910 INFO this is information
root 2021-08-18 13:43:53,911 WARNING this is a warning
root 2021-08-18 13:43:53,911 INFO this is information
root 2021-08-18 13:43:53,911 CRITICAL this is critical
```

Table 20. Log entry formatting directives

Directive	Description
%(name)s	Name of the logger (logging channel)
%(levelno)s	Numeric logging level for the message (DEBUG, INFO, WARNING, ERROR, CRITICAL)
%(levelname)s	Text logging level for the message ("DEBUG", "INFO", "WARNING", "ERROR", "CRITICAL")
%(pathname)s	Full pathname of the source file where the logging call was issued (if available)
%(filename)s	Filename portion of pathname
%(module)s	Module (name portion of filename)
%(lineno)d	Source line number where the logging call was issued (if available)
%(funcName)s	Function name
%(created)f	Time when the LogRecord was created (time.time() return value)
%(asctime)s	Textual time when the LogRecord was created
%(msecs)d	Millisecond portion of the creation time
%(relativeCreated)d	Time in milliseconds when the LogRecord was created, relative to the time the logging module was loaded (typically at application startup time)
%(thread)d	Thread ID (if available)
%(threadName)s	Thread name (if available)
%(process)d	Process ID (if available)
%(message)s	The result of record.getMessage(), computed just as the record is emitted

Logging exception information

- Use logging.exception()
- Adds exception info to message
- Only in **except** blocks

The logging.exception() function will add exception information to the log message. It should only be called in an **except** block.

Example

logging_exception.py

```
#!/usr/bin/env python

import logging

logging.basicConfig( ①
    filename='../TEMP/exception.log',
    level=logging.WARNING,  ②
)

for i in range(3):
    try:
        result = i/0
    except ZeroDivisionError:
        logging.exception('Logging with exception info') ③
```

① configure logging

② minimum level

③ add exception info to the log

exception.log

```
ERROR:root:Logging with exception info
Traceback (most recent call last):
  File "logging_exception.py", line 12, in <module>
    result = i/0
ZeroDivisionError: division by zero
ERROR:root:Logging with exception info
Traceback (most recent call last):
  File "logging_exception.py", line 12, in <module>
    result = i/0
ZeroDivisionError: division by zero
ERROR:root:Logging with exception info
Traceback (most recent call last):
  File "logging_exception.py", line 12, in <module>
    result = i/0
ZeroDivisionError: division by zero
```

Logging to other destinations

- Use specialized handlers to write to other destinations
- Multiple handlers can be added to one logger
  - NTEventLogHandler for Windows event log
  - SysLogHandler for syslog
  - SMTPHandler for logging via email

The logging module provides some preconfigured log handlers to send log messages to destinations other than a file.

Each handler has custom configuration appropriate to the destination. Multiple handlers can be added to the same logger, so a log message will go to a file and to email, for instance, and each handler can have its own minimum level. Thus, all messages could go to the message file, but only CRITICAL messages would go to email.

Be sure to read the documentation for the particular log handler you want to use

NOTE On Windows, you must run the example script (logging.altdest.py) as administrator. You can find `Command Prompt (admin)` on the main Windows 8/10 menu. You can also right-click on `Command Prompt` from the Windows 7 menu and choose "Run as administrator".

Example

logging_altdest.py

```
#!/usr/bin/env python
import sys
import logging
import logging.handlers

logger = logging.getLogger('ThisApplication')  ①
logger.setLevel(logging.DEBUG)  ②

if sys.platform == 'win32':
    eventlog_handler = logging.handlers.NTEventLogHandler("Python Log Test")  ③
    logger.addHandler(eventlog_handler)  ④
else:
    syslog_handler = logging.handlers.SysLogHandler()  ⑤
    logger.addHandler(syslog_handler)  ⑥

# note -- use your own SMTP server...
email_handler = logging.handlers.SMTPHandler(
    ('smtpcorp.com', 8025),
    'LOGGER@pythonclass.com',
    ['jstrick@mindspring.com'],
    'ThisApplication Log Entry',
    ('jstrickpython', 'python(monty)'),
)  ⑦

logger.addHandler(email_handler)  ⑧

logger.debug('this is debug')  ⑨
logger.critical('this is critical')  ⑨
logger.warning('this is a warning')  ⑨
```

① get logger for application

② minimum log level

③ create NT event log handler

④ install NT event handler

⑤ create syslog handler

⑥ install syslog handler

⑦ create email handler

⑧ install email handler

⑨ goes to all handlers

Chapter 12 Exercises

Exercise 12-1 (copy_files.py)

Write a script to find all text files (only the files that end in ".txt") in the DATA folder of the student files and copy them to C:\TEMP (Windows) or /tmp (non-windows). On Windows, create the C:\TEMP folder if it does not already exist.

Add logging to the script, and log each filename at level INFO.

TIP use shutil.copy() to copy the files.

Chapter 13: Developer Tools

Objectives

- Run pylint to check source code
- Debug scripts
- Find speed bottlenecks in code
- Compare algorithms to see which is faster

Program development

- More than just coding
    - Design first
    - Consistent style
    - Comments
    - Debugging
    - Testing
    - Documentation

Comments

- Keep comments up-to-date
- Use complete sentences
- Block comments describe a section of code
- Inline comments describe a line
- Don’t state the obvious

Comments that contradict the code are worse than no comments. Always make a priority of keeping the comments up-to-date when the code changes!

Comments should be complete sentences. If a comment is a phrase or sentence, its first word should be capitalized, unless it is an identifier that begins with a lower case letter (never alter the case of identifiers!).

Block comments generally apply to some (or all) code that follows them, and are indented to the same level as that code. Each line of a block comment starts with a # and a single space (unless it is indented text inside the comment).

Paragraphs inside a block comment are separated by a line containing a single #.

Use inline comments sparingly. Inline comments should be separated by at least two spaces from the statement; they should start with a # and a single space.

Inline comments are unnecessary and in fact distracting if they state the obvious. Don’t do this:

```
x = x + 1       # Increment x
```

Only use an inline comment if the reason for the statement is not obvious:

```
x = x + 1       # Add one so range() does the right thing
```

The above was adapted from PEP 8

pylint

- Checks many aspects of code
- Finds mistakes
- Rates your code for standards compliance
- Don’t worry if your code has a lower rating!
- Can be highly customized

pylint is a Python source code analyzer which looks for programming errors, helps enforcing a coding standard and sniffs for some code smells (as defined in Martin Fowler’s Refactoring book)

from the pylint documentation

pylint can be very helpful in identifying errors and pointing out where your code does not follow standard coding conventions. It was developed by Python coders at Logilab http://www.logilab.fr.

It has very verbose output, which can be modified via command line options.

pylint can be customized to reflect local coding conventions.

pylint usage:

```
pylint filename(s) or directory
pylint -ry filename(s) or directory
```

The **-ry** option says to generate a full detailed report.

Most Python IDEs have pylint, or the equivalent, built in.

Other tools for analyzing Python code: * pyflakes * pychecker

Customizing pylint

- Use pylint --generate-rcfile
- Redirect to file
- Edit as needed
- Knowledge of regular expressions useful
- Name file \~/.pylintrc on Linux/Unix/OS X
- Use –rcfile file to specify custom file on Windows

To customize pylint, run pylint with only the -generate-rcfile option. This will output a well-commented configuration file to STDOUT, so redirect it to a file.

Edit the file as needed. The comments describe what each part does. You can change the allowed names of variables, functions, classes, and pretty much everything else. You can even change the rating algorithm.

Windows

Put the file in a convenient location (name it something like pylintrc). Invoke pylint with the –rcfile option to specify the location of the file.

pylint will also find a file named pylintrc in the current directory, without needing the -rcfile option.

Non-Windows systems

On Unix-like systems (Unix, Mac OS, Linux, etc.), /etc/pylintrc and ~/.pylintrc will be automatically loaded, in that order.

See docs.pylint.org for more details.

Using pyreverse

- Source analyzer
- Reverse engineers Python code
- Part of pylint
- Generates UML diagrams

pyreverse is a Python source code analyzer. It reads a script, and the modules it depends on, and generates UML diagrams. It is installed as part of the pylint package.

There are many options to control what it analyzes and what kind of output it produces.

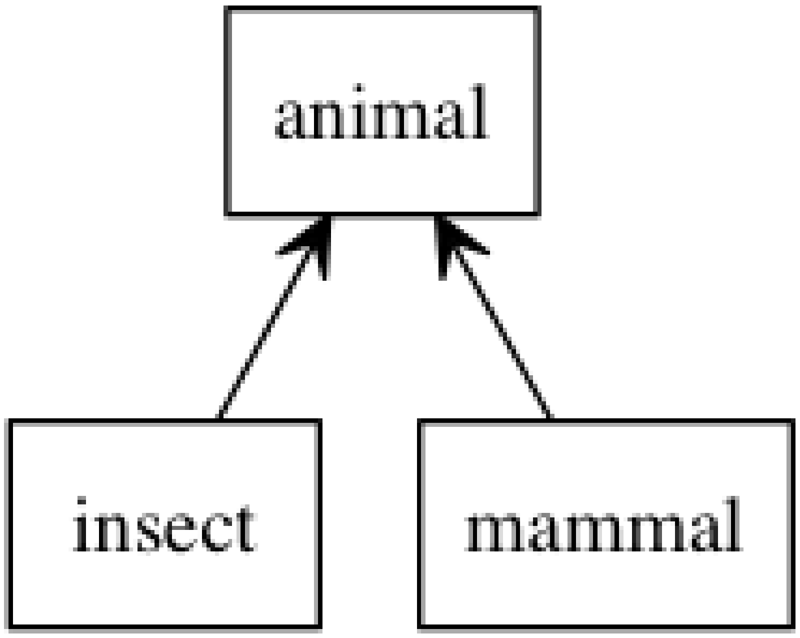
Use ``-A' to search all ancestors, `-p`` to specify the project name, `-o` to specify output type (e.g., **pdf**, **png**, **jpg**).

NOTE **pyreverse** requires **Graphviz**, a graphics tool that must be installed separately from Python

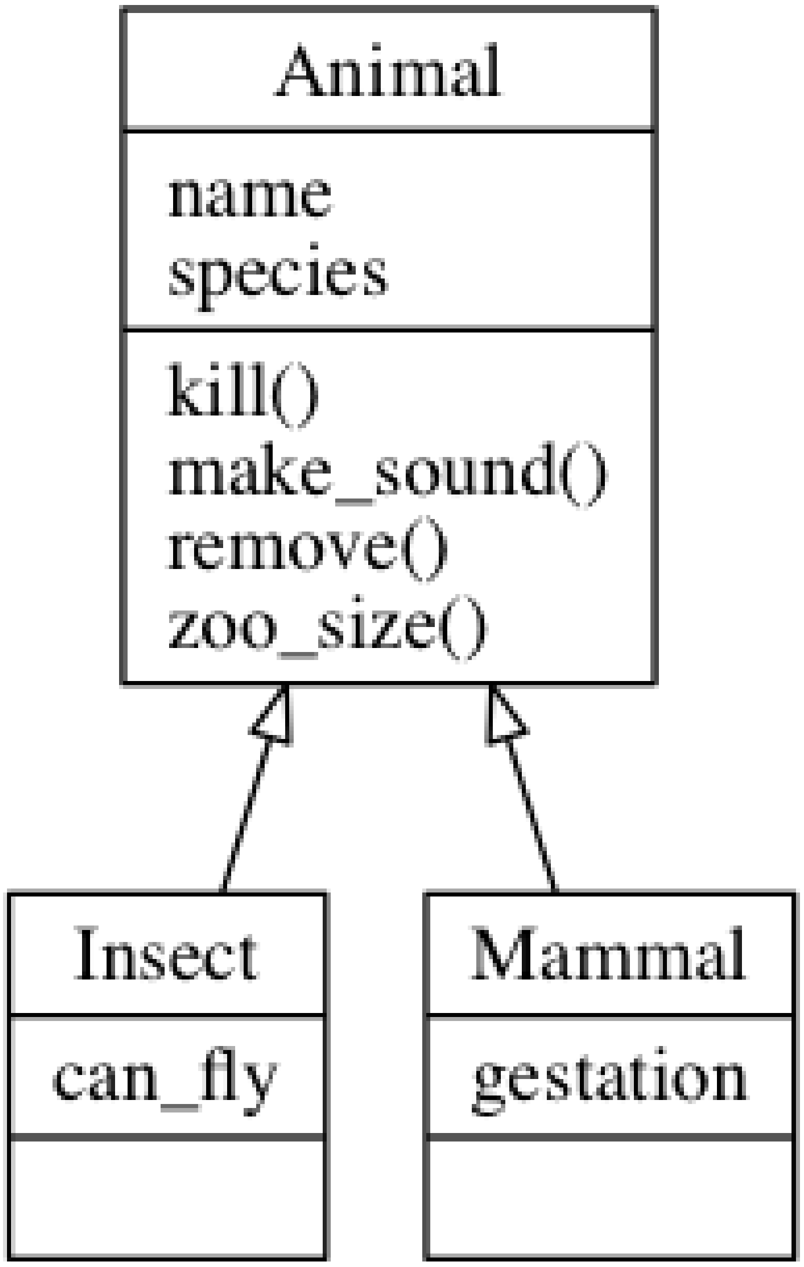
Example

```
pyreverse -o png -p MyProject -A animal.py mammal.py insect.py
```

packages_MyProject.png



classes_MyProject.png



NOTE **pyreverse** requires the (non-Python) Graphviz utility to be installed.

The Python debugger

- Implemented via pdb module
- Supports breakpoints and single stepping
- Based on gdb

While most IDEs have an integrated debugger, it is good to know how to debug from the command line. The pdb module provides debugging facilities for Python.

The usual way to use pdb is from the command line:

```
python -mpdb script_to_be_debugged.py
```

Once the program starts, it will pause at the first executable line of code and provide a prompt, similar to the interactive Python prompt. There is a large set of debugging commands you can enter at the prompt to step through your program, set breakpoints, and display the values of variables.

Since you are in the Python interpreter as well, you can enter any valid Python expression.

You can also start debugging mode from within a program.

Starting debug mode

- Syntax

```
python -m pdb script
```

or

```
import pdb
pdb.run('function')
```

pdb is usually invoked as a script to debug other scripts. For example:

```
python -m pdb myscript.py
```

Typical usage to run a program under control of the debugger is:

```
>>> import pdb
>>> import some_module
>>> pdb.run('some_module.function_to_text()')
> <string>(0)?()
(Pdb) c    # (c)ontinue
> <string>(1)?()
(Pdb) c    # (c)ontinue
NameError: 'spam'
> <string>(1)?()
(Pdb)
```

To get help, type **h** at the debugger prompt.

Stepping through a program

- s single-step, stepping into functions
- n single-step, stepping over functions
- r return from function
- c run to next breakpoint or end

The debugger provides several commands for stepping through a program. Use **s** to step through one line at a time, stepping into functions.

Use **n** to step over functions; use **r** to return from a function; use **c** to continue to next breakpoint or end of program.

Pressing Enter repeats most commands; if the previous command was list, the debugger lists the next set of lines.

Setting breakpoints

- Syntax

```
b list all breakpoints
b linenumber (, condition)
b file:linenumber (, condition)
b function name (, condition)
```

Breakpoints can be set with the b command. Specify a line number, or a function name, optionally preceded by the filename that contains it.

Any of the above can be followed by an expression (use comma to separate) to create a conditional breakpoint.

The **tbreak** command creates a one-time breakpoint that is deleted after it is hit the first time.

Profiling

- Use the **profile** module from the command line
- Shows where program spends the most time
- Output can be tweaked via options

Profiling is the technique of discovering the part of your code where your application spends the most time. It can help you find bottlenecks in your code that might be candidates for revision or refactoring.

To use the profiler, execute the following at the command line:

```
python -m profile scriptname.py
```

This will output a simple report to STDOUT. You can also specify an output file with the -o option, and the sort order with the -s option. See the docs for more information.

TIP The **pycallgraph2** module (third-party module) will create a graphical representation of an application's profile, indicating visually where the application is spending the most time.

Example

```
python -m profile count_with_dict.py
...script output...
         19 function calls in 0.000 seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
       14    0.000    0.000    0.000    0.000 :0(get)
        1    0.000    0.000    0.000    0.000 :0(items)
        1    0.000    0.000    0.000    0.000 :0(open)
        1    0.000    0.000    0.000    0.000 :0(setprofile)
        1    0.000    0.000    0.000    0.000 count_with_dict.py:3(<module>)
        1    0.000    0.000    0.000    0.000 profile:0(<code object <module> at
0xb74c36e0, file "count_with_dict.py", line 3>)
        0    0.000             0.000          profile:0(profiler)
```

Benchmarking

- Use the timeit module
- Create a timer object with specified # of repetitions

Use the timeit module to benchmark two or more code snippets. To time code, create a Timer object, which takes two strings of code. The first is the code to test; the second is setup code, that is only run once per timer .

Call the timeit() method with the number of times to call the test code, or call the repeat() method which repeats timeit() a specified number of times.

You can also use the **timeit** module from the command line. Use the **-s** option to specify startup code:

```
python -m timeit -s ▯startup code…▯ ▯code….▯
```

Example

bm_range_vs_while.py

```
#!/usr/bin/env python
from timeit import Timer

setup_code = """
values = []
"""  ①

test_code_one = '''
for i in range(10000):
    values.append(i)
values.clear()
'''  ②

test_code_two = '''
i = 0
while i < 10000:
    values.append(i)
    i += 1
values.clear()
'''  ②

t1 = Timer(test_code_one, setup_code)  ③
t2 = Timer(test_code_two, setup_code)  ③

print("test one:")
print(t1.timeit(1000))  ④
print()

print("test two:")
print(t2.timeit(1000))  ④
print()
```

① setup code is only executed once

② code fragment executed many times

③ Timer object creates time-able code

④ timeit() runs code fragment N times

bm_range_vs_while.py

```
test one:
0.6021613050000001

test two:
0.9247809820000001
```

Chapter 13 Exercises

Exercise 13-1

Pick several of your scripts (from class, or from real life) and run pylint on them.

Exercise 13-2

Use the builtin debugger or one included with your IDE to step through any of the scripts you have written so far.

Chapter 14: Using openpyxl with Excel spreadsheets

Objectives

- Learn the basics of **openpyxl**
- Open **Excel** spreadsheets and extract data
- Update spreadsheets
- Create new spreadsheets
- Add styles and conditional formatting

The openpyxl module

- Provides full read/write access to Excel spreadsheets
- Creates new workbooks/worksheets
- Does not require Excel

The **openpyxl** module allows you to read, write, and create **Excel** spreadsheets.

openpyxl does not require Excel to be installed.

You can open existing workbooks or create new ones. You can do most anything that you could do manually in a spreadsheet – update or insert data, create formulas, add or change styles, even hide columns.

When you open an existing spreadsheet or create a new one, openpyxl creates an instance of `Workbook`. A Workbook contains one or more `Worksheet` objects.

From a worksheet you can access cells directly, or create a range of cells.

The data in each cell can be manipulated through its `.value` property. Other properties, such as `.font` and `.number_format`, control the display of the data.

View the full documentation at http://openpyxl.readthedocs.org/en/latest/index.html.

TIP To save typing, import **openpyxl** as **px**.

Reading an existing spreadsheet

- Use `load_workbook()` to open file
- Get active worksheet with `WB.active`
- List all worksheets with `get_sheet_by_name()`
- Get named worksheet with `WB['worksheet-name']`

To open and read an existing spreadsheet, use the `load_workbook()` function. This returns a WorkBook object.

There are several ways to get a worksheet from a workbook. To list all the sheets by name, use `WB.get_sheet_names()`.

To get a particular worksheet, index the workbook by sheet name, e.g. `WB['sheetname']`.

A workbook is also an iterable of all the worksheets it contains, so to work on all the worksheets one at a time, you can loop over the workbook.

```
for ws in WB:
    print(ws.title)
```

The `.active` property of a workbook is the currently active worksheet. `WB.active` may be used as soon as a workbook is open.

The `.title` property of a worksheet lets you get or set the title (name) of the worksheet.

Example

px_load_worksheet.py

```
#!/usr/bin/env python
import openpyxl as px

def main():
    wb = px.load_workbook('../DATA/presidents.xlsx')

# three ways to get to a worksheet:

    # 1
    print(wb.sheetnames, '\n')
    ws = wb['US Presidents']
    print(ws, '\n')

    # 2
    for ws in wb:
        print(ws.title, ws.dimensions)
    print()

    # 3
    ws = wb.active
    print(ws, '\n')

    print(ws['B2'].value)


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

px_load_worksheet.py

```
['US Presidents', 'President Names']

<Worksheet "US Presidents">

US Presidents A1:J47
President Names B2:C47

<Worksheet "President Names">

Washington
```

Worksheet info

- Worksheet attributes
  - dimensions
  - min_row
  - max_row
  - min_column
  - max_column
  - *many others…*

Once a worksheet is opened, you can get information about the worksheet directly from the worksheet object.

The dimensions are based on the extent of the cells that actually contain data.

NOTE Worksheets can have a maximum of 1,048,576 rows and 16,384 columns.

Example

px_worksheet_info.py

```
#!/usr/bin/env python
import openpyxl as px


def main():
    """program entry point"""
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    print("Title:", ws.title)
    print("Dimensions:", ws.dimensions)
    print("Minimum column:", ws.min_column)
    print("Minimum row:", ws.min_row)
    print("Maximum column:", ws.max_column)
    print("Maximum row:", ws.max_row)
    print("Parent:", ws.parent)
    print("Active cell:", ws.active_cell)

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

px_worksheet_info.py

```
Title: US Presidents
Dimensions: A1:J47
Minimum column: 1
Minimum row: 1
Maximum column: 10
Maximum row: 47
Parent: <openpyxl.workbook.workbook.Workbook object at 0x7fccb04510d0>
Active cell: J48
```

Table 21. Useful Worksheet Attributes

Attribute	Data type	Description
`active_cell`	str	coordinates ("A1"-style) of active cell
`columns`	generator	iterable of all columns, as tuples of Cell objects
`dimensions`	str	coordinate range ("A1:B2") of all cells containing data
`encoding`	str	text encoding of worksheet
`max_column`	int	maximum column index (1-based)
`max_row`	int	maximum row index (1-based)
`mime_type`	str	MIME type of document
`min_column`	int	minimum column index (1-based)
`min_row`	int	minimum row index (1-based)
`parent`	Workbook	Workbook object that this worksheet belongs to
`rows`	generator	iterable of all rows, as tuples of Cell objects
`selected_cell`	str	coordinates of currently selected cell
`tables`	dict	dictionary of tables
`title`	str	title of this worksheet
`values`	generator	iterable of all values in the worksheet (actual values, not Cell objects)

NOTE min and max row/column refer to extent of cells containing data

Accessing cells

- Each cell is instance of Cell
- Attributes
  - value
  - number_format
  - font
  - *and others*
- Get cell with
  - `ws["COORDINATES"]`
  - `ws.cell(row, column)`

A worksheet consists of *cells*. There are two ways to access an individual cell:

- lookup the cell using the cell coordinates, e.g. `ws["B3"]`.
- specify the row and column as integers (1-based) using the `.cell` method of the worksheet, e.g. `ws.cell(4, 5)`. You can used named arguments for the row and column: `ws.cell(row=4, column=5)`.

In both cases, to get the actual value, use the `.value` attribute of the cell.

NOTE Cell coordinates are case-insensitive.

Example

px_access_cells.py

```
#!/usr/bin/env python
import openpyxl as px

def main():
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    # access cell by cell name
    print(ws['A1'].value)
    print(ws['C2'].value, ws['B2'].value)
    print()

    # same, but lower-case
    print(ws['a1'].value)
    print(ws['c2'].value, ws['b2'].value)
    print()

    # access cell by row/column (1-based)
    print(
        ws.cell(row=27, column=3).value,  # "C27"
        ws.cell(row=27, column=2).value,  # "B27"
    )
    print()

    # same, without argument names
    print(
        ws.cell(27, 3).value,  # "C27"
        ws.cell(27, 2).value,  # "B27"
    )
    print()

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

px_access_cells.py

```
Term
George Washington

Term
George Washington

Theodore Roosevelt

Theodore Roosevelt
```

Table 22. Cell attributes

Attribute	Type	Description
`alignment`	openpyxl.styles.alignment.Alignment	display alignment info
`border`	openpyxl.styles.borders.Border	border info
`col_idx`	int	column index as integer
`column`	int	column index as integer
`column_letter`	str	column index as string
`comment`	any	cell comment
`coordinate`	str	coordinate of cell (e.g. ("B2")
`data_type`	str	data type code (s=str, n=numeric, etc)
`encoding`	str	text encoding (e.g. 'utf-8')
`fill`	openpyxl.styles.fills.PatternFill	fill (background) style
`font`	openpyxl.styles.fonts.Font	font color, family, style
`has_style`	bool	True if cell has style assigned
`hyperlink`	openpyxl.worksheet.hyperlink.Hyperlink	hyperlink for cell
`internal_value`	any	value of cell
`is_date`	bool	True if value is a date
`number_format`	str	Code for number format, e.g. "0.0"
`parent`	openpyxl.worksheet.worksheet.Worksheet	worksheet in which cell is located
`protection`	openpyxl.styles.protection.Protection	protection settings (e.g., hidden, locked)
`quotePrefix`	bool	character used for quoting
`row`	int	row index
`style`	str	name of style
`value`	any	actual value of cell

Getting raw values

- Use `worksheet.values`
- Returns row generator
- Each row is a tuple of column values

To iterate over all the values in the spreadsheet, use `worksheet.values`. It is a generator of the rows in the worksheet. Each element is a tuple of column values.

Only populated cells will be part of the returned data.

Example

px_raw_values.py

```
#!/usr/bin/env python
import openpyxl as px

def main():
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']  ①
    headers = next(ws.values)   ②
    for row in ws.values:  ③
        print(row[:5])   ④


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

① get active sheet

② read first row from generator

③ loop over rows in generator

④ print first 5 elements of row tuple

px_raw_values.py

```
('Term', 'Last Name', 'First Name', 'Birth Date', 'Death Date')
(1, 'Washington', 'George', '1732-02-22', '1799-12-14')
(2, 'Adams', 'John', '1735-10-30', '1826-07-04')
(3, 'Jefferson', 'Thomas', '1743-04-13', '1826-07-04')
(4, 'Madison', 'James', '1751-03-16', '1836-06-28')
(5, 'Monroe', 'James', '1758-04-28', '1831-07-04')
(6, 'Adams', 'John Quincy', '1767-07-11', '1848-02-23')
(7, 'Jackson', 'Andrew', '1767-03-15', '1845-06-08')
(8, 'Van Buren', 'Martin', '1782-12-05', '1862-07-24')
(9, 'Harrison', 'William Henry', '1773-02-09', '1841-04-04')
```

```
...
```

```
(37, 'Nixon', 'Richard Milhous', '1913-01-09', '1994-04-22')
(38, 'Ford', 'Gerald Rudolph', '1913-07-14', '2006-12-26')
(39, 'Carter', "James Earl 'Jimmy'", '1924-10-01', 'NONE')
(40, 'Reagan', 'Ronald Wilson', '1911-02-06', '2004-06-05')
(41, 'Bush', 'George Herbert Walker', '1924-06-12', datetime.datetime(2018, 11, 30, 0,
0))
(42, 'Clinton', "William Jefferson 'Bill'", '1946-08-19', 'NONE')
(43, 'Bush', 'George Walker', '1946-07-06', 'NONE')
(44, 'Obama', 'Barack Hussein', '1961-08-04', 'NONE')
(45, 'Trump', 'Donald J', '1946-06-14', 'NONE')
(46, 'Biden', 'Joseph Robinette', datetime.datetime(1942, 11, 10, 0, 0), 'NONE')
```

Working with ranges

- Range represents a rectangle of cells
- Use slice notation
- Iterate through rows, then columns

To get a range of cells, use slice notation on the worksheet object and standard cell notation, e.g. `WS['A1':'M9']` or `WS['A1:M9']`. Note that the range can consist of one string containing the range, or two strings separated by `:`.

The range is a virtual list of rows, and so can be iterated over. Each element of a row is a Cell object. Use the .value attribute to get or set the cell value.

Example

px_get_ranges.py

```python
#!/usr/bin/env python
import openpyxl as px


def main():
    """program entry point"""
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    print_first_and_last_names(ws)


def print_first_and_last_names(ws):
    """Print first and last names of all presidents"""
    pres_range = ws['B2':'C47']  # cell range
    for row in pres_range:  # row object
        print(row[1].value, row[0].value)


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

px_get_ranges.py

```
George Washington
John Adams
Thomas Jefferson
James Madison
James Monroe
John Quincy Adams
Andrew Jackson
Martin Van Buren
William Henry Harrison
John Tyler
```

...

Modifying a worksheet

- Assign to cells
  - WS.cell(row=ROW, column=COLUMN).value = *value*
  - WS.cell(ROW, COLUMN).value = *value*
  - WS[*coordinate*] = *value*

To modify a worksheet, you can either iterate through rows and columns as described above, or assign to the `.value` attribute of individual cells using either `WS.cell()` or `WS["coordinates"]`.

Use `ws.append(iterable)` to append a new row to the spreadsheet.

Use `workbook.save('name.xlsx')` to save the changes. To save to the original workbook, use its name.

TIP Assigning to *cell* is a shortcut for assigning to *cell*.value(). That is, you can say `ws['B4'] = 10`.

NOTE See the later section on inserting and moving rows and columns.

Example

px_modify_sheet.py

```python
#!/usr/bin/env python
from datetime import date
import openpyxl as px


def main():
    """program entry point"""
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    add_age_at_inauguration(ws)

    wb.save('presidents1.xlsx')  # save as ...


def make_date(date_str):
    """Convert date string returned by CELL.value into Python date object"""
    year, month, day = date_str.split('-')
    return date(int(year), int(month), int(day))


def add_age_at_inauguration(ws):
    """Add a new column with age of inauguration"""
    new_col = ws.max_column + 1
    print(new_col)
    ws.cell(row=1, column=new_col).value = 'Age at Inauguration'
    for row in range(2, 47):
        birth_date = make_date(ws.cell(row=row, column=4).value)  # treat date as string
        inaugural_date = make_date(ws.cell(row=row, column=8).value)
        raw_age_took_office = inaugural_date - birth_date
        age_took_office = raw_age_took_office.days / 365.25
        ws.cell(row=row, column=new_col).value = age_took_office


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

Working with formulas

- Assign to cell value as a string
- Be sure to start with '='

To add or update a formula, assign the formula as a string to the cell value.

NOTE Remember that **openpyxl** can not *recalculate* a worksheet.

Example

px_formulas.py

```
#!/usr/bin/env python
import openpyxl as px

def main():
    """program entry point"""
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    add_age_at_inauguration(ws)

    wb.save('presidents_formula.xlsx')

def add_age_at_inauguration(ws):
    """Add a new column with age of inauguration"""
    new_col = ws.max_column + 1
    print(new_col)
    ws.cell(row=1, column=new_col).value = 'Age at Inauguration'
    for row in range(2, 47):
        new_cell = ws.cell(row=row, column=new_col)
        new_cell.value = '=(H{0}-D{0})/365.25'.format(row)
        new_cell.number_format = '0.0'


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

Creating a new spreadsheet

- Use the Workbook() function
- One worksheet created by default
- Add worksheets with WB.create_sheet(n)
- Copy worksheets with WB.copy_sheet(n)
- Add data rows with WS.append(iterable)

To create a new spreadsheet file, use the Workbook() function. It creates a new workbook, with a default worksheet named "Sheet1".

Add worksheets with `WB.create_sheet(n)`. The parameter indicates where to insert the new worksheet; if not specified, it is appended.

To get or set the name of the worksheet, use its `.title` property.

To easily add rows to the worksheet, use `WS.append(iterable)`, where *iterable* is an iterable of column values.

Example

px_create_worksheet.py

```
#!/usr/bin/env python
import openpyxl as px

fruits = [
    "pomegranate", "cherry", "apricot", "date", "apple", "lemon",
    "kiwi", "orange", "lime", "watermelon", "guava", "papaya",
    "fig", "pear", "banana", "tamarind", "persimmon", "elderberry",
    "peach", "blueberry", "lychee", "grape"
]

wb = px.Workbook()

ws = wb.active

ws.title = 'fruits'

ws.append(['Fruit', 'Length'])

for fruit in fruits:
    ws.append([fruit, len(fruit)])

# hard way
# for i, fruit in enumerate(fruits, 1):
#     ws.cell(row=i, column=1).value = fruit
#     ws.cell(row=i, column=2).value = len(fruit)

wb.save('fruits.xlsx')
```

Inserting, Deleting, and moving cells

- Insert
  - `ws.insert_rows(row_index, num_rows=1)`
  - `ws.insert_cols(col_index, num_cols=1)`
- Delete
  - `ws.delete_rows(row_index, num_rows)`
  - `ws.delete_cols(col_index, num_cols)`
- Move
  - `ws.move_range(range, rows=row_delta, cols=col_delta)`
- Append
  - `ws.append(iterable)`

To insert one or more blank rows or columns, use `ws.insert_rows()` or `ws.insert_cols()`. The first argument is the positional index of the row or column (1-based), and the second argument is how many columns to insert.

To delete rows or columns, use `ws.delete_rows()` or `ws.delete_cols()`. The first argument is the index of the first row or column to delete; the second is the number of rows or columns.

To move a range of rows and columns, use `ws.move_range()`. The first argument is a range string such as `A1:F10`. Add named arguments `rows` and `cols` to specify how many cells to move. Positive values move down or right, and negative values move up or left. Existing data will be overwritten at the new location of the moved cells.

To append a row of data to a worksheet, pass an iterable to `ws.append()`.

Example

px_insert_delete_move.py

```
#!/usr/bin/env python
import openpyxl as px

RAW_DATA = [47, "Mouse", "Mickey", None, None, "Anaheim", "California", "2025-01-20",
None, "Imagineer"]

def main():
    """program entry point"""
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    insert_cells(ws)
    delete_cells(ws)
    move_cells(ws)
    append_cells(ws)

    print(ws.dimensions)

    wb.save('presidents_insert_delete_move.xlsx')

def append_cells(ws):
    ws.append(RAW_DATA)

def insert_cells(ws):
    ws.insert_rows(1, 3)  # insert three rows at top
    ws.insert_cols(5)  # insert one col at position 5

def delete_cells(ws):
    ws.delete_rows(15,5)
    ws.delete_cols(6)

def move_cells(ws):
    ws.move_range('A43:K45', rows=6, cols=3)


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

Hiding and freezing columns

- Hide
  - `ws.column_dimensions[column]`
  - `ws.column_dimensions.group(column, …)`
- Freeze
  - `ws.freeze_panes = 'coordinate'`

You can hide a column by using the `.column_dimensions` property of a worksheet. Specify a column letter inside square brackets, and assign `True` to the `.hidden` property. To hide multiple columns, use `.column_dimensions.group()`. Specify start and end columns, and set the `hidden` argument to `True`

```
ws.column_dimensions['M'].hidden = True
ws.column_dimensions.group(start="C", end="F", hidden=True)
```

To freeze rows and columns for scrolling, assign the coordinates of the first row and column that you want to scroll to `ws.freeze_panes`. For example, to freeze the first 3 columns and start scrolling with column 'D', use

```
ws.freeze_panes = 'A4'
```

Example

px_hide_freeze.py

```
#!/usr/bin/env python
import openpyxl as px


def main():
    """program entry point"""
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    hide_columns(ws)

    wb.save('presidents_hidden.xlsx')

    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    freeze_columns(ws)

    wb.save('presidents_frozen.xlsx')



def hide_columns(ws):
    """Hide single columnn and multiple columns"""

    # hide birthplace column
    ws.column_dimensions['F'].hidden = True

    # hide inauguration columns
    ws.column_dimensions.group(start='H', end='I', hidden=True)

def freeze_columns(ws):
    """Freeze the first 2 columns"""
    ws.freeze_panes = "C1"


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

Setting Styles

- Must be set on each cell individually
- Cannot change, once assigned (but can be replaced)
- Copy style to make changes

Each cell has a group of attributes that control its styles and formatting. Most of these have a corresponding class; to change styles, create an instance of the appropriate class and assign it to the attribute.

You can also make a copy of an existing style object, and just change the attributes you need.

Example

px_styles.py

```
#!/usr/bin/env python
import openpyxl as px

def main():
    """program entry point"""
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    update_last_names(ws)

    wb.save('presidents_styles.xlsx')

def update_last_names(ws):
    """Make the last name column blue and bold"""
    for row in ws['B2:B47']:
        cell = row[0]
        cell.value = cell.value.upper()
        cell.font = px.styles.Font(color='FF0000FF')

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

Table 23. openpyxl Cell Style Attributes

Cell attribute	Class	Parameters	Default value
font	Font		
		name	'Calibri'
		size	11
		bold	False
		italic	False
		vertAlign	None
		underline	'none'
		strike	False
		color	'FF000000'
fill	PatternFill		
		fill_type	None
		start_color	'FFFFFFFF'
		end_color	'FF000000'
border	Border		
		left	Side(border_style=None, color='FF000000')
		right	Side(border_style=None, color='FF000000')
		top	Side(border_style=None, color='FF000000')
		bottom	Side(border_style=None, color='FF000000')
		diagonal	Side(border_style=None, color='FF000000')
		diagonal_direction	
		outline	Side(border_style=None, color='FF000000')
		vertical	Side(border_style=None, color='FF000000')
		horizontal	Side(border_style=None, color='FF000000')
alignment	Alignment		

Cell attribute	**Class**	**Parameters**	**Default value**
		horizontal	'general'
		vertical	'bottom'
		text_rotation	0
		wrap_text	False
		shrink_to_fit	False
		indent	0
number_format	None	N/A	'General'
protection	Protection		
		locked	True
		hidden	False

Conditional Formatting

- Apply styles per values
- Types
  - Builtin
  - Standard
  - Custom
- Components
  - Differential Style
  - Rule
    - Formula

Conditional formatting means applying styles to cells based on their values. In openpyxl, conditional formatting can be a little complicated.

There are three kinds of rules for conditional formatting:

- Builtin — predefined rules with predefined styles
- Standard — predefined rules with custom styles
- Custom — custom rules with custom styles

Because this is complicated, there are some convenience functions for generating some formats.

Components

Formatting requres *styles*, which are either builtin or configured via a `DifferentialStyle` object, and *rules*, which are embedded in the formats. For custom rules, you provide a *formula* that defines when the rule should be used.

Builtin formats

There are three conditional formats: `ColorScale`, `IconSet`, and `DataBar`. These formats contain various settings, which compare the value to ann integer using one of these types: `num`, `percent`, `max`, `min`, `formula`, or `percentile`.

ColorScale

`ColorScale` provides a rule for a gradient from one color to another for the values within a range. You can add a second `ColorScale` for two gradients.

The convenience function for `ColorScale` is `openpyxl.formatting.rule.ColorScaleRule()`.

IconSet

`IconSet` provides a rule for applying different icons to different values.

The convenience function for `IconSet` is `openpyxl.formatting.rule.IconSetRule()`.

DataBar

`DataBar` provides a rule for adding "data bars", similar to the bars used by mobile phones to indicate signal strength.

The convenience function for `DataBar` is `openpyxl.formatting.rule.DataBarRule()`.

Example

px_conditional_styles.py

```python
#!/usr/bin/env python
import openpyxl as px
from openpyxl.formatting.rule import (
    Rule, ColorScale, FormatObject, IconSet, DataBar
)

from openpyxl.styles import Font, PatternFill, Color
from openpyxl.styles.differential import DifferentialStyle

CONDITIONAL_CONFIG = {
    'Republican': {
        'font_color': "FF0000",
        'fill': "FFC0CB",
    },
    'Democratic': {
        'font_color': "0000FF",
        'fill': "ADD8E6",
    },
    'Whig': {
        'font_color': "008000",
        'fill': "98FB98",
    }
}

def main():
    """program entry point"""
    wb = px.load_workbook('../DATA/presidents.xlsx')
    ws = wb['US Presidents']

    colorscale_values(ws)

    color_potus_parties(ws)

    icon_values(ws)

    wb.save('presidents_conditional.xlsx')

    wb = px.load_workbook('../DATA/columns_of_numbers.xlsx')
    icon_values(wb.active)
    databar_values(wb.active)
    wb.save('columns_with_icons.xlsx')

def colorscale_values(ws):
    """
    Add conditional style to the "TERM" column using a builtin
    type.

    :param ws: the worksheet
    :return: None
    """
    first = FormatObject(type="min")
    last = FormatObject(type="max")
    colors = [Color('AA0000'), Color('00AA00')]
    cs2 = ColorScale(cfvo=[first, last], color=colors)
    rule = Rule(type='colorScale', colorScale=cs2)

    last_row = ws.max_row
    ws.conditional_formatting.add(f'A2:A{last_row}', rule)



def color_potus_parties(ws):
    """
        Make Republicans red and Democrats blue, etc.

        This is a custom rule with a custom formula.

        :param ws: Worksheet to format
        :returns: None
    """
    for text, config in CONDITIONAL_CONFIG.items():
        font = Font(color=config['font_color'])
        fill = PatternFill(bgColor=config['fill'])
        dxf = DifferentialStyle(font=font, fill=fill)

        # make a rule for this condition
        rule = Rule(type="expression", dxf=dxf)

        # add an Excel formula to the rule. Cell must be first cell of
        # range; otherwise formatting is offset by difference from first
        # cell to specified cell
        #
        # can use any Excel text operations here
        rule.formula=[f'EXACT("{text}",$J2)']

        # add the rule to desired range
        ws.conditional_formatting.add('J2:J47', rule)

def icon_values(ws):
    """
    Add icons for numeric values in column.
    :param ws: worksheet to format
    :return: None
    """
    thresholds = [0, 33, 67]
    icons = [FormatObject(type='percent', val=t) for t in thresholds]
    iconset = IconSet(iconSet='3TrafficLights1', cfvo=icons)
    rule = Rule(type='iconSet', iconSet=iconset)
    format_range = f"A2:A{ws.max_row}"
    ws.conditional_formatting.add(format_range, rule)

def databar_values(ws):
    """
    Add conditional databars to worksheet.

    :param ws: worksheet to format
    :return: None
    """
    first = FormatObject(type='min')
    second = FormatObject(type='max')
    data_bar = DataBar(cfvo=[first, second], color="638EC6")
    rule = Rule(type='dataBar', dataBar = data_bar)
    format_range = f"F2:F{ws.max_row}"
    ws.column_dimensions['F'].width = 25  # make column wider for data bar
    ws.conditional_formatting.add(format_range, rule)


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

Chapter 14 Exercises

Exercise 14-1 (age_of_geeks.py,age_of_geeks_formula.py)

Write a script to compute the average age of the people on the worksheet 'people' in **computer_people.xlsx**. First, you'll have to calculate the age from the birth date. (Some of the people in the worksheet have died. Just include them for purposes of this exercise).

TIP TO calculate the age, get today's date (`datetime.datetime.now()`), subtract the DOB cell value from today's date. This gets a **timedelta** object. Use the **days** attribute of the timedelta divided by 365 to get the age.

NOTE Another way to do this lab (if Excel is available) is to use this Excel formula: `=DATEDIF(DOB,TODAY(),"y")` where DOB is the cell containing the birthdate, such as "D2". Add an additional column. Then add a formula to average the values in this new column. Since OpenPyXL can't recalculate a sheet, open the sheet in Excel to the the results. (You could also use Libre Office or Open Office to open the workbook).

Print out the average.

Exercise 14-2 (knights_to_spreadsheet.py, knights_to_spreadsheet_extra.py

Write a script to create a new spreadsheet with data from the knights.txt file. The first row of the spreadsheet should have the column headings:

Name, Title, Favorite Color, Quest, Comment

The data should start after that.

Save the workbook as knights.xlsx.

NOTE For extra fun, make the headers bold, the name fields red, and the comments in italics.

Chapter 15: Serializing Data

Objectives

- Have a good understanding of the XML format
- Know which modules are available to process XML
- Use lxml ElementTree to create a new XML file
- Parse an existing XML file with ElementTree
- Using XPath for searching XML nodes
- Load JSON data from strings or files
- Write JSON data to strings or files
- Read and write CSV data
- Read and write YAML data

Which XML module to use?

- Bewildering array of XML modules
- Some are SAX, some are DOM
- Use xml.etree.ElementTree

When you are ready to process Python with XML, you turn to the standard library, only to find a number of different modules with confusing names.

To cut to the chase, use **lxml.etree**, which is based on **ElementTree** with some nice extra features, such as pretty-printing. While not part of the core Python library, it is provided by the Anaconda bundle.

If `lxml.etree` is not available, you can use **xml.etree.ElementTree** from the core library.

Getting Started With ElementTree

- Import xml.etree.ElementTree (or lxml.etree) as ET for convenience
- Parse XML or create empty ElementTree

ElementTree is part of the Python standard library; lxml is included with the Anaconda distribution.

Since putting "xml.etree.ElementTree" in front of its methods requires a lot of extra typing , it is typical to alias xml.etree.ElementTree to just ET when importing it: import xml.etree.ElementTree as ET

You can check the version of ElementTree via the VERSION attribute:

```
import xml.etree.ElementTree as ET
print(ET.VERSION)
```

How ElementTree Works

- ElementTree contains root Element
- Document is tree of Elements

In ElementTree, an XML document consists of a nested tree of Element objects. Each Element corresponds to an XML tag.

An ElementTree object serves as a wrapper for reading or writing the XML text.

If you are parsing existing XML, use ElementTree.parse(); this creates the ElementTree wrapper and the tree of Elements. You can then navigate to, or search for, Elements within the tree. You can also insert and delete new elements.

If you are creating a new document from scratch, create a top-level (AKA "root") element, then create child elements as needed.

```
element = root.find('sometag')
for subelement in element:
    print(subelement.tag)
print(element.get('someattribute'))
```

Elements

- Element has
  - Tag name
  - Attributes (implemented as a dictionary)
  - Text
  - Tail
  - Child elements (implemented as a list) (if any)
- SubElement creates child of Element

When creating a new Element, you can initialize it with the tag name and any attributes. Once created, you can add the text that will be contained within the element's tags, or add other attributes.

When you are ready to save the XML into a file, initialize an ElementTree with the root element.

The **Element** class is a hybrid of list and dictionary. You access child elements by treating it as a list. You access attributes by treating it as a dictionary. (But you can't use subscripts for the attributes – you must use the get() method).

The Element object also has several useful properties: **tag** is the element's tag; **text** is the text contained inside the element; **tail** is any text following the element, before the next element.

The **SubElement** class is a convenient way to add children to an existing Element.

TIP Only the tag property of an Element is required; other properties are optional.

Table 24. Element properties and methods

Property	**Description**
append(element)	Add a subelement element to end of subelements
attrib	Dictionary of element’s attributes
clear()	Remove all subelements
find(path)	Find first subelement matching path
findall(path)	Find all subelements matching path
findtext(path)	Shortcut for find(path).text
get(attr)	Get an attribute; Shortcut for attrib.get()
getiterator()	Returns an iterator over all descendants
getiterator(path)	Returns an iterator over all descendants matching path
insert(pos,element)	Insert subelement element at position pos
items()	Get all attribute values; Shortcut for attrib.items()
keys()	Get all attribute names; Shortcut for attrib.keys()
remove(element)	Remove subelement element
set(attrib,value)	Set an attribute value; shortcut for attr[attrib] = value
tag	The element’s tag
tail	Text following the element
text	Text contained within the element

Table 25. ElementTree properties and methods

Property	**Description**
find(path)	Finds the first toplevel element with given tag; shortcut for getroot().find(path).
findall(path)	Finds all toplevel elements with the given tag; shortcut for getroot().findall(path).
findtext(path)	Finds element text for first toplevel element with given tag; shortcut for getroot().findtext(path).
getiterator(path)	Returns an iterator over all descendants of root node matching path. (All nodes if path not specified)
getroot()	Return the root node of the document

parse(filename)
parse(fileobj)
	Parse an XML source (filename or file-like object)

write(filename,encoding)	Writes XML document to filename, using encoding (Default us-ascii).

Creating a New XML Document

- Create root element
- Add descendants via SubElement
- Use keyword arguments for attributes
- Add text after element created
- Create ElementTree for import/export

To create a new XML document, first create the root (top-level) element. This will be a container for all other elements in the tree. If your XML document contains books, for instance, the root document might use the "books" tag. It would contain one or more "book" elements, each of which might contain author, title, and ISBN elements.

Once the root element is created, use SubElement to add elements to the root element, and then nested Elements as needed. SubElement returns the new element, so you can assign the contents of the tag to the **text** attribute.

Once all the elements are in place, you can create an ElementTree object to contain the elements and allow you to write out the XML text. From the ElementTree object, call write.

To output an XML string from your elements, call ET.tostring(), passing the root of the element tree as a parameter. It will return a bytes object (pure ASCII), so use .decode() to convert it to a normal Python string.

For an example of creating an XML document from a data file, see **xml_create_knights.py** in the EXAMPLES folder

Example

xml_create_movies.py

```python
#!/usr/bin/env python

# from xml.etree import ElementTree as ET
import lxml.etree as ET

movie_data = [
    ('Jaws', 'Spielberg, Stephen'),
    ('Vertigo', 'Alfred Hitchcock'),
    ('Blazing Saddles', 'Brooks, Mel'),
    ('Princess Bride', 'Reiner, Rob'),
    ('Avatar', 'Cameron, James'),
]

movies = ET.Element('movies')

for name, director in movie_data:
    movie = ET.SubElement(movies, 'movie', name=name)
    ET.SubElement(movie, 'director').text = director

print(ET.tostring(movies, pretty_print=True).decode())

doc = ET.ElementTree(movies)

doc.write('movies.xml')
```

xml_create_movies.py

```
<movies>
  <movie name="Jaws">
    <director>Spielberg, Stephen</director>
  </movie>
  <movie name="Vertigo">
    <director>Alfred Hitchcock</director>
  </movie>
  <movie name="Blazing Saddles">
    <director>Brooks, Mel</director>
  </movie>
  <movie name="Princess Bride">
    <director>Reiner, Rob</director>
  </movie>
  <movie name="Avatar">
    <director>Cameron, James</director>
  </movie>
</movies>
```

Parsing An XML Document

- Use ElementTree.parse()
- returns an ElementTree object
- Use get* or find* methods to select an element

Use the parse() method to parse an existing XML document. It returns an ElementTree object, from which you can find the root, or any other element within the document.

To get the root element, use the getroot() method.

Example

```
import xml.etree.ElementTree as ET

doc = ET.parse('solar.xml')

root = doc.getroot()
```

Navigating the XML Document

- Use find() or findall()
- Element is iterable of it children
- findtext() retrieves text from element

To find the first child element with a given tag, use find('tag'). This will return the first matching element. The findtext('tag') method is the same, but returns the text within the tag.

To get all child elements with a given tag, use the findall('tag') method, which returns a list of elements.

to see whether a node was found, say

```
if node is None:
```

but to check for existence of child elements, say

```
if len(node) > 0:
```

A node with no children tests as false because it is an empty list, but it is not None.

TIP The ElementTree object also supports the find() and findall() methods of the Element object, searching from the root object.

Example

xml_planets_nav.py

```
#!/usr/bin/env python
'''Use etree navigation to extract planets from solar.xml'''
import lxml.etree as ET


def main():
    '''Program entry point'''
    doc = ET.parse('../DATA/solar.xml')  ①

    solar_system = doc.getroot()  ②

    print(solar_system)
    print()

    inner = solar_system.find('innerplanets')  ③
    print('Inner:')

    for planet in inner:  ④
        if planet.tag == 'planet':
            print('\t', planet.get("planetname", "NO NAME"))

    outer = solar_system.find('outerplanets')
    print('Outer:')

    for planet in outer:
        print('\t', planet.get("planetname"))

    plutoids = solar_system.find('dwarfplanets')
    print('Dwarf:')

    for planet in plutoids:
        print('\t', planet.get("planetname"))


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

xml_planets_nav.py

```
<Element solarsystem at 0x7fde4000bdc0>

Inner:
     Mercury
     Venus
     Earth
     Mars
Outer:
     Jupiter
     Saturn
     Uranus
     Neptune
Dwarf:
     Pluto
```

Example

xml_read_movies.py

```
#!/usr/bin/env python

# import xml.etree.ElementTree as ET
import lxml.etree as ET

movies_doc = ET.parse('movies.xml')  ①

movies = movies_doc.getroot()  ②

for movie in movies:  ③
    print('{} by {}'.format(
        movie.get('name'),  ④
        movie.findtext('director'),  ⑤
    )
    )
```

① read and parse the XML file

② get the root element (<movies>)

③ loop through children of root element

④ get 'name' attribute of movie element

⑤ get 'director' attribute of movie element

xml_read_movies.py

```
Jaws by Spielberg, Stephen
Vertigo by Alfred Hitchcock
Blazing Saddles by Brooks, Mel
Princess Bride by Reiner, Rob
Avatar by Cameron, James
```

Using XPath

- Use simple XPath patterns Works with find* methods

When a simple tag is specified, the find* methods only search for subelements of the current element. For more flexible searching, the find* methods work with simplified **XPath** patterns. To find all tags named 'spam', for instance, use `.//spam`.

```
.//movie
presidents/president/name/last
```

Example

xml_planets_xpath1.py

```
#!/usr/bin/env python

# import xml.etree.ElementTree as ET
import lxml.etree as ET

doc = ET.parse('../DATA/solar.xml')  ①

inner_nodes = doc.findall('innerplanets/planet')  ②

outer_nodes = doc.findall('outerplanets/planet')  ③

print('Inner:')
for planet in inner_nodes:  ④
    print('\t', planet.get("planetname"))  ⑤

print('Outer:')
for planet in outer_nodes:  ④
    print('\t', planet.get("planetname"))  ⑤
```

① parse XML file

② find all elements (relative to root element) with tag "planet" under "innerplanets" element

③ find all elements with tag "planet" under "outerplanets" element

④ loop through search results

⑤ print "name" attribute of planet element

xml_planets_xpath1.py

```
Inner:
     Mercury
     Venus
     Earth
     Mars
Outer:
     Jupiter
     Saturn
     Uranus
     Neptune
```

Example

xml_planets_xpath2.py

```
#!/usr/bin/env python

# import xml.etree.ElementTree as ET
import lxml.etree as ET

doc = ET.parse('../DATA/solar.xml')

jupiter = doc.find('.//planet[@planetname="Jupiter"]')

if jupiter is not None:
    for moon in jupiter:
        print(moon.text)  # grab attribute
```

xml_planets_xpath2.py

```
Metis
Adrastea
Amalthea
Thebe
Io
Europa
Gannymede
Callista
Themisto
Himalia
Lysithea
Elara
```

Table 26. ElementTree XPath Summary

Syntax	**Meaning**
tag	Selects all child elements with the given tag. For example, “spam” selects all child elements named “spam”, “spam/egg” selects all grandchildren named “egg” in all child elements named “spam”. You can use universal names (“{url}local”) as tags.
*	Selects all child elements. For example, “*/egg” selects all grandchildren named “egg”.
.	Select the current node. This is mostly useful at the beginning of a path, to indicate that it’s a relative path.
//	Selects all subelements, on all levels beneath the current element (search the entire subtree). For example, “.//egg” selects all “egg” elements in the entire tree.
..	Selects the parent element.
[@attrib]	Selects all elements that have the given attribute. For example, “.//a[@href]” selects all “a” elements in the tree that has a “href” attribute.
[@attrib=’value’]	Selects all elements for which the given attribute has the given value. For example, “.//div[@class=’sidebar’]” selects all “div” elements in the tree that has the class “sidebar”. In the current release, the value cannot contain quotes.
parent_tag[*child_tag*]	Selects all parent elements that has a child element named *child_tag*. In the current version, only a single tag can be used (i.e. only immediate children are supported). Parent tag can be *****.

About JSON

- Lightweight, human-friendly format for data
- Contains dictionaries and lists
- Stands for JavaScript Object Notation
- Looks like Python
- Basic types: Number, String, Boolean, Array, Object
- White space is ignored
- Stricter rules than Python

JSON is a lightweight and human-friendly format for sharing or storing data. It was developed and popularized by Douglas Crockford starting in 2001.

A JSON file contains objects and arrays, which correspond exactly to Python dictionaries and lists.

White space is ignored, so JSON may be formatted for readability.

Data types are Number, String, and Boolean. Strings are enclosed in double quotes (only); numbers look like integers or floats; Booleans are represented by true or false; null (None in Python) is represented by null.

Reading JSON

- json module in standard library
- json.load() parse from file-like object
- json.loads() parse from string
- Both methods return Python dict or list

To read a JSON file, import the json module. Use json.loads() to parse a string containing valid JSON. Use json.load() to read JSON from a file-like object0.

Both methods return a Python dictionary containing all the data from the JSON file.

Example

json_read.py

```
#!/usr/bin/env python

import json

with open('../DATA/solar.json') as solar_in:  ①
    solar = json.load(solar_in)  ②

# json.loads(STRING)
# json.load(FILE_OBJECT)

# print(solar)

print(solar['innerplanets'])  ③
print('*' * 60)
print(solar['innerplanets'][0]['name'])
print('*' * 60)
for planet in solar['innerplanets'] + solar['outerplanets']:
    print(planet['name'])

print("*" * 60)
for group in solar:
    if group.endswith('planets'):
        for planet in solar[group]:
            print(planet['name'])
```

① open JSON file for reading

② load from file object and convert to Python data structure

③ solar is just a Python dictionary

json_read.py

```
[{'name': 'Mercury', 'moons': None}, {'name': 'Venus', 'moons': None}, {'name': 'Earth',
'moons': ['Moon']}, {'name': 'Mars', 'moons': ['Deimos', 'Phobos']}]
************************************************************
Mercury
************************************************************
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
************************************************************
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto
```

Writing JSON

- Use json.dumps() or json.dump()

To output JSON to a string, use json.dumps(). To output JSON to a file, pass a file-like object to json.dump(). In both cases, pass a Python data structure as the data to be output.

Example

json_write.py

```
#!/usr/bin/env python

import json

george = [
    {
        'num': 1,
        'lname': 'Washington',
        'fname': 'George',
        'dstart': [1789, 4, 30],
        'dend': [1797, 3, 4],
        'birthplace': 'Westmoreland County',
        'birthstate': 'Virginia',
        'dbirth': [1732, 2, 22],
        'ddeath': [1799, 12, 14],
        'assassinated': False,
        'party': None,
    },
    {
        'spam': 'ham',
        'eggs': [1.2, 2.3, 3.4],
        'toast': {'a': 5, 'm': 9, 'c': 4},
    }
]  ①

js = json.dumps(george, indent=4)  ②
print(js)

with open('george.json', 'w') as george_out:  ③
    json.dump(george, george_out, indent=4)  ④
```

① Python data structure

② dump structure to JSON string

③ open file for writing

④ dump structure to JSON file using open file object *json_write.py*

```
[
    {
        "num": 1,
        "lname": "Washington",
        "fname": "George",
        "dstart": [
            1789,
            4,
            30
        ],
        "dend": [
            1797,
            3,
            4
        ],
        "birthplace": "Westmoreland County",
        "birthstate": "Virginia",
        "dbirth": [
            1732,
            2,
            22
        ],
        "ddeath": [
            1799,
            12,
            14
        ],
        "assassinated": false,
        "party": null
    },
    {
        "spam": "ham",
        "eggs": [
            1.2,
            2.3,
            3.4
        ],
        "toast": {
            "a": 5,
            "m": 9,
            "c": 4
        }
    }
]
```

Customizing JSON

- JSON data types limited
- simple cases — dump dict
- create custom encoders

The JSON spec only supports a limited number of datatypes. If you try to dump a data structure contains dates, user-defined classes, or many other types, the json encoder will not be able to handle it.

You can a custom encoder for various data types. To do this, write a function that expects one Python object, and returns some object that JSON can parse, such as a string or dictionary. The function can be called anything. Specify the function with the **default** parameter to json.dump().

The function should check the type of the object. If it is a type that needs special handling, return a JSON-friendly version, otherwise just return the original object.

Table 27. Python types that JSON can encode

Python	JSON
dict	object
list	array
str	string
int	number (int)
float	number (real)
True	true
False	false
None	null

NOTE see the file **json_custom_singledispatch.py** in EXAMPLES for how to use the **singledispatch** decorator (in the **functools** module to handle multiple data types.

Example

json_custom_encoding.py

```
#!/usr/bin/env python
#
import json
from datetime import date


class Parrot():  ①
    def __init__(self, name, color):
        self._name = name
        self._color = color

    @property
    def name(self):  ②
        return self._name

    @property
    def color(self):
        return self._color


parrots = [  ③
    Parrot('Polly', 'green'),  #
    Parrot('Peggy', 'blue'),
    Parrot('Roger', 'red'),
]


def encode(obj):  ④
    if isinstance(obj, date):  ⑤
        return obj.ctime()  ⑥
    elif isinstance(obj, Parrot):  ⑦
        return {'name': obj.name, 'color': obj.color}  ⑧
    return obj  ⑨


data = {  ⑩
    'spam': [1, 2, 3],
    'ham': ('a', 'b', 'c'),
    'toast': date(2014, 8, 1),
    'parrots': parrots,
}

print(json.dumps(data, default=encode, indent=4))  ⑪
```

① sample user-defined class (not JSON-serializable)

② JSON does not understand arbitrary properties

③ list of Parrot objects

④ custom JSON encoder function

⑤ check for date object

⑥ convert date to string

⑦ check for Parrot object

⑧ convert Parrot to dictionary

⑨ if not processed, return object for JSON to parse with default parser

⑩ dictionary of arbitrary data

⑪ convert Python data to JSON data; 'default' parameter specifies function for custom encoding; 'indent' parameter says to indent and add newlines for readability *json_custom_encoding.py*

```
{
    "spam": [
        1,
        2,
        3
    ],
    "ham": [
        "a",
        "b",
        "c"
    ],
    "toast": "Fri Aug  1 00:00:00 2014",
    "parrots": [
        {
            "name": "Polly",
            "color": "green"
        },
        {
            "name": "Peggy",
            "color": "blue"
        },
        {
            "name": "Roger",
            "color": "red"
        }
    ]
}
```

Reading and writing YAML

- yaml module from PYPI
- syntax like **json** module
- yaml.load(), dump() parse from/to file-like object
- yaml.loads(), dumps() parse from/to string

YAML is a structured data format which is a superset of JSON. However, YAML allows for a more compact and readable format.

Reading and writing YAML uses the same syntax as JSON, other than using the **yaml** module, which is NOT in the standard library. To install the **yaml** module:

```
pip install pyyaml
```

To read a YAML file (or string) into a Python data structure, use `yaml.load(file_object)` or `yaml.loads(string)`.

To write a data structure to a YAML file or string, use `yaml.dump(data, file_object)` or `yaml.dumps(data)`.

You can also write custom YAML processors.

NOTE YAML parsers will parse JSON data

Example

yaml_read_solar.py

```python
import yaml

PLANET_SECTIONS = "inner outer plutoid".split()

with open('../DATA/solar.yaml') as solar_in:
    solar_data = yaml.load(solar_in, Loader=yaml.FullLoader)

star = solar_data['star']
print("Our star is {}\n".format(star))

for section in PLANET_SECTIONS:
    for planet in solar_data[section]:
        print(planet['name'])
        for moon in planet['moons']:
            print("\t{}".format(moon))
```

yaml_read_solar.py

```
Our star is Sun

Mercury
    None
Venus
    None
Earth
    Moon
Mars
    Deimos
    Phobos
    Metis
Jupiter
    Adrastea
    Amalthea
    Thebe
    Io
    Europa
    Gannymede
    Callista
    Themisto
    Himalia
    Lysithea
    Elara
Saturn
    Rhea
    Hyperion
    Titan
    Iapetus
    Mimas
```

...

Example

yaml_create_file.py

```
import sys
from datetime import date
import yaml

potus = {
    'presidents': [
         {
            'lastname': 'Washington',
            'firstname': 'George',
            'dob': date(1732, 2, 22),
            'dod': date(1799, 12, 14),
            'birthplace': 'Westmoreland County',
            'birthstate': 'Virginia',
            'term': [ date(1789, 4, 30), date(1797, 3, 4) ],
            'assassinated': False,
            'party': None,
        },
        {
            'lastname': 'Adams',
            'firstname': 'John',
            'dob': date(1735, 10, 30),
            'dod': date(1826, 7, 4),
            'birthplace': 'Braintree, Norfolk',
            'birthstate': 'Massachusetts',
            'term': [date(1797, 3, 4), date(1801, 3, 4)],
            'assassinated': False,
            'party': 'Federalist',

        }
    ]
}

with open('potus.yaml', 'w') as potus_out:
    yaml.dump(potus, potus_out)

yaml.dump(potus, sys.stdout)
```

yaml_create_file.py

```
presidents:
- assassinated: false
  birthplace: Westmoreland County
  birthstate: Virginia
  dob: 1732-02-22
  dod: 1799-12-14
  firstname: George
  lastname: Washington
  party: null
  term:
  - 1789-04-30
  - 1797-03-04
- assassinated: false
  birthplace: Braintree, Norfolk
  birthstate: Massachusetts
  dob: 1735-10-30
  dod: 1826-07-04
  firstname: John
  lastname: Adams
  party: Federalist
  term:
  - 1797-03-04
  - 1801-03-04
```

Reading CSV data

- Use csv module
- Create a reader with any iterable (e.g. file object)
- Understands Excel CSV and tab-delimited files
- Can specify alternate configuration
- Iterate through reader to get rows as lists of columns

To read CSV data, use the reader() method in the csv module.

To create a reader with the default settings, use the reader() constructor. Pass in an iterable – typically, but not necessarily, a file object.

You can also add parameters to control the type of quoting, or the output delimiters.

Example

csv_read.py

```
#!/usr/bin/env python
import csv

with open('../DATA/knights.csv') as knights_in:
    rdr = csv.reader(knights_in)  ①
    for name, title, color, quest, comment, number, ladies in rdr:  ②
        print('{:4s} {:9s} {}'.format(
            title, name, quest
        ))
```

① create CSV reader

② Read and unpack records one at a time; each record is a list

csv_read.py

```
King Arthur    The Grail
Sir  Lancelot  The Grail
Sir  Robin     Not Sure
Sir  Bedevere  The Grail
Sir  Gawain    The Grail
```

...

Nonstandard CSV

- Variations in how CSV data is written
- Most common alternate is for Excel
- Add parameters to reader/writer

You can customize how the CSV parser and generator work by passing extra parameters to csv.reader() or csv.writer(). You can change the field and row delimiters, the escape character, and for output, what level of quoting.

You can also create a "dialect", which is a custom set of CSV parameters. The csv module includes one extra dialect, **excel**, which handles CSV files generated by Microsoft Excel. To use it, specify the *dialect* parameter:

```
rdr = csv.reader(csvfile, dialect='excel')
```

Table 28. CSV reader()/writer() Parameters

Parameter	Meaning
quotechar	One-character string to use as quoting character (default: '"')
delimiter	One-character string to use as field separator (default: ',')
skipinitialspace	If True, skip white space after field separator (default: False)
lineterminator	The character sequence which terminates rows (default: depends on OS)
quoting	When should quotes be generated when writing CSV csv.QUOTE_MINIMAL – only when needed (default) csv.QUOTE_ALL – quote all fields csv.QUOTE_NONNUMERIC – quote all fields that are not numbers csv.QUOTE_NONE – never put quotes around fields
escapechar	One-character string to escape delimiter when quoting is set to csv.QUOTE_NONE
doublequote	Control quote handling inside fields. When True, two consecutive quotes are read as one, and one quote is written as two. (default: True)

Example

csv_nonstandard.py

```
#!/usr/bin/env python
import csv

with open('../DATA/computer_people.txt') as computer_people_in:
    rdr = csv.reader(computer_people_in, delimiter=';')  ①

    for first_name, last_name, known_for, birth_date in rdr:  ②
        print('{}: {}'.format(last_name, known_for))
```

① specify alternate field delimiter

② iterate over rows of data — csv reader is a generator

csv_nonstandard.py

```
Gates: Gates Foundation
Jobs: Apple
Wall: Perl
Allen: Microsoft
Ellison: Oracle
Gates: Microsoft
Zuckerberg: Facebook
Brin: Google
Page: Google
Torvalds: Linux
```

Using csv.DictReader

- Returns each row as dictionary
- Keys are field names
- Use header or specify

Instead of the normal reader, you can create a dictionary-based reader by using the DictReader class.

If the CSV file has a header, it will parse the header line and use it as the field names. Otherwise, you can specify a list of field names with the **fieldnames** parameter. For each row, you can look up a field by name, rather than position.

Example

csv_dictreader.py

```
#!/usr/bin/env python
import csv

field_names = ['term', 'firstname', 'lastname', 'birthplace', 'state', 'party'] ①

with open('../DATA/presidents.csv') as presidents_in:
    rdr = csv.DictReader(presidents_in, fieldnames=field_names)  ②
    for row in rdr:  ③
        print('{:25s} {:12s} {}'.format(row['firstname'], row['lastname'], row['party']))
④
        # string .format can use keywords from an unpacked dict as well:
        # print('{firstname:25s} {lastname:12s} {party}'.format(**row))
```

① field names, which will become dictionary keys on each row

② create reader, passing in field names (if not specified, uses first row as field names)

③ iterate over rows in file

④ print results with formatting

csv_dictreader.py

```
George                     Washington   no party
John                       Adams        Federalist
Thomas                     Jefferson    Democratic - Republican
James                      Madison      Democratic - Republican
James                      Monroe       Democratic - Republican
John Quincy                Adams        Democratic - Republican
Andrew                     Jackson      Democratic
Martin                     Van Buren    Democratic
William Henry              Harrison     Whig
John                       Tyler        Whig
James Knox                 Polk         Democratic
Zachary                    Taylor       Whig
Millard                    Fillmore     Whig
Franklin                   Pierce       Democratic
James                      Buchanan     Democratic
Abraham                    Lincoln      Republican
Andrew                     Johnson      Republican
Ulysses Simpson            Grant        Republican
Rutherford Birchard        Hayes        Republican
James Abram                Garfield     Republican
```

…

Writing CSV Data

- Use csv.writer()
- Parameter is file-like object (must implement write() method)
- Can specify parameters to writer constructor
- Use writerow() or writerows() to output CSV data

To output data in CSV format, first create a writer using csv.writer(). Pass in a file-like object.

For each row to write, call the writerow() method of the writer, passing in an iterable with the values for that row.

To modify how data is written out, pass parameters to the writer.

TIP On Windows, to prevent double-spaced output, add `lineterminator='\n'` when creating a CSV writer.

Example

csv_write.py

```
#!/usr/bin/env python
import sys
import csv

data = [
    ('February', 28, 'The shortest month, with 28 or 29 days'),
    ('March', 31, 'Goes out like a "lamb"'),
    ('April', 30, 'Its showers bring May flowers'),
]

with open('../TEMP/stuff.csv', 'w') as stuff_in:
    if sys.platform == 'win32':
        wtr = csv.writer(stuff_in, linineeterminator='\n') ①
    else:
        wtr = csv.writer(stuff_in) ①
    for row in data:
        wtr.writerow(row) ②
```

① create CSV writer from file object that is opened for writing; on windows, need to set output line terminator to '\n'

② write one row (of iterables) to output file

Pickle

- Use the pickle module
- Create a binary stream that can be saved to file
- Can also be transmitted over the network

Python uses the pickle module for data serialization.

To create pickled data, use either pickle.dump() or pickle.dumps(). Both functions take a data structure as the first argument. dumps() returns the pickled data as a string. dump () writes the data to a file-like object which has been specified as the second argument. The file-like object must be opened for writing.

To read pickled data, use pickle.load(), which takes a file-like object that has been open for writing, or pickle.loads() which reads from a string. Both functions return the original data structure that had been pickled.

NOTE The syntax of the **json** module is based on the **pickle** module.

Example

pickling.py

```
#!/usr/bin/env python
import pickle
from pprint import pprint

①
airports = {
    'RDU': 'Raleigh-Durham', 'IAD': 'Dulles', 'MGW': 'Morgantown',
    'EWR': 'Newark', 'LAX': 'Los Angeles', 'ORD': 'Chicago'
}

colors = [
    'red', 'blue', 'green', 'yellow', 'black',
    'white', 'orange', 'brown', 'purple'
]

data = [  ②
    colors,
    airports,
]

with open('../TEMP/pickled_data.pic', 'wb') as pic_out:  ③
    pickle.dump(data, pic_out)  ④

with open('../TEMP/pickled_data.pic', 'rb') as pic_in:  ⑤
    pickled_data = pickle.load(pic_in)  ⑥

pprint(pickled_data)  ⑦
```

① some data structures

② list of data structures

③ open pickle file for writing in binary mode

④ serialize data structures to pickle file

⑤ open pickle file for reading in binary mode

⑥ de-serialize pickle file back into data structures

⑦ view data structures

pickling.py

```
[['red',
  'blue',
  'green',
  'yellow',
  'black',
  'white',
  'orange',
  'brown',
  'purple'],
 {'EWR': 'Newark',
  'IAD': 'Dulles',
  'LAX': 'Los Angeles',
  'MGW': 'Morgantown',
  'ORD': 'Chicago',
  'RDU': 'Raleigh-Durham'}]
```

Chapter 15 Exercises

Exercise 15-1 (xwords.py)

Using ElementTree, create a new XML file containing all the words that start with 'x' from words.txt. The root tag should be named 'words', and each word should be contained in a 'word' tag. The finished file should look like this:

```
<words>
   <word>xanthan</word>
   <word>xanthans</words>
   and so forth
</words>
```

Exercise 15-2 (xpresidents.py)

Use ElementTree to parse presidents.xml. Loop through and print out each president’s first and last names and their state of birth.

Exercise 15-3 (jpresidents.py)

Rewrite xpresidents.py to parse presidents.json using the json module.

Exercise 15-4 (cpresidents.py)

Rewrite xpresidents.py to parse presidents.csv using the csv module.

Exercise 15-5 (pickle_potus.py)

Write a script which reads the data from presidents.csv into an dictionary where the key is the term number, and the value is another dictionary of data for one president.

Using the pickle module, Write the entire dictionary out to a file named presidents.pic.

Exercise 15-6 (unpickle_potus.py)

Write a script to open presidents.pic, and restore the data back into a dictionary.

Then loop through the array and print out each president’s first name, last name, and party.

Chapter 16: iPython and Jupyter

Objectives

- Learn the basics of iPython
- Apply magics
- Use Jupyter notebooks

About iPython

- Enhanced interpreter for exploratory computing
- Efficient for data analysis (what-if? Scenarios)
- Great for plotting-tweaking-plotting
- Not intended for general development
- Embedded in Jupyter notebooks

iPython is an enhanced interpreter for Python. It provides a large number of "creature comforts" for the user, such as name completion and improved help features.

It’s great for ad-hoc queries, what-if scenarios, when you are not developing a full application.

iPython features

- Name completion (variables, modules, methods, folders, files, etc.)
- Enhanced help system
- Autoindent
- Syntax highlighting
- Inline plots and other figures
- Dynamic introspection (dir() on steroids)
- Search namespaces with wildcards
- Auto-parentheses ('sin 3' becomes 'sin(3)'
- Auto-quoting (',foo a b' becomes 'foo("a","b")'
- Commands are numbered (and persistent) for recall
- 'Magic' commands for controlling iPython itself
- Aliasing system for interpreter commands
- Easy access to shell commands
- Background execution in separate thread
- Simplified (and lightweight) persistence
- Session logging (can be saved as scripts)
- Detailed tracebacks when errors occur
- Session restoring (playback log to specific state)
- Flexible configuration system
- Easy access to Python debugger
- Simple profiling
- Interactive parallel computing (if supported by hardware)

The many faces of iPython

- Console
- Colorized console (default)
- QTConsole (obsolete)
- Jupyter notebook

iPython can be run in several different modes. The most basic mode is console, which runs from the command prompt, without syntax colorizing.

If your terminal supports it (and most do), iPython can run as a colorized console, using different colors for variables, functions, strings, comments, and so forth.

Both the default console and the colorized console display plots in a separate popup window.

If QT is installed, iPython can run a GUI console, which looks and acts like a regular text console, but allows plots to be generated inline, and has enhanced context-sensitive help. This mode is deprecated, as it is simpler to just run a notebook. However, this is obsolete due to Jupyter (formerly iPython) *notebooks*.

The most flexible and powerful way to run iPython is in notebook mode. This mode starts a dedicated web server and begins a session using your default web browser. Other users can load notebooks from the notebook server, similarly to MatLab. The notebook part of iPython was split out and is now part of the Jupyter Project.

NOTE iPython also supports parallel computing, which will not be covered here.

Starting iPython

- Type **ipython** at the command line
- Huge number of options

To get started with iPython in console mode, just type ipython at the command line, or double-click the icon in Windows explorer.

In general, it works like the normal interpreter, but with many more features.

There is a huge number of options. To see them all, invoke iPython with the --help-all option:

```
ipython ▯help-all
```

Getting Help

- ? basic help
- %quickref quick reference
- help standard Python help
- thing? help on thing

iPython provides help in several ways.

Typing **?** at the prompt will display an introduction to iPython and a feature overview.

For a quick reference card, type %quickref.

To start Python’s normal help system, type help.

For help on any Python object, type `object?` or `?object`. This is similar to saying help("object") in the default interpreter, but is "smarter".

TIP For more help, add a second question mark. This does not work for all objects.

Tab Completion

- Press tab to complete
- keywords
- modules
- methods and attributes
- parameters to functions
- file and directory names

Pressing the <TAB> key will invoke autocomplete. If there is only one possible completion, it will be expanded. If there is more than one completion that will match, iPython will display a list of possible completions.

Autocomplete works on keywords, functions, classes, methods, and object attributes, as well as paths from your file system.

Magic Commands

- Start with % (line magic) or %% (cell magic)
- Simplify common tasks
- Use %lsmagic to list all magic commands

One of the enhancements in iPython is the set of "magic" commands. These are meta-commands that help you manipulate the iPython environment.

Normal magics apply to a single line. Cell magics apply to a cell (a group of lines).

For instance, `%history` will list previous commands.

TIP Type lsmagic for a list of all magics

Benchmarking

- Use %timeit

iPython has a handy magic for benchmarking.

```
In [1]: color_values = { 'red':66, 'green':85, 'blue':77 }

In [2]: %timeit red_value = color_values['red']
10000000 loops, best of 3: 54.5 ns per loop

In [3]: %timeit red_value = color_values.get('red')
10000000 loops, best of 3: 115 ns per loop
```

%timeit will benchmark whatever code comes after it on the same line. %%timeit will benchmark contents of a notebook cell

External commands

- Precede command with !
- Can assign output to variable

Any shell command can be run by starting it with a !.

The resulting output is returned as a list of strings (retaining the **\n**). The result can be assigned to a variable.

Windows

```
In [3]: !dir DATA\*.csv
 Volume in drive Z is Shared Folders
 Volume Serial Number is 0000-0064

 Directory of Z:\Desktop\py2forsci\DATA

02/20/2014  01:53 PM             5,511 airport_boardings.csv
02/20/2014  01:53 PM             2,182 energy_use_quad.csv
02/20/2014  01:53 PM             4,993 parasite_data.csv
               3 File(s)         12,686 bytes
               0 Dir(s)  352,625,324,032 bytes free

In [4]:
```

Non-Windows (Linux, OS X, etc)

```
In [2]: !ls -l DATA/*.csv
-rwxr-xr-x  1 jstrick  staff  5511 Jan 27 19:44 DATA/airport_boardings.csv
-rwxr-xr-x  1 jstrick  staff  2182 Jan 27 19:44 DATA/energy_use_quad.csv
-rwxr-xr-x  1 jstrick  staff  4642 Jan 27 19:44 DATA/parasite_data.csv

In [3]:
```

Jupyter notebooks

- Extension of iPython
- Puts the interpreter in a web browser
- Code is grouped into "cells"
- Cells can be edited, repeated, etc.

In 2015, the developers of iPython pulled the notebook feature out of iPython to make a separate product called Jupyter. It is still invoked via the ipython command, but now supports over 130 language kernels in addition to Python.

A Jupyter notebook is a journal-like python interpreter that lives in a browser window. Code is grouped into cells, which can contain multiple statements. Cells can be edited, repeated, rearranged, and otherwise manipulated.

A notebook (i.e, a set of cells, can be saved, and reopened). Notebooks can be shared among members of a team via the notebook server which is built into Jupyter.

Jupyter Demo

At this point please start the Jupyter notebook server and follow along with a demo of Jupyter notebooks as directed by the instructor

Open an Anaconda prompt and navigate to the top folder of the student files, then

```
cd NOTEBOOKS
jupyter notebook
```

Chapter 17: Introduction to NumPy

Objectives

- See the "big picture" of NumPy
- Create and manipulate arrays
- Learn different ways to initialize arrays
- Understand the NumPy data types available
- Work with shapes, dimensions, and ranks
- Broadcast changes across multiple array dimensions
- Extract multidimensional slices
- Perform matrix operations

Python’s scientific stack

- NumPy, SciPy, MatPlotLib (and many others)
- Python extensions, written in C/Fortran
- Support for math, numerical, and scientific operations

NumPy is part of what is sometimes called Python’s "scientific stack". Along with SciPy, Matplotlib, and other libraries, it provides a broad range of support for scientific and engineering tasks.

SciPy is a large group of mathematical algorithms, along with some convenience functions, for doing scientific and engineering calculations, including data science. SciPy routines accept and return NumPy arrays.

pandas ties some of the libraries together, and is frequently used interactively via **iPython** in a **Jupyter** notebook. Of course you can also create scripts using any of the scientific libraries.

NOTE There is not an integrated *application* for all of the Python scientific libraries.

NumPy overview

- Install numpy module from numpy.scipy.org (included with Anaconda)
- Basic object is the array
- Up to 100x faster than normal Python math operations
- Functional-based (fewer loops)
- Dozens of utility functions

The basic object that NumPy provides is the array. Arrays can have as many dimensions as needed. Working with NumPy arrays can be 100 times faster than working with normal Python lists.

Operations are applied to arrays in a functional manner – instead of the programmer explicitly looping through elements of the array, the programmer specifies an expression or function to be applied, and the array object does all of the iteration internally.

There are many utility functions for accessing arrays, for creating arrays with specified values, and for performing standard numerical operations on arrays.

To get started, import the **numpy** module. It is conventional to import numpy as **np**. The examples in this chapter will follow that convention.

NumPy and the rest of the Python scientific stack is included with the Anaconda, Canopy, Python(x,y), and WinPython bundles. If you are not using one of these, install NumPy with

```
pip install numpy
```

NOTE all top-level NumPy routines are also available directly through the scipy package.

Creating Arrays

- Create with
    - array() function initialized with nested sequences
    - Other utilities (arange(), zeros(), ones(), empty()
- All elements are same type (default float)
- Useful properties: ndim, shape, size, dtype
- Can have any number of axes (dimensions)
- Each axis has a length

An array is the most basic object in NumPy. It is a table of numbers, indexed by positive integers. All of the elements of an array are of the same type.

An array can have any number of dimensions; these are referred to as axes. The number of axes is called the rank.

Arrays are rectangular, not ragged.

One way to create an array is with the `array()` function, which can be initialized from existing arrays.

The `zeros()` function expects a *shape* (tuple of axis lengths), and creates the corresponding array, with all values set to zero. The `ones()` function is the same, but initializes with ones.

The `full()` function expects a shape and a value. It creates the array, putting the specified value in every element.

The `empty()` function creates an array of specified shape initialized with random floats.

However, the most common way to crate an array is by loading data from a text or binary file.

When you print an array, NumPy displays it with the following layout:

- the last axis is printed from left to right,
- the second-to-last is printed from top to bottom,
- the rest are also printed from top to bottom, with each slice separated from the next by an empty line.

NOTE the `ndarray()` object is initialized with the *shape*, not the *data*.

Example

np_create_arrays.py

```
import numpy as np
data = [[1, 2.1, 3], [4, 5, 6], [7, 8, 9], [20, 30, 40]]

a = np.array(data)  ①
print(a)
print("# dims", a.ndim)  ②
print("shape", a.shape)  ③
print()

a_zeros = np.zeros((3, 5), dtype=np.uint32)  ④
print(a_zeros)
print()

a_ones = np.ones((2, 3, 4, 5))  ⑤
print(a_ones)
print()

# with uninitialized values
a_empty = np.empty((3, 8))  ⑥
print(a_empty)

print(a.dtype)  ⑦

nan_array = np.full((5, 10), np.NaN)  ⑧
print(nan_array)
```

① create array from nested sequences

② get number of dimensions

③ get shape

④ create array of specified shape and datatype, initialized to zeroes

⑤ create array of specified shape, initialized to ones

⑥ create uninitialized array of specified shape

⑦ defaults to float64

⑧ create array of NaN values

np_create_arrays.py

```
[[ 1.   2.1  3. ]
 [ 4.   5.   6. ]
 [ 7.   8.   9. ]
 [20.  30.  40. ]]
# dims 2
shape (4, 3)

[[0 0 0 0 0]
 [0 0 0 0 0]
 [0 0 0 0 0]]

[[[[1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]]

  [[1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]]

  [[1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]]]


 [[[1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]]

  [[1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]]

  [[1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]
   [1. 1. 1. 1. 1.]]]]

[[-2.31584178e+077  1.49457045e-154  6.92680447e-310  6.92680448e-310
   6.92680448e-310  6.92680448e-310  6.92680448e-310  6.92680448e-310]
 [ 6.92680448e-310  6.92680448e-310  6.92680448e-310  6.92680448e-310
   6.92680448e-310  6.92680448e-310  6.92680448e-310  6.92680448e-310]
 [ 6.92680448e-310  6.92680448e-310 -2.31584178e+077 -2.31584178e+077
   4.44659081e-323  0.00000000e+000  3.95252517e-323  0.00000000e+000]]
float64
[[nan nan nan nan nan nan nan nan nan nan]
 [nan nan nan nan nan nan nan nan nan nan]
 [nan nan nan nan nan nan nan nan nan nan]
 [nan nan nan nan nan nan nan nan nan nan]
 [nan nan nan nan nan nan nan nan nan nan]]
```

Creating ranges

- Similar to builtin `range()`
- Returns a one-dimensional NumPy array
- Can use floating point values
- Can be reshaped

The `arange()` function takes a size, and returns a one-dimensional NumPy array. This array can then be reshaped as needed. The start, stop, and step parameters are similar to those of `range()`, or Python slices in general. Unlike the builtin Python `range()`, start, stop, and step can be floats.

The `linspace()` function creates a specified number of equally-spaced values. As with `numpy.arange()`, start and stop may be floats.

The resulting arrays can be reshaped into multidimensional arrays.

Example

np_create_ranges.py

```
#!/usr/bin/env python
import numpy as np

r1 = np.arange(50)  ①
print(r1)
print("size is", r1.size)  ②
print()

r2 = np.arange(5, 101, 5)  ③
print(r2)
print("size is", r2.size)
print()

r3 = np.arange(1.0, 5.0, .3333333)  ④
print(r3)
print("size is", r3.size)
print()

r4 = np.linspace(1.0, 2.0, 10)  ⑤
print(r4)
print("size is", r4.size)
print()
```

① create range of ints from 0 to 49

② size is 50

③ create range of ints from 5 to 100 counting by 5

④ start, stop, and step may be floats

⑤ 10 equal steps between 1.0 and 2.0

np_create_ranges.py

```
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49]
size is 50

[  5  10  15  20  25  30  35  40  45  50  55  60  65  70  75  80  85  90
  95 100]
size is 20

[1.        1.3333333 1.6666666 1.9999999 2.3333332 2.6666665 2.9999998
 3.3333331 3.6666664 3.9999997 4.333333  4.6666663 4.9999996]
size is 13

[1.         1.11111111 1.22222222 1.33333333 1.44444444 1.55555556
 1.66666667 1.77777778 1.88888889 2.        ]
size is 10
```

Working with arrays

- Use normal math operators (+, -, /, and *)
- Use NumPy's builtin functions
- By default, apply to every element
- Can apply to single axis
- Operations on between two arrays applies operator to pairs of element

The array object is smart about applying functions and operators. A function applied to an array is applied to every element of the array. An operator applied to two arrays is applied to corresponding elements of the two arrays.

In-place operators (+=, *=, etc) efficiently modify the array itself, rather than returning a new array.

Example

np_basic_array_ops.py

```
#!/usr/bin/env python
import numpy as np

a = np.array(
    [
        [5, 10, 15],
        [2, 4, 6],
        [3, 6, 9, ],
    ]
)  ①

b = np.array(
    [
        [10, 85, 92],
        [77, 16, 14],
        [19, 52, 23],
    ]
)  ②
print("a")
print(a)
print()
print("b")
print(b)
print()

print("a * 10")
print(a * 10)  ③
print()

print("a + b")
print(a + b)  ④
print()

print("b + 3")
print(b + 3)  ⑤
print()

s1 = a.sum()  ⑥
s2 = b.sum()  ⑥
print("sum of a is {0}; sum of b is {1}".format(s1, s2))
print()

a += 1000  ⑦
print(a)
```

① create 2D array

② create another 2D array

③ multiply every element by 10 (not in place)

④ add every element of a to the corresponding element of b

⑤ add 3 to every element of b

⑥ calculate sum of all elements

⑦ add 1000 to every element of a (in place)

np_basic_array_ops.py

```
a
[[ 5 10 15]
 [ 2  4  6]
 [ 3  6  9]]

b
[[10 85 92]
 [77 16 14]
 [19 52 23]]

a * 10
[[ 50 100 150]
 [ 20  40  60]
 [ 30  60  90]]

a + b
[[ 15  95 107]
 [ 79  20  20]
 [ 22  58  32]]

b + 3
[[13 88 95]
 [80 19 17]
 [22 55 26]]

sum of a is 60; sum of b is 388

[[1005 1010 1015]
 [1002 1004 1006]
 [1003 1006 1009]]
```

Shapes

- Number of elements on each axis
- array.shape has shape tuple
- Assign to array.shape to change
- Convert to one dimension
    - array.ravel()
    - array.flatten()
- array.transpose() to flip the shape

Every array has a shape, which is the number of elements on each axis. For instance, an array might have the shape (3,5), which means that there are 3 rows and 5 columns.

The shape is stored as a tuple, in the shape attribute of an array. To change the shape of an array, assign to the shape attribute.

The `ravel()` and `flatten()` methods will flatten any array into a single dimension. `ravel()` returns a "view" of the original array, while `flatten()` returns a new array. If you modify the result of ravel(), it will modify the original data.

The `transpose()` method will flip shape (x,y) to shape (y,x). It is equivalent to `array.shape = list(reversed(array.shape))`.

Example

np_shapes.py

```
#!/usr/bin/env python
import numpy as np

a1 = np.arange(15)  ①
print("a1 shape", a1.shape)  ②
print()

print(a1)
print()

a1.shape = 3, 5  ③
print(a1)
print()

a1.shape = 5, 3  ④
print(a1)
print()

print(a1.flatten())  ⑤
print()

print(a1.transpose())  ⑥
print("------------------")

a2 = np.arange(40)  ⑦
a2.shape = 2, 5, 4  ⑧

print(a2)
print()
```

① create 1D array

② get shape

③ reshape to 3x5

④ reshape to 5x3

⑤ print array as 1D

⑥ print transposed array

⑦ create 1D array

⑧ reshape go 2x5x4

np_shapes.py

```
a1 shape (15,)

[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14]

[[ 0  1  2  3  4]
 [ 5  6  7  8  9]
 [10 11 12 13 14]]

[[ 0  1  2]
 [ 3  4  5]
 [ 6  7  8]
 [ 9 10 11]
 [12 13 14]]

[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14]

[[ 0  3  6  9 12]
 [ 1  4  7 10 13]
 [ 2  5  8 11 14]]
------------------
[[[ 0  1  2  3]
  [ 4  5  6  7]
  [ 8  9 10 11]
  [12 13 14 15]
  [16 17 18 19]]

 [[20 21 22 23]
  [24 25 26 27]
  [28 29 30 31]
  [32 33 34 35]
  [36 37 38 39]]]
```

Slicing and indexing

- Simple indexing similar to lists
- start, stop, step
- start is INclusive, stop is Exclusive
- : used for range for one axis
- … means "as many : as needed"

NumPy arrays can be indexed and sliced like regular Python lists, but with some convenient extensions. Instead of `[x][y]`, NumPy arrays can be indexed with `[x,y]`. Within an axis, ranges can be specified with slice notation (start:stop:step) as usual.

For arrays with more than 2 dimensions, `…` can be used to mean "and all the other dimensions".

Example

np_indexing.py

```
#!/usr/bin/env python
import numpy as np

a = np.array(
    [[70, 31, 21, 76, 19, 5, 54, 66],
     [23, 29, 71, 12, 27, 74, 65, 73],
     [11, 84, 7, 10, 31, 50, 11, 98],
     [25, 13, 43, 1, 31, 52, 41, 90],
     [75, 37, 11, 62, 35, 76, 38, 4]]
)  ①

print(a)
print()

print('a[0] =>', a[0])  ②
print('a[0][0] =>', a[0][0])  ③
print('a[0,0] =>', a[0, 0])  ④
print('a[0,:3] =>', a[0, :3])  ⑤
print('a[0,::2] =>', a[0, ::2])  ⑥
print()
print('a[::2] =>', a[::2])  ⑦
print()
print('a[:3, -2:] =>', a[:3, -2:])  ⑧
```

① sample data

② first row

③ first element of first row

④ same, but numpy style

⑤ first 3 elements of first row

⑥ every second element of first row

⑦ every second row

⑧ every third element of every second row *np_indexing.py*

```
[[70 31 21 76 19  5 54 66]
 [23 29 71 12 27 74 65 73]
 [11 84  7 10 31 50 11 98]
 [25 13 43  1 31 52 41 90]
 [75 37 11 62 35 76 38  4]]

a[0] => [70 31 21 76 19  5 54 66]
a[0][0] => 70
a[0,0] => 70
a[0,:3] => [70 31 21]
a[0,::2] => [70 21 19 54]

a[::2] => [[70 31 21 76 19  5 54 66]
 [11 84  7 10 31 50 11 98]
 [75 37 11 62 35 76 38  4]]

a[:3, -2:] => [[54 66]
 [65 73]
 [11 98]]
```

Indexing with Booleans

- Apply relational expression to array
- Result is array of Booleans
- Booleans can be used to index original array

If a relational expression (>, <, >=, ⇐) is applied to an array, the result is a new array containing Booleans reflecting whether the expression was true for each element. That is, for each element of the original array, the resulting array is set to True if the expression is true for that element, and False otherwise.

The resulting Boolean array can then be used as an index, to modify just the elements for which the expression was true.

Example

np_bool_indexing.py

```
#!/usr/bin/env python
import numpy as np

a = np.array(
    [[70, 31, 21, 76, 19, 5, 54, 66],
     [23, 29, 71, 12, 27, 74, 65, 73],
     [11, 84, 7, 10, 31, 50, 11, 98],
     [25, 13, 43, 1, 31, 52, 41, 90],
     [75, 37, 11, 62, 35, 76, 38, 4]]
)  ①

print('a =>', a, '\n')

i = a > 50  ②
print('i (a > 50) =>', i, '\n')

print('a[i] =>', a[i], '\n')  ③

print('a[a > 50] =>', a[a > 50], '\n')  ④

print('a[i].min(), a[i].max() =>', a[i].min(), a[i].max(), '\n')  ⑤

a[i] = 0  ⑥
print('a =>', a, '\n')

print("a[a < 15] += 10")
a[a < 15] += 10  ⑦
print(a, '\n')
```

① sample data

② create Boolean mask

③ print elements of a that are > 50 using mask

④ same, but without creating a separate mask

⑤ min and max values of result set with values less than 50

⑥ set elements with value > 50 to 0

⑦ add 10 to elements < 15

np_bool_indexing.py

```
a => [[70 31 21 76 19  5 54 66]
 [23 29 71 12 27 74 65 73]
 [11 84  7 10 31 50 11 98]
 [25 13 43  1 31 52 41 90]
 [75 37 11 62 35 76 38  4]]

i (a > 50) => [[ True False False  True False False  True  True]
 [False False  True False False  True  True  True]
 [False  True False False False False False  True]
 [False False False False False  True False  True]
 [ True False False  True False  True False False]]

a[i] => [70 76 54 66 71 74 65 73 84 98 52 90 75 62 76]

a[a > 50] => [70 76 54 66 71 74 65 73 84 98 52 90 75 62 76]

a[i].min(), a[i].max() => 52 98

a => [[ 0 31 21  0 19  5  0  0]
 [23 29  0 12 27  0  0  0]
 [11  0  7 10 31 50 11  0]
 [25 13 43  1 31  0 41  0]
 [ 0 37 11  0 35  0 38  4]]

a[a < 15] += 10
[[10 31 21 10 19 15 10 10]
 [23 29 10 22 27 10 10 10]
 [21 10 17 20 31 50 21 10]
 [25 23 43 11 31 10 41 10]
 [10 37 21 10 35 10 38 14]]
```

Selecting rows based on conditions

- Index with boolean expressions
- Use **&**, not **and**

To select rows from an array, based on conditions, you can index the array with two or more Boolean expressions.

Since the Boolean expressions return arrays of True/False values, use the **&** bitwise AND operator (or **|** for OR).

Any number of conditions can be applied this way.

```
new_array = old_array[bool_expr1 & bool_expr2 ...]
```

Example

np_select_rows.py

```
#!/usr/bin/env python
import numpy as np

sample_data = np.loadtxt(   ①
    "../DATA/columns_of_numbers.txt",
    skiprows=1,
)

print("first 5 rows of sample_data:")
print(sample_data[:5, :], '\n')

selected = sample_data[  ②
    (sample_data[:, 0] < 10) &  ③
    (sample_data[:, -1] > 35)
]

print("selected")
print(selected)
```

① Read some data into 2d array

② Index into the existing data

③ Combine two Boolean expressions with **&**

np_select_rows.py

```
first 5 rows of sample_data:
[[63. 51. 59. 61. 50.  4.]
 [40. 66.  9. 64. 63. 17.]
 [18. 23.  2. 61.  1.  9.]
 [29.  8. 40. 59. 10. 26.]
 [54.  9. 68.  4. 16. 21.]]

selected
[[ 8. 49.  2. 40. 50. 36.]
 [ 4. 49. 39. 50. 23. 39.]
 [ 6.  7. 40. 56. 31. 38.]
 [ 6.  1. 44. 55. 49. 36.]
 [ 5. 22. 45. 49. 10. 37.]]
```

Stacking

- Combining 2 arrays vertically or horizontally
- use `vstack()` or `hstack()`
- Arrays must have compatible shapes

You can combine two or more arrays vertically or horizontally with the `vstack()` or `hstack()` functions. These functions are also handy for adding rows or columns with the results of operations.

Example

np_stacking.py

```
#!/usr/bin/env python
import numpy as np

a = np.array(
    [[70, 31, 21, 76, 19, 5, 54, 66],
     [23, 29, 71, 12, 27, 74, 65, 73]]
)  ①

b = np.array(
    [[11, 84, 7, 10, 31, 50, 11, 98],
     [25, 13, 43, 1, 31, 52, 41, 90]]
)  ②

print('a =>\n', a)
print()
print('b =>\n', b)
print()
print('vstack((a,b)) =>\n', np.vstack((a, b)))  ③
print()

print('vstack((a,a[0] + a[1])) =>\n', np.vstack((a, a[0] + a[1])))  ④
print()

print('hstack((a,b)) =>\n', np.hstack((a, b)))  ⑤
```

① sample array a

② sample array b

③ stack arrays vertically (like pancakes)

④ add a row with sums of first two rows

⑤ stack arrays horizontally (like books on a shelf)

np_stacking.py

```
a =>
 [[70 31 21 76 19  5 54 66]
 [23 29 71 12 27 74 65 73]]

b =>
 [[11 84  7 10 31 50 11 98]
 [25 13 43  1 31 52 41 90]]

vstack((a,b)) =>
 [[70 31 21 76 19  5 54 66]
 [23 29 71 12 27 74 65 73]
 [11 84  7 10 31 50 11 98]
 [25 13 43  1 31 52 41 90]]

vstack((a,a[0] + a[1])) =>
 [[ 70  31  21  76  19   5  54  66]
 [ 23  29  71  12  27  74  65  73]
 [ 93  60  92  88  46  79 119 139]]

hstack((a,b)) =>
 [[70 31 21 76 19  5 54 66 11 84  7 10 31 50 11 98]
 [23 29 71 12 27 74 65 73 25 13 43  1 31 52 41 90]]
```

ufuncs and builtin operators

- Builtin functions for efficiency
- Map over array
- No **for** loops
- Use **vectorize()** for custom ufuncs

In normal Python, you are used to iterating over arrays, especially nested arrays, with a **for** loop. However, for large amounts of data, this is slow. The reason is that the interpreter must do type-checking and lookups for each item being looped over.

NumPy provides *vectorized* operations which are implemented by *ufuncs* — universal functions. ufuncs are implemented in C and work directly on NumPy arrays. When you use a normal math operator (+ - * /, etc) on a NumPy array, it calls the underlying ufunc. For instance, `array1 + array2` calls `np.add(array1, array2)`.

There are over 60 ufuncs built into NumPy. These normally return a NumPy array with the results of the operation. Some have options for putting the output into a different object.

The official docs for ufuncs are here: https://docs.scipy.org/doc/numpy/reference/ufuncs.html

You can scroll down to the list of available ufuncs.

Vectorizing functions

- Many functions "just work"
- `np.vectorize()` allows user-defined function to be broadcast.

ufuncs will automatically be broadcast across any array to which they are applied. For user-defined functions that don’t correctly broadcast, NumPy provides the **vectorize()** function. It takes a function which accepts one or more scalar values (float, integers, etc.) and returns a single scalar value.

Example

np_vectorize.py

```
#!/usr/bin/env python
import time
import numpy as np

sample_data = np.loadtxt(   ①
    "../DATA/columns_of_numbers.txt",
    skiprows=1,
)

def set_default(value, limit, default): ②
    if value > limit:
        value = default

    return value

MAX_VALUE = 50      ③
DEFAULT_VALUE = -1  ④

print("Version 1: looping over arrays")
start = time.time() ⑤
try:
    version1_array = np.zeros(sample_data.shape, dtype=int)  ⑥
    for i, row in enumerate(sample_data):  ⑦
        for j, column in enumerate(row):
            version1_array[i, j] = set_default(sample_data[i, j], MAX_VALUE,
DEFAULT_VALUE)   ⑧
except ValueError as err:
    print("Function failed:", err)
else:
    end = time.time()  ⑨
    elapsed = end - start  ⑩
    print(version1_array)
    print("took {:.5f} seconds".format(elapsed))
finally:
    print()


print("Version 2: broadcast without vectorize()")
start = time.time()
try:
    print("Without sp.vectorize:")
    version2_array = set_default(sample_data, MAX_VALUE, DEFAULT_VALUE) ⑪
except ValueError as err:
    print("Function failed:", err)
```

```
else:
    end = time.time()
    elapsed = end - start
    print(version2_array)
    print("took {:.5f} seconds".format(elapsed))
finally:
    print()

print("Version 3: broadcast with vectorize()")
set_default_vect = np.vectorize(set_default)  ⑫

start = time.time()
try:
    print("With sp.vectorize:")
    version3_array = set_default_vect(sample_data, MAX_VALUE, DEFAULT_VALUE) ⑬
except ValueError as err:
    print("Function failed:", err)
else:
    end = time.time()
    elapsed = end - start
    print(version3_array)
    print("took {:.5f} seconds".format(elapsed))
finally:
    print()
```

① Create some sample data

② Define function with more than one parameter

③ Define max value

④ Define default value

⑤ Get the current time as Unix timestamp (large integer)

⑥ Create array to hold results

⑦ Iterate over rows and columns of input array

⑧ Call function and put result in new array

⑨ Get current time

⑩ Get elapsed number of seconds and print them out

⑪ Pass array to function; it fails because it has more than one parameter

⑫ Convert function to vectorized version — creates function that takes one parameter and has the other two "embedded" in it

⑬ Call vectorized version with same parameters *np_vectorize.py*

```
Version 1: looping over arrays
[[-1 -1 -1 -1 50  4]
 [40 -1  9 -1 -1 17]
 [18 23  2 -1  1  9]
 ...
 [26 20 -1 46 38 23]
 [ 9  5 -1 23  2 26]
 [46 34 25  8 39 34]]
took 0.00500 seconds

Version 2: broadcast without vectorize()
Without sp.vectorize:
Function failed: The truth value of an array with more than one element is ambiguous. Use
a.any() or a.all()

Version 3: broadcast with vectorize()
With sp.vectorize:
[[-1 -1 -1 -1 50  4]
 [40 -1  9 -1 -1 17]
 [18 23  2 -1  1  9]
 ...
 [26 20 -1 46 38 23]
 [ 9  5 -1 23  2 26]
 [46 34 25  8 39 34]]
took 0.00095 seconds
```

Getting help

- Several help functions
  - `numpy.info()`
  - `numpy.lookfor()`
  - `numpy.source()`

NumPy has several functions for getting help. The first is `numpy.info()`, which provides a brief explanation of a function, class, module, or other object as well as some code examples.

If you're not sure what function you need, you can try `numpy.lookfor()`, which does a keyword search through the NumPy documentation.

These functions are convenient when using **iPython** or **Jupyter**.

Example

np_info.py

```
#!/usr/bin/env python
import numpy as np
import scipy.fftpack as ff


def main():
    np.info(ff.fft)  ①

    print('-' * 60)

    np.source(ff.fft)  ②




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

① Get help on the fft() function

② View the source of the fft() function

Iterating

- Similar to normal Python
- Iterates through first dimension
- Use array.flat to iterate through all elements
- Don't do it unless you have to

Iterating through a NumPy array is similar to iterating through any Python list; iteration is across the first dimension. Slicing and indexing can be used.

To iterate across every element, use `array.flat`.

However, iterating over a NumPy array is generally much less efficient than using a *vectorized* approach — calling a *ufunc* or directly applying a math operator. Some tasks may require it, but you should avoid it if possible.

Example

np_iterating.py

```
#!/usr/bin/env python
import numpy as np

a = np.array(
    [[70, 31, 21, 76],
     [23, 29, 71, 12]]
)  ①

print('a =>\n', a)
print()

print("for row in a: =>")
for row in a:  ②
    print("row:", row)
print()

print("for column in a.T:")
for column in a.T:  ③
    print("column:", column)
print()

print("for elem in a.flat: =>")
for elem in a.flat:  ④
    print("element:", elem)
```

① sample array

② iterate over rows

③ iterate over columns by transposing the array

④ iterate over all elements (row-major)

np_iterating.py

```
a =>
 [[70 31 21 76]
 [23 29 71 12]]

for row in a: =>
row: [70 31 21 76]
row: [23 29 71 12]

for column in a.T:
column: [70 23]
column: [31 29]
column: [21 71]
column: [76 12]

for elem in a.flat: =>
element: 70
element: 31
element: 21
element: 76
element: 23
element: 29
element: 71
element: 12
```

Matrix Multiplication

- Use normal ndarrays
- Most operations same as ndarray
- Use @ for multiplication

For traditional matrix operations, use a normal ndarray. Most operations are the same as for ndarrays. For matrix (diagonal) multiplication, use the @ (matrix multiplication) operator.

For transposing, use *array*.transpose(), or just *array*.T.

NOTE There was formerly a Matrix type in NumPy, but it is deprecated since the addition of the @ operator in Python 3.5

Example

np_matrices.py

```
#!/usr/bin/env python
import numpy as np

m1 = np.array(
    [[2, 4, 6],
     [10, 20, 30]]
)  ①

m2 = np.array([[1, 15],
                [3, 25],
                [5, 35]])  ②

print('m1 =>\n', m1)
print()

print('m2 =>\n', m2)
print()

print('m1 * 10 =>\n', m1 * 10)  ③
print()

print('m1 @ m2 =>\n', m1 @ m2)  ④
print()
```

① sample 2x3 array

② sample 3x2 array

③ multiply every element of m1 times 10

④ matrix multiply m1 times m2 — diagonal product

np_matrices.py

```
m1 =>
 [[ 2  4  6]
 [10 20 30]]

m2 =>
 [[ 1 15]
 [ 3 25]
 [ 5 35]]

m1 * 10 =>
 [[ 20  40  60]
 [100 200 300]]

m1 @ m2 =>
 [[  44  340]
 [ 220 1700]]
```

Data Types

- Default is **float**
- Data type is inferred from initialization data
- Can be specified with `arange()`, `ones()`, `zeros()`, etc.

Numpy defines around 30 numeric data types. Integers can have different sizes and byte orders, and be either signed or unsigned. The data type is normally inferred from the initialization data. When using `arange()`, `ones()`, etc., to create arrays, the **dtype** parameter can be used to specify the data type.

The default data type is **np.float_**, which maps to the Python builtin type **float**.

The data type cannot be changed after an array is created.

See https://numpy.org/devdocs/user/basics.types.html for more details.

Example

np_data_types.py

```
#!/usr/bin/env python
import numpy as np

r1 = np.arange(45)  ①
r1.shape = (3, 3, 5)  ②
print('r1 datatype:', r1.dtype)
print('r1 =>\n', r1, '\n')

r2 = np.arange(45.)  ③
r2.shape = (3, 3, 5)
print('r2 datatype:', r2.dtype)
print('r2 =>\n', r2, '\n')

r3 = np.arange(45, dtype=np.int16)  ③
r3.shape = (3, 3, 5)
print('r3 datatype:', r3.dtype)
print('r3 =>\n', r3, '\n')
```

① create array — arange() defaults to int

② create array — passing float makes all elements float

③ create array — set datatype to short int *np_data_types.py*

```
r1 datatype: int64
r1 =>
 [[[ 0  1  2  3  4]
  [ 5  6  7  8  9]
  [10 11 12 13 14]]

 [[15 16 17 18 19]
  [20 21 22 23 24]
  [25 26 27 28 29]]

 [[30 31 32 33 34]
  [35 36 37 38 39]
  [40 41 42 43 44]]]

r2 datatype: float64
r2 =>
 [[[ 0.  1.  2.  3.  4.]
  [ 5.  6.  7.  8.  9.]
  [10. 11. 12. 13. 14.]]

 [[15. 16. 17. 18. 19.]
  [20. 21. 22. 23. 24.]
  [25. 26. 27. 28. 29.]]

 [[30. 31. 32. 33. 34.]
  [35. 36. 37. 38. 39.]
  [40. 41. 42. 43. 44.]]]

r3 datatype: int16
r3 =>
 [[[ 0  1  2  3  4]
  [ 5  6  7  8  9]
  [10 11 12 13 14]]

 [[15 16 17 18 19]
  [20 21 22 23 24]
  [25 26 27 28 29]]

 [[30 31 32 33 34]
  [35 36 37 38 39]
  [40 41 42 43 44]]]
```

Reading and writing Data

- Read data from files into **ndarray**
- Text files
  - `loadtxt()`
  - `savetxt()`
  - `genfromtxt()`
- Binary (or text) files
  - `fromfile()`
  - `tofile()`

NumPy has several functions for reading data into an array.

`numpy.loadtxt()` reads a delimited text file. There are many options for fine-tuning the import.

`numpy.genfromtxt()` is similar to `numpy.loadtxt()`, but also adds support for handling missing data

Both functions allow skipping rows, user-defined per-column converters, setting the data type, and many others.

To save an array as a text file, use the `numpy.savetxt()` function. You can specify delimiters, header, footer, and formatting.

To read binary data, use `numpy.fromfile()`. It expects a file to contain all the same data type, i.e., ints or floats of a specified type. It will default to floats. `fromfile()` can also be used to read text files.

To save as binary data, you can use `numpy.tofile()`, but **tofile()** and **fromfile()** are not platform-independent. See the next section on **save()** and **load()** for platform-independent I/O.

Example

np_savetxt_loadtxt.py

```
#!/usr/bin/env python
import numpy as np

sample_data = np.loadtxt(   ①
    "../DATA/columns_of_numbers.txt",
    skiprows=1,
    dtype=float
)

print(sample_data)
print('-' * 60)

sample_data  /= 10  ②

float_file_name = 'save_data_float.txt'

np.savetxt(float_file_name, sample_data, delimiter=",", fmt="%5.2f")  ③

int_file_name = 'save_data_int.txt'

np.savetxt(int_file_name, sample_data, delimiter=",", fmt="%d")  ④

data = np.loadtxt(float_file_name, delimiter=",")  ⑤
print(data)
```

① Load data from space-delimited file

② Modify sample data

③ Write data to text file as floats, rounded to two decimal places, using commas as delimiter

④ Write data to text file as ints, using commas as delimiter

⑤ Read data back into **ndarray**

np_savetxt_loadtxt.py

```
[[63. 51. 59. 61. 50.  4.]
 [40. 66.  9. 64. 63. 17.]
 [18. 23.  2. 61.  1.  9.]
 ...
 [26. 20. 54. 46. 38. 23.]
 [ 9.  5. 59. 23.  2. 26.]
 [46. 34. 25.  8. 39. 34.]]
------------------------------------------------------------
[[6.3 5.1 5.9 6.1 5.  0.4]
 [4.  6.6 0.9 6.4 6.3 1.7]
 [1.8 2.3 0.2 6.1 0.1 0.9]
 ...
 [2.6 2.  5.4 4.6 3.8 2.3]
 [0.9 0.5 5.9 2.3 0.2 2.6]
 [4.6 3.4 2.5 0.8 3.9 3.4]]
```

Example

np_tofile_fromfile.py

```
#!/usr/bin/env python
import numpy as np

sample_data = np.loadtxt(   ①
    "../DATA/columns_of_numbers.txt",
    skiprows=1,
    dtype=float
)

sample_data  /= 10  ②

print(sample_data)
print("-" * 60)

file_name = 'sample.dat'

sample_data.tofile(file_name)  ③

data = np.fromfile(file_name)  ④
data.shape = sample_data.shape  ⑤

print(data)
```

① Read in sample data

② Modify sample data

③ Write data to file (binary, but not portable)

④ Read binary data from file as one-dimensional array

⑤ Set shape to shape of original array

np_tofile_fromfile.py

```
[[6.3 5.1 5.9 6.1 5.  0.4]
 [4.  6.6 0.9 6.4 6.3 1.7]
 [1.8 2.3 0.2 6.1 0.1 0.9]
 ...
 [2.6 2.  5.4 4.6 3.8 2.3]
 [0.9 0.5 5.9 2.3 0.2 2.6]
 [4.6 3.4 2.5 0.8 3.9 3.4]]
------------------------------------------------------------
[[6.3 5.1 5.9 6.1 5.  0.4]
 [4.  6.6 0.9 6.4 6.3 1.7]
 [1.8 2.3 0.2 6.1 0.1 0.9]
 ...
 [2.6 2.  5.4 4.6 3.8 2.3]
 [0.9 0.5 5.9 2.3 0.2 2.6]
 [4.6 3.4 2.5 0.8 3.9 3.4]]
```

Saving and retrieving arrays

- Efficient binary format
- Save as NumPy data
  - Use `numpy.save()`
- Read into ndarray
  - Use `numpy.load()`

To save an array as a NumPy data file, use `numpy.save()`. This will write the data out to a specified file name, adding the extension '.npy'.

To read the data back into a NumPy ndarray, use `numpy.load()`. Data are read and written in a way that preserves precision and endianness.

This the most efficient way to store numeric data for later retrieval, compared to **savetext()** and **loadtext()** or **tofile()** and **fromfile()**. Files written with `numpy.save()` are not human-readable.

Example

np_save_load.py

```
#!/usr/bin/env python


import numpy as np

sample_data = np.loadtxt(   ①
    "../DATA/columns_of_numbers.txt",
    skiprows=1,
    dtype=int
)

sample_data  *= 100  ②

print(sample_data)

file_name = 'sampledata'

np.save(file_name, sample_data)  ③

retrieved_data = np.load(file_name + '.npy')  ④

print('-' * 60)
print(retrieved_data)
```

① Read some sample data into an ndarray

② Modify the sample data (multiply every element by 100)

③ Write entire array out to NumPy-format data file (adds **.npy** extension)

④ Retrieve data from saved file

np_save_load.py

```
[[6300 5100 5900 6100 5000  400]
 [4000 6600  900 6400 6300 1700]
 [1800 2300  200 6100  100  900]
 ...
 [2600 2000 5400 4600 3800 2300]
 [ 900  500 5900 2300  200 2600]
 [4600 3400 2500  800 3900 3400]]
------------------------------------------------------------
[[6300 5100 5900 6100 5000  400]
 [4000 6600  900 6400 6300 1700]
 [1800 2300  200 6100  100  900]
 ...
 [2600 2000 5400 4600 3800 2300]
 [ 900  500 5900 2300  200 2600]
 [4600 3400 2500  800 3900 3400]]
```

Array creation shortcuts

- Use "magic" arrays r_, c_
- Either creates a new NumPy array
  - Index values determine resulting array
  - List of arrays creates a "stacked" array
  - List of values creates a 1D array
  - Slice notation creates a range of values
  - A complex step creates equally-spaced value

NumPy provides several shortcuts for working with arrays.

The **r_** object can be used to magically build arrays via its index expression. It acts like a magic array, and "returns" (evaluates to) a normal NumPy ndarray object. (The **c_** object is the same, but is column-oriented).

There are two main ways to use r_():

If the index expression contains a list of arrays, then the arrays are "stacked" along the first axis.

If the index contains slice notation, then it creates a one-dimensional array, similar to numpy.arange(). It uses start, stop, and step values. However, if step is an imaginary number (a literal that ends with 'j'), then it specifies the number of points wanted, more like numpy.linspace().

There can be more than one slice, as well as individual values, and ranges. They will all be concatenated into one array.

TIP If the first element in the index is a string containing one, two, or three integers separated by commas, then the first integer is the axis to stack the arrays along; the second is the minimum number of dimensions to force each entry into; the third allows you to control the shape of the resulting array.
This is especially useful for making a new array from selected parts of an existing array.

NOTE Most of the time you will be creating arrays by reading data — these are mostly useful for edge cases when you’re creating some smaller specialized array.

Example

np_tricks.py

```
#!/usr/bin/env python
import numpy as np

a1 = np.r_[np.array([1, 2, 3]), 0, 0, np.array([4, 5, 6])]  ①
print(a1)
print()

a2 = np.r_[-1:1:6j, [0] * 3, 5, 6]  ②
print(a2)
print()

a = np.array([[0, 1, 2], [3, 4, 5]])  ③
a3 = np.r_['-1', a, a]  ④
print(a3)
print()

a4 = np.r_['0,2', [1, 2, 3], [4, 5, 6]]  ④
print(a4)
print()

a5 = np.r_['0,2,0', [1, 2, 3], [4, 5, 6]]  ⑤
print(a5)
print()

a6 = np.r_['1,2,0', [1, 2, 3], [4, 5, 6]]  ⑥
print(a6)
print()

m = np.r_['r', [1, 2, 3], [4, 5, 6]]
print(m)
print(type(m))
```

① build array from a sequence of array-like things

② faux slice with complex step implements linspace <3>

np_tricks.py

```
[1 2 3 0 0 4 5 6]

[-1.  -0.6 -0.2  0.2  0.6  1.   0.   0.   0.   5.   6. ]

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

[[1 2 3]
 [4 5 6]]

[[1]
 [2]
 [3]
 [4]
 [5]
 [6]]

[[1 4]
 [2 5]
 [3 6]]

[[1 2 3 4 5 6]]
<class 'numpy.matrix'>
```

Chapter 17 Exercises

Exercise 17-1 (big_arrays.py)

Starting with the file big_arrays.py, convert the Python list values into a NumPy array.

Make a copy of the array named values_x_3 with all values multiplied by 3.

Print out values_x_3

Exercise 17-2 (create_range.py)

Using arange(), create an array of 35 elements.

Reshape the arrray to be 5 x 7 and print it out.

Reshape the array to be 7 x 5 and print it out.

Exercise 17-3 (create_linear_space.py)

Using linspace(), create an array of 500 elements evenly spaced between 100 and 200.

Reshape the array into 5 x 10 x 10.

Multiply every element by .5

Print the result.

Chapter 18: Introduction to SciPy

Objectives

- Understand the motivation for scipy
- See what the scipy module provides
- Import scipy and friends using standard abbreviations
- Learn which functions are aliased from numpy
- Use the scipy documentation commands
- Tour scipy's many subpackages

About scipy

- Part of the "Python Scientific Stack"
- Often used with matplotlib
- Many mathematical and statistical algorithms
- Includes numpy "under the hood"
- Can be used with iPython
- Very large collection of routines and subpackages

scipy is a collection of modules and submodules for doing scientific (mostly numerical) analysis.

The scipy module itself acts as an umbrella module, or repository, for many useful submodules.

Although it can be used alone, numpy is part of scipy, and many useful numpy functions are aliased into the scipy namespace.

In addition, many common functions from scipy’s dozens of submodules have been aliased to the scipy namespace.

All of the top-level **numpy** functions are available through scipy as well.

Polynomials

- Create a poly1d object
- Represented in either of two ways
  - list of coefficients (1st element is coefficient of highest power)
  - list of roots
- Call polynomial with value to solve for
- r attribute represents list of roots

Polynomials can be represented in scipy in two ways using numpy's poly1d() method, which takes a list of coefficients; the other is to just provide a list of coefficients, where the first element is the coefficient of the highest power.

The poly1d() method takes a list of coefficients (or roots) and returns a poly1d object.

Treating the polynomial object like a string returns a text representation of the polynomial.

By default, pass an iterable of integers to poly1d which represent the coefficients. To specify roots, pass a second parameter to poly1d with a true value.

The variable used when displaying the polynomial is normally x. To use a different variable, add a third parameter with a string.

To solve for a specific value, call the polynomial with that value. The r property of the polynomial contains the roots.

You can use the addition, subtraction, division, multiplication, and exponentiation operators between polynomials and scalar values.

NOTE poly1d is automatically imported to scipy's namespace as well

Example

sp_polynomials.py

```
#!/usr/bin/env python
import scipy as sp

p1 = sp.poly1d([2, 1, 4])  ①
print(p1)
print()

print(p1(.75))  ②
print(p1.r)  ③
print()

p2 = sp.poly1d([2, 1, -4], True)  ④
print(p2)
print()

print(p2(.75))  ⑤
print(p2.r)  ⑥
print()

p3 = sp.poly1d([1, 2, 3], False, 'm')  ⑦
print(p3)
print()

print(p3(100))  ⑧

print(p3.r)  ⑨
print()

p4 = sp.poly1d([1, 2])  ⑩
p5 = sp.poly1d([3, 4])
print()

print(p4)
print()

print(p5)
print()

print(p4 + p5)
print()

print(p4 - p5)
print()

print(p4 ** 3)
print()
```

① 2,1,4 are coefficients

② evaluate for x = .75

③ get the roots

④ 2,1,-4 are roots

⑤ evaluate for x = .75

⑥ get the roots

⑦ 1,2,3 are coefficients, variable is 'm'

⑧ evaluate for m = 100

⑨ get the roots

⑩ polynomial arithmetic

sp_polynomials.py

```
   2
2 x + 1 x + 4

5.875
[-0.25+1.39194109j -0.25-1.39194109j]

   3     2
1 x + 1 x - 10 x + 8

1.484375
[-4.  2.  1.]

   2
1 m + 2 m + 3

10203
[-1.+1.41421356j -1.-1.41421356j]



1 x + 2


3 x + 4


4 x + 6


-2 x - 2

   3     2
1 x + 6 x + 12 x + 8
```

Working with SciPy

- Some functions imported to scipy
- Hundreds more in subpackages
- Most functions have similar interfaces
- Use numpy plus scipy.subpackage routines as needed

scipy’s subpackages have hundreds of functions. For convenience, some of them have been imported into the scipy namespace. While numpy is mostly about arrays and matrices, there are some useful data handling functions as well.

Example

sp_functions.py

```
#!/usr/bin/env python
import numpy as np
import matplotlib.pyplot as plt

dt = np.dtype([('Month', 'int8'), ('Day', 'int8'), ('Year', 'int16'), ('Temp',
'float64')]) ①
data = np.loadtxt('../DATA/weather/NYNEWYOR.txt', dtype=dt) ②

print(data['Temp'])

temps = data['Temp'] ③

plt.plot(temps) ④
plt.show() ⑤
plt.cla() ⑥

normalized_data = data[data['Temp'] > -50] ⑦
temps = normalized_data['Temp'] ⑧
plt.plot(temps) ⑨
plt.show()
```

① define custom numpy datatype

② read flat-file data into numpy array

③ get data from 'Temp' column

④ plot days against temps

⑤ display plot

⑥ clear first axis but not the whole figure

⑦ remove readings < -50, which seem to be default N/A values

⑧ grab temps again

⑨ replot

NOTE see plot

SciPy Subpackages

- cluster — Clustering algorithms
- constants — Physical and mathematical constants
- fftpack --Fast Fourier Transform routines
- integrate — Integration and ordinary differential equation solvers
- interpolate — Interpolation and smoothing splines
- io — Input and Output
- linalg — Linear algebra
- ndimage — N-dimensional image processing
- odr — Orthogonal distance regression
- optimize — Optimization and root-finding routines
- signal — Signal processing
- sparse — Sparse matrices and associated routines
- spatial — Spatial data structures and algorithms
- special — Special functions
- stats — Statistical distributions and functions
- weave — C/C++ integration

Python and C/C++

- Ctypes allows loading of shared libraries (dll/dylib/so)
- Cython is optimizing static compiler

When there is not a fast numpy/scipy routine that implements a needed algorithm, you can write the algorithm in C/C++.

This may not help with code that already uses existing numpy/scipy functions, but if the code contains nested loops, the speedup can be significant.

Of course, extending scipy with C requires a C development package. This can be either **Microsoft Visual C++** or **MinGW** on Windows, and is typically **gcc** on other platforms.

The simplest approach is **ctypes**. This is part of the standard library, and allows direct import of C/C shared libraries (.dll, .dylib, or .so) without writing any custom C/C code.

cython is a version of Python that automatically pre-compiles selected Python code into C. It looks like Python, but has type declarations similar to those in C.

numba is a library that contains the **jit** decorator. Using this will dramatically speed up calculation-heavy functions without changing any code.

Tour of SciPy subpackages

- 20 subpackages
- Hundreds of routines

SciPy has 20 main subpackages, each of which can have hundreds of routines. They are all designed to work with NumPy arrays, and there is some overlap among them. Some of the routines are also available from the **scipy** package itself, without having to import the subpackage.

We will now visit the SciPy documentation for a brief tour of the SciPy packages, at https://docs.scipy.org/doc/scipy/reference/

Chapter 19: Introduction to pandas

Objectives

- Understand what the pandas module provides
- Load data from CSV and other files
- Access data tables
- Extract rows and columns using conditions
- Calculate statistics for rows or columns

About pandas

- Reads data from file, database, or other sources
- Deals with real-life issues such as invalid data
- Powerful selecting and indexing tools
- Builtin statistical functions
- Munge, clean, analyze, and model data
- Works with numpy and matplotlib

pandas is a package designed to make it easy to get, organize, and analyze large datasets. Its strengths lie in its ability to read from many different data sources, and to deal with real-life issues, such as missing, incomplete, or invalid data.

pandas also contains functions for calculating means, sums and other kinds of analysis.

For selecting desired data, pandas has many ways to select and filter rows and columns.

It is easy to integrate pandas with NumPy, Matplotlib, and other scientific packages.

While pandas can handle three (or higher) dimensional data, it is generally used with two-dimensional (row/column) data, which can be visualized like a spreadsheet.

pandas provides powerful split-apply-combine operations — **groupby** enables transformations, aggregations, and easy-access to plotting functions. It is easy to emulate R's plyr package via pandas.

NOTE pandas gets its name from *pan*el *da*ta *s*ystem

Tidy data

- Tidy data is neatly grouped
- Data
  - *Value* = "observation"
  - *Column* = "variable"
  - *Row* = "related observations"
- Pandas best with tidy data

A dataset contains *values*. Those values can be either numbers or strings. Values are grouped into *variables*, which are usually represented as *columns*. For instance, a column might contain "unit price" or "percentage of NaCL". An individual value is sometimes called an *observation*. A *row* represents a group of related observations. Every combination of row and column is a single observation.

When data is arranged this way, it is said to be "tidy". Pandas is designed to work best with tidy data.

For instance,

```
Product    SalesYTD
oranges    5000
bananas    1000
grapefruit 10000
```

is tidy data. The variables are "Product" and "SalesYTD", and the observations are the names of the fruits and the sales figures.

The following dataset is NOT tidy:

```
Fruit     oranges bananas grapefruit
SalesYTD  5000    1000    10000
```

To make selecting data easy, Pandas dataframes always have variable labels (columns) and observation (row) labels (index). A row index could be something simple like increasing integers, but it could also be a time series, or any set of strings, including a column pulled from the data set.

NOTE See https://cran.r-project.org/web/packages/tidyr/vignettes/tidy-data.html for a detailed discussion of tidy data.

pandas architecture

- Two main structures: Series and DataFrame
- Series – one-dimensional
- DataFrame – two-dimensional

The two main data structures in pandas are the **Series** and the **DataFrame**. A series is a one-dimensional indexed list of values, something like an ordered dictionary. A DataFrame is is a two-dimensional grid, with both row and column indexes (like the rows and columns of a spreadsheet, but more flexible).

You can specify the indexes, or pandas will use successive integers. Each row or column of a DataFrame is a Series.

NOTE pandas used to support the **Panel** type, which is more more or less a collection of DataFrames, but Panel has been deprecated in favor of hierarchical indexing.

Series

- Indexed list of values
- Similar to a dictionary, but ordered
- Can get sum(), mean(), etc.
- Use index to get individual values
- indexes are not positional

A Series is an indexed sequence of values. Each item in the sequence has an index. The default index is a set of increasing integer values, but any set of values can be used.

For example, you can create a series with the values 5, 10, and 15 as follows:

```
s1 = pd.Series([5,10,15])
```

This will create a Series indexed by [0, 1, 2]. To provide index values, add a second list:

```
s2 = pd.Series([5,10,15], ['a','b','c'])
```

This specifies the indexes as 'a', 'b', and 'c'.

You can also create a Series from a dictionary. pandas will put the index values in order:

```
s3 = pd.Series({'b':10, 'a':5, 'c':15})
```

There are many methods that can be called on a Series, and Series can be indexed in many flexible ways.

Example

pandas_series.py

```
#!/usr/bin/env python
import numpy as np
import pandas as pd

NUM_VALUES = 10
index = [chr(i) for i in range(97, 97 + NUM_VALUES)]  ①
print("index:", index, '\n')

s1 = pd.Series(np.linspace(1, 5, NUM_VALUES), index=index)  ②
s2 = pd.Series(np.linspace(1, 5, NUM_VALUES))  ③

print("s1:", s1, "\n")
print("s2:", s2, "\n")

print("selecting elements")
print(s1[['h', 'b']], "\n")  ④

print(s1[['a', 'b', 'c']], "\n")  ④

print("slice of elements")
print(s1['b':'d'], "\n")  ⑤

print("sum(), mean(), min(), max():")
print(s1.sum(), s1.mean(), s1.min(), s1.max(), "\n")  ⑥

print("cumsum(), cumprod():")
print(s1.cumsum(), s1.cumprod(), "\n")  ⑥

print('a' in s1)  ⑦
print('m' in s1)  ⑦
print()

s3 = s1 * 10  ⑧
print("s3 (which is s1 * 10)")
print(s3, "\n")

s1['e'] *= 5

print("boolean mask where s3 > 25:")
print(s3 > 25, "\n")  ⑨

print("assign -1 where mask is true")
s3[s3 < 25] = -1  ⑩
print(s3, "\n")
```

```
s4 = pd.Series([-0.204708, 0.478943, -0.519439])  ⑪
print("s4.max(), .min(), etc.")
print(s4.max(), s4.min(), s4.max() - s4.min(), '\n')  ⑫

s = pd.Series([5, 10, 15], ['a', 'b', 'c'])  ⑬
print("creating series with index")
print(s)
```

① make list of 'a', 'b', 'c', ...

② create series with specified index

③ create series with auto-generated index (0, 1, 2, 3, ...)

④ select items from series

⑤ select slice of elements

⑥ get stats on series

⑦ test for existence of label

⑧ create new series with every element of s1 multiplied by 10

⑨ create boolean mask from series

⑩ set element to -1 where mask is True

⑪ create new series

⑫ print stats

⑬ create new series with index

DataFrames

- Two-dimensional grid of values
- Row and column labels (indexes)
- Rich set of methods
- Powerful indexing

A DataFrame is the workhorse of pandas. It represents a two-dimensional grid of values, containing indexed rows and columns, something like a spreadsheet.

There are many ways to create a DataFrame. They can be modified to add or remove rows/columns. Missing or invalid data can be eliminated or normalized.

DataFrames can be initialized from many kinds of data. See the table on the next page for a list of possibilities.

NOTE The panda DataFrame is modeled after R’s data.frame

Table 29. DataFrame Initializers

Initializer	Description
2D ndarray	A matrix of data, passing optional row and column labels
dict of arrays, lists, or tuples	Each sequence becomes a column in the DataFrame. All sequences must be the same length.
NumPy structured/record array	Treated as the “dict of arrays” case
dict of Series	Each value becomes a column. Indexes from each Series are union-ed together to form the result’s row index if no explicit index is passed.
dict of dicts	Each inner dict becomes a column. Keys are union-ed to form the row index as in the “dict of Series” case.
list of dicts or Series	Each item becomes a row in the DataFrame. Union of dict keys or Series indexes become the DataFrame’s column labels
List of lists or tuples	Treated as the “2D ndarray” case
Another DataFrame	The DataFrame’s indexes are used unless different ones are passed
NumPy MaskedArray	Like the “2D ndarray” case except masked values become NA/missing in the DataFrame result

IMPORTANT Much of the time you will create Series and Dataframes by reading data.

Example

pandas_simple_dataframe.py

```
#!/usr/bin/env python
import pandas as pd
from printheader import print_header


cols = ['alpha', 'beta', 'gamma', 'delta', 'epsilon']  ①
indices = ['a', 'b', 'c', 'd', 'e', 'f']  ②

values = [  ③
    [100, 110, 120, 130, 140],
    [200, 210, 220, 230, 240],
    [300, 310, 320, 330, 340],
    [400, 410, 420, 430, 440],
    [500, 510, 520, 530, 540],
    [600, 610, 620, 630, 640],
]
print_header('cols')
print(cols, '\n')

print_header('indices')
print(indices, '\n')

print_header('values')
print(values, '\n')

df = pd.DataFrame(values, index=indices, columns=cols)  ④
print_header('DataFrame df')
print(df, '\n')

print_header("df['gamma']")
print(df['gamma'])  ⑤
```

① column names

② row names

③ sample data

④ create dataframe with row and column names

⑤ select column 'gamma'

pandas_simple_dataframe.py

```
==================================================
=                       cols                     =
==================================================
['alpha', 'beta', 'gamma', 'delta', 'epsilon']

==================================================
=                     indices                    =
==================================================
['a', 'b', 'c', 'd', 'e', 'f']

==================================================
=                      values                    =
==================================================
[[100, 110, 120, 130, 140], [200, 210, 220, 230, 240], [300, 310, 320, 330, 340], [400,
410, 420, 430, 440], [500, 510, 520, 530, 540], [600, 610, 620, 630, 640]]

==================================================
=                   DataFrame df                 =
==================================================
   alpha  beta  gamma  delta  epsilon
a    100   110    120    130      140
b    200   210    220    230      240
c    300   310    320    330      340
d    400   410    420    430      440
e    500   510    520    530      540
f    600   610    620    630      640

==================================================
=                   df['gamma']                  =
==================================================
a    120
b    220
c    320
d    420
e    520
f    620
Name: gamma, dtype: int64
```

Reading Data

- Supports many data formats
- Reads headings to create column indexes
- Auto-creates indexes as needed
- Can used specified column as row index

Pandas supports many different input formats. It will read file headings and use them to create column indexes. By default, it will use integers for row indexes, but you can specify a column to use as the index, or provide a list of index values.

The **read_...()** functions have many options for controlling and parsing input. For instance, if large integers in the file contain commas, the thousands options let you set the separator as comma (in the US), so it will ignore them.

read_csv() is the most frequently used function, and has many options. It can also be used to read generic flat-file formats. **read_table** is similar to **read_csv()**, but doesn't assume CSV format.

There are corresponding **to_...()** functions for many of the read functions. `to_csv()` and `to_ndarray()` are very useful.

NOTE

See **Jupyter** notebook **pandas_Input_Demo** (in the **NOTEBOOKS** folder) for examples of reading most types of input.

See https://pandas.pydata.org/pandas-docs/stable/user_guide/io.html?highlight=output#io-html for details on the I/O functions.

Example

pandas_read_csv.py

```
import pandas as pd

df = pd.read_csv('../DATA/sales_records.csv')  ①

print(df.describe())  ②
print()

print(df.info())  ③
print()

print(df.head())  ④
```

① Read CSV data into dataframe. Pandas automatically uses the first row as column names

② Get statistics on the numeric columns (use `df.describe(include='O')` for text columns)

③ Get information on all the columns ('object' means text/string)

④ Display first 5 rows of the dataframe (`df.describe(n)` displays n rows) *pandas_read_csv.py*

```
           Order ID   Units Sold   Unit Price    Unit Cost
count  5.000000e+03  5000.000000  5000.000000  5000.000000
mean   5.486447e+08  5030.698200   265.745564   187.494144
std    2.594671e+08  2914.515427   218.716695   176.416280
min    1.000909e+08     2.000000     9.330000     6.920000
25%    3.201042e+08  2453.000000    81.730000    35.840000
50%    5.523150e+08  5123.000000   154.060000    97.440000
75%    7.687709e+08  7576.250000   437.200000   263.330000
max    9.998797e+08  9999.000000   668.270000   524.960000

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 5000 entries, 0 to 4999
Data columns (total 11 columns):
 #   Column          Non-Null Count  Dtype
---  ------          --------------  -----
 0   Region          5000 non-null   object
 1   Country         5000 non-null   object
 2   Item Type       5000 non-null   object
 3   Sales Channel   5000 non-null   object
 4   Order Priority  5000 non-null   object
 5   Order Date      5000 non-null   object
 6   Order ID        5000 non-null   int64
 7   Ship Date       5000 non-null   object
 8   Units Sold      5000 non-null   int64
 9   Unit Price      5000 non-null   float64
 10  Unit Cost       5000 non-null   float64
dtypes: float64(2), int64(2), object(7)
memory usage: 429.8+ KB
None

                              Region  ... Unit Cost
0  Central America and the Caribbean  ...    159.42
1  Central America and the Caribbean  ...     97.44
2                             Europe  ...     31.79
3                               Asia  ...    117.11
4                               Asia  ...     97.44

[5 rows x 11 columns]
```

Table 30. pandas I/O functions

Format	Input function	Output function
CSV	read_csv()	to_csv()
Delimited file (generic)	read_table()	to_csv()
Excel worksheet	read_excel()	to_excel()
File with fixed-width fields	read_fwf()	
Google BigQuery	read_gbq()	to_gbq()
HDF5	read_hdf()	to_hdf()
HTML table	read_html()	to_html()
JSON	read_json()	to_json()
OS clipboard data	read_clipboard()	to_clipboard()
Parquet	read_parquet()	to_parquet()
pickle	read_pickle()	to_pickle()
SAS	read_sas()	
SQL query	read_sql()	to_sql()

NOTE All **read_...()** functions return a new **DataFrame**, except **read_html()**, which returns a list of **DataFrames**

Data summaries

- `describe()` *basic statistical details*
- `info()` *per-column details (shallow memory use)*
- `info(memory_usage='deep')` *actual memory use*

You can call the `describe()` and `info()` methods on a dataframe to get summaries of the kind of data contained.

The `describe()` method, by default, shows statistics on all numeric columns. Add `include='int'` or `include='float'` to restrict the output to those types. `include='all'` will show all types, including "objects" (AKA text).

To show just objects (strings), use `include='O'`. This will show all text columns. You can compare the **count** and **unique** valeus to check the *cardinality* of the column, or how many distinct values there are. Columns with few unique values are said to have low cardinality, and are candidates for saving space by using the `Categorical` data type.

The `info()` method will show the names and types of teach column, as well as the count of non-null values. Adding `memory_usage='deep'` will display the total memory actually used by the dataframe. (Otherwise, it's only the memory used by the top-level data structures).

Example

pandas_data_summaries.py

```
#!/usr/bin/env python
import pandas as pd
from printheader import print_header

df = pd.read_csv('../DATA/airport_boardings.csv', thousands=',', index_col=1)

print_header('df.head()')
print(df.head())
print()

print_header('df.describe()')
print(df.describe())

print_header("df.describe(include='int')")
print(df.describe(include='int'))

print_header("df.info()")
print(df.info())
```

pandas_data_summaries.py

```
==================================================
=                   df.head()                    =
==================================================
                                               Airport  ...  Percent change 2010-2011
Code                                                    ...
ATL   Atlanta, GA (Hartsfield-Jackson Atlanta Intern...  ...                     -22.6
ORD          Chicago, IL (Chicago O'Hare International)  ...                     -25.5
DFW        Dallas, TX (Dallas/Fort Worth International)  ...                     -23.7
DEN                   Denver, CO (Denver International)  ...                     -23.1
LAX         Los Angeles, CA (Los Angeles International)  ...                     -19.6

[5 rows x 9 columns]

==================================================
=                 df.describe()                  =
==================================================
       2001 Rank  ...  Percent change 2010-2011
count  50.000000  ...                 50.000000
mean   26.460000  ...                -23.758000
std    15.761242  ...                  2.435963
min     1.000000  ...                -32.200000
25%    13.250000  ...                -25.275000
```

```
50%    26.500000  ...                -23.650000
75%    38.750000  ...                -22.075000
max    59.000000  ...                -19.500000

[8 rows x 8 columns]
==================================================
=           df.describe(include='int')           =
==================================================
       2001 Rank    2001 Total  ...  2011 Rank         Total
count  50.000000  5.000000e+01  ...   50.00000  5.000000e+01
mean   26.460000  9.848488e+06  ...   25.50000  8.558513e+06
std    15.761242  7.042127e+06  ...   14.57738  6.348691e+06
min     1.000000  2.503843e+06  ...    1.00000  2.750105e+06
25%    13.250000  4.708718e+06  ...   13.25000  3.300611e+06
50%    26.500000  7.626439e+06  ...   25.50000  6.716353e+06
75%    38.750000  1.282468e+07  ...   37.75000  1.195822e+07
max    59.000000  3.638426e+07  ...   50.00000  3.303479e+07

[8 rows x 6 columns]
==================================================
=                   df.info()                    =
==================================================
<class 'pandas.core.frame.DataFrame'>
Index: 50 entries, ATL to IND
Data columns (total 9 columns):
 #   Column                    Non-Null Count  Dtype
---  ------                    --------------  -----
 0   Airport                   50 non-null     object
 1   2001 Rank                 50 non-null     int64
 2   2001 Total                50 non-null     int64
 3   2010 Rank                 50 non-null     int64
 4   2010 Total                50 non-null     int64
 5   2011 Rank                 50 non-null     int64
 6    Total                    50 non-null     int64
 7   Percent change 2001-2011  50 non-null     float64
 8   Percent change 2010-2011  50 non-null     float64
dtypes: float64(2), int64(6), object(1)
memory usage: 3.9+ KB
None
```

Basic Indexing

- Similar to normal Python or numpy
- Slices select rows

One of the real strengths of pandas is the ability to easily select desired rows and columns. This can be done with simple subscripting, like normal Python, or extended subscripting, similar to numpy. In addition, pandas has special methods and attributes for selecting data.

For selecting columns, use the column name as the subscript value. This selects the entire column. To select multiple columns, use a sequence (list, tuple, etc.) of column names.

For selecting rows, use slice notation. This may not map to similar tasks in normal python. That is, dataframe[x:y] selects rows x through y, but dataframe[x] selects column x.

NOTE the *DF*.loc and *DF*.iloc operators provide more extensive and consistent indexing. They will be covered later in the chapter.

Example

pandas_selecting.py

```
#!/usr/bin/env python
import pandas as pd
from printheader import print_header

cols = ['alpha', 'beta', 'gamma', 'delta', 'epsilon']  ①
index = ['a', 'b', 'c', 'd', 'e', 'f']  ②

values = [  ③
    [100, 110, 120, 130, 140],
    [200, 210, 220, 230, 240],
    [300, 310, 320, 330, 340],
    [400, 410, 420, 430, 440],
    [500, 510, 520, 530, 540],
    [600, 610, 620, 630, 640],
]

df = pd.DataFrame(values, index=index, columns=cols)  ④
print_header('DataFrame df')
print(df, '\n')

print_header("df['alpha']")
print(df['alpha'], '\n')  ⑤

print_header("df.beta")
print(df.beta, '\n')  ⑥

print_header("df['b':'e']")
print(df['b':'e'], '\n')  ⑦

print_header("df[['alpha','epsilon','beta']]")
print(df[['alpha', 'epsilon', 'beta']])  ⑧
print()

print_header("df[['alpha','epsilon','beta']]['b':'e']")
print(df[['alpha', 'epsilon', 'beta']]['b':'e'])  ⑨
print()
```

① column labels

② row labels

③ sample data

④ create dataframe with data, row labels, and column labels

⑤ select column 'alpha'

⑥ same, but alternate syntax (only works if column name is letters, digits, and underscores)

⑦ select rows 'b' through 'e' using slice of row labels

⑧ select columns — note index is an iterable

⑨ select columns AND slice rows

pandas_selecting.py

```
==================================================
=                  DataFrame df                  =
==================================================
   alpha  beta  gamma  delta  epsilon
a    100   110    120    130      140
b    200   210    220    230      240
c    300   310    320    330      340
d    400   410    420    430      440
e    500   510    520    530      540
f    600   610    620    630      640

==================================================
=                  df['alpha']                   =
==================================================
a    100
b    200
c    300
d    400
e    500
f    600
Name: alpha, dtype: int64

==================================================
=                    df.beta                     =
==================================================
a    110
b    210
c    310
d    410
e    510
f    610
Name: beta, dtype: int64
```

```
==================================================
=                 df['b':'e']                    =
==================================================
   alpha  beta  gamma  delta  epsilon
b    200   210    220    230      240
c    300   310    320    330      340
d    400   410    420    430      440
e    500   510    520    530      540

==================================================
=         df[['alpha','epsilon','beta']]         =
==================================================
   alpha  epsilon  beta
a    100      140   110
b    200      240   210
c    300      340   310
d    400      440   410
e    500      540   510
f    600      640   610

==================================================
=    df[['alpha','epsilon','beta']]['b':'e']     =
==================================================
   alpha  epsilon  beta
b    200      240   210
c    300      340   310
d    400      440   410
e    500      540   510
```

Broadcasting

- Operation is applied across rows and columns
- Can be restricted to selected rows/columns
- Sometimes called vectorization
- Use apply() for more complex operations

If you multiply a dataframe by some number, the operation is broadcast, or vectorized, across all values. This is true for all basic math operations.

The operation can be restricted to selected columns.

For more complex operations, the apply() method will apply a function that selects elements. You can use the name of an existing function, or supply a lambda (anonymous) function.

Example

pandas_broadcasting.py

```
#!/usr/bin/env python
import pandas as pd
from printheader import print_header

cols = ['alpha', 'beta', 'gamma', 'delta', 'epsilon']  ①
index = pd.date_range('2013-01-01 00:00:00', periods=6, freq='D')  ②

print(index, "\n")

values = [  ③
    [100, 110, 120, 930, 140],
    [250, 210, 120, 130, 840],
    [300, 310, 520, 430, 340],
    [275, 410, 420, 330, 777],
    [300, 510, 120, 730, 540],
    [150, 610, 320, 690, 640],
]

df = pd.DataFrame(values, index, cols)  ④
print_header("Basic DataFrame:")
print(df)
print()

print_header("Triple each value")
print(df * 3)
print()  ⑤

print_header("Multiply column gamma by 1.5")
df['gamma'] *= 1.5  ⑥
print(df)
print()
```

① column labels

② date range to be used as row indexes

③ sample data

④ create dataframe from data

⑤ multiply every value by 3

⑥ multiply values in column 'gamma' by 1.

pandas_broadcasting.py

```
DatetimeIndex(['2013-01-01', '2013-01-02', '2013-01-03', '2013-01-04',
               '2013-01-05', '2013-01-06'],
              dtype='datetime64[ns]', freq='D')

==================================================
=                Basic DataFrame:                =
==================================================
            alpha  beta  gamma  delta  epsilon
2013-01-01    100   110    120    930      140
2013-01-02    250   210    120    130      840
2013-01-03    300   310    520    430      340
2013-01-04    275   410    420    330      777
2013-01-05    300   510    120    730      540
2013-01-06    150   610    320    690      640

==================================================
=               Triple each value                =
==================================================
            alpha  beta  gamma  delta  epsilon
2013-01-01    300   330    360   2790      420
2013-01-02    750   630    360    390     2520
2013-01-03    900   930   1560   1290     1020
2013-01-04    825  1230   1260    990     2331
2013-01-05    900  1530    360   2190     1620
2013-01-06    450  1830    960   2070     1920

==================================================
=          Multiply column gamma by 1.5          =
==================================================
            alpha  beta  gamma  delta  epsilon
2013-01-01    100   110  180.0    930      140
2013-01-02    250   210  180.0    130      840
2013-01-03    300   310  780.0    430      340
2013-01-04    275   410  630.0    330      777
2013-01-05    300   510  180.0    730      540
2013-01-06    150   610  480.0    690      640
```

Counting unique occurrences

- Use `.value_counts()`
- Called from column

To count the unique occurrences within a column, call the method `value_counts()` on the column. It returns a `Series` object with the column values and their counts.

Example

pandas_unique.py

```
import pandas as pd

df = pd.read_excel('http://qrc.depaul.edu/Excel_Files/Presidents.xlsx',
sheet_name='Master',
                  na_values='NA()')
df.index = range(1,len(df)+1)

# print(df.head())
parties = df['Political Party'].value_counts()
print(parties)
# parties.plot(kind='bar')
```

pandas_unique.py

```
Republican               19
Democrat                 15
Whig                      4
Democratic-Republican     4
None                      1
National Union            1
Federalist                1
Name: Political Party, dtype: int64
```

Removing entries

- Remove rows or columns
- Use drop() method

To remove columns or rows, use the drop() method, with the appropriate labels. Use axis=1 to drop columns, or axis=0 to drop rows.

Example

pandas_drop.py

```
#!/usr/bin/env python
import pandas as pd
from printheader import print_header

cols = ['alpha', 'beta', 'gamma', 'delta', 'epsilon']
index = ['a', 'b', 'c', 'd', 'e', 'f']
values = [
    [100, 110, 120, 130, 140],
    [200, 210, 220, 230, 240],
    [300, 310, 320, 330, 340],
    [400, 410, 420, 430, 440],
    [500, 510, 520, 530, 540],
    [600, 610, 620, 630, 640],
]
print_header('values:')
print(values, '\n\n')

df = pd.DataFrame(values, index=index, columns=cols)  ①
print_header('DataFrame df')
print(df, '\n')

df2 = df.drop(['beta', 'delta'], axis=1)  ②
print_header("After dropping beta and delta:")
print(df2, '\n')

print_header("After dropping rows b, c, and e")
df3 = df.drop(['b', 'c', 'e'])  ③
print(df3)
```

① create dataframe

② drop columns beta and delta (axes: 0=rows, 1=columns)

③ drop rows b, c, and e

pandas_drop.py

```
==================================================
=                    values:                     =
==================================================
[[100, 110, 120, 130, 140], [200, 210, 220, 230, 240], [300, 310, 320, 330, 340], [400,
410, 420, 430, 440], [500, 510, 520, 530, 540], [600, 610, 620, 630, 640]]



==================================================
=                  DataFrame df                  =
==================================================
   alpha  beta  gamma  delta  epsilon
a    100   110    120    130      140
b    200   210    220    230      240
c    300   310    320    330      340
d    400   410    420    430      440
e    500   510    520    530      540
f    600   610    620    630      640

==================================================
=         After dropping beta and delta:         =
==================================================
   alpha  gamma  epsilon
a    100    120      140
b    200    220      240
c    300    320      340
d    400    420      440
e    500    520      540
f    600    620      640

==================================================
=        After dropping rows b, c, and e         =
==================================================
   alpha  beta  gamma  delta  epsilon
a    100   110    120    130      140
d    400   410    420    430      440
f    600   610    620    630      640
```

Index objects

- Used to index Series or DataFrames
- index = pandas.core.frame.Index(sequence)
- Can be named

An *index object* is a kind of ordered set that is used to access rows or columns in a dataset. As shown earlier, indexes can be specified as lists or other sequences when creating a Series or DataFrame.

You can create an index object and then create a Series or a DataFrame using the index object. Index objects can be named, either something obvious like 'rows' or columns', or more appropriate to the specific type of of data being indexed.

Remember that index objects act like sets, so the main operations on them are unions, intersections, or differences.

TIP You can replace an existing index on a DataFrame with the set_index() method.

Example

pandas_index_objects.py

```
#!/usr/bin/env python
import pandas as pd
from printheader import print_header

index1 = pd.Index(['a', 'b', 'c'], name='letters')  ①
index2 = pd.Index(['b', 'a', 'c'])
index3 = pd.Index(['b', 'c', 'd'])
index4 = pd.Index(['red', 'blue', 'green'], name='colors')

print_header("index1, index2, index3", 70)  ②
print(index1)
print(index2)
print(index3)
print()

print_header("index2 & index3", 70)
# these are the same
print(index2 & index3)  ③
print(index2.intersection(index3))  ③
print()
```

```
print_header("index2 | index3", 70)
# these are the same
print(index2 | index3)  ④
print(index2.union(index3))
print()

print_header("index1.difference(index3)", 70)
print(index1.difference(index3))  ⑤
print()

print_header("Series([10,20,30], index=index1)", 70)
series1 = pd.Series([10, 20, 30], index=index1)  ⑥
print(series1)
print()

print_header("DataFrame([(1,2,3),(4,5,6),(7,8,9)], index=index1, columns=index4)", 70)
dataframe1 = pd.DataFrame([(1, 2, 3), (4, 5, 6), (7, 8, 9)], index=index1,
columns=index4)
print(dataframe1)
print()

print_header("DataFrame([(1,2,3),(4,5,6),(7,8,9)], index=index4, columns=index1)", 70)
dataframe2 = pd.DataFrame([(1, 2, 3), (4, 5, 6), (7, 8, 9)], index=index4,
columns=index1)
print(dataframe2)
print()
```

① create some indexes

② display indexes

③ get intersection of indexes

④ get union of indexes

⑤ get difference of indexes

⑥ use index with series (can also be used with dataframe) *pandas_index_objects.py*

```
======================================================================
=                       index1, index2, index3                       =
======================================================================
Index(['a', 'b', 'c'], dtype='object', name='letters')
Index(['b', 'a', 'c'], dtype='object')
Index(['b', 'c', 'd'], dtype='object')

======================================================================
=                          index2 & index3                           =
======================================================================
Index(['b', 'c'], dtype='object')
Index(['b', 'c'], dtype='object')

======================================================================
=                          index2 | index3                           =
======================================================================
Index(['a', 'b', 'c', 'd'], dtype='object')
Index(['a', 'b', 'c', 'd'], dtype='object')

======================================================================
=                     index1.difference(index3)                      =
======================================================================
Index(['a'], dtype='object')

======================================================================
=                  Series([10,20,30], index=index1)                  =
======================================================================
letters
a    10
b    20
c    30
dtype: int64

======================================================================
= DataFrame([(1,2,3),(4,5,6),(7,8,9)], index=index1, columns=index4) =
======================================================================
colors   red  blue  green
letters
a          1     2      3
b          4     5      6
c          7     8      9

======================================================================
= DataFrame([(1,2,3),(4,5,6),(7,8,9)], index=index4, columns=index1) =
======================================================================
letters  a  b  c
```

```
colors
red      1  2  3
blue     4  5  6
green    7  8  9
```

Data alignment

- pandas will auto-align data by rows and columns
- Non-overlapping data will be set as NaN

When two dataframes are combined, columns and indexes are aligned.

The result is the union of matching rows and columns. Where data doesn't exist in one or the other dataframe, it is set to NaN.

A default value can be specified for the overlapping cells when combining dataframes with methods such as add() or mul().

Use the fill_value parameter to set a default for missing values.

Example

pandas_alignment.py

```
#!/usr/bin/env python
import numpy as np
import pandas as pd
from printheader import print_header  ①

dataset1 = np.arange(9.).reshape((3, 3))  ②

df1 = pd.DataFrame(  ③
    dataset1,
    columns=['apple', 'banana', 'mango'],
    index=['orange', 'purple', 'blue']
)

dataset2 = np.arange(12.).reshape((4, 3))  ②

df2 = pd.DataFrame(  ③
    dataset2,
    columns=['apple', 'banana', 'kiwi'],
    index=['orange', 'purple', 'blue', 'brown']
)

print_header('df1')
print(df1)  ④
print()

print_header('df2')
print(df2)  ④
print()

print_header('df1 + df2')
print(df1 + df2)  ⑤

print_header('df1.add(df2, fill_value=0)')
print(df1.add(df2, fill_value=0))  ⑥
```

Time Series

- Use time_series()
- Specify start/end time/date, number of periods, time units
- Useful as index to other data
- freq=time_unit
- periods=number_of_periods

pandas provides a function **time_series()** to generate a list of timestamps. You can specify the start/end times as dates or dates/times, and the type of time units. Alternatively, you can specify a start date/time and the number of periods to create.

The frequency strings can have multiples – 5H means every 5 hours, 3S means every 3 seconds, etc.

Table 31. Units for time_series() freq flag

Unit	Represents
M	Month
D	Day
H	Hour
T	Minute
S	Second

Example

pandas_time_slices.py

```
#!/usr/bin/env python
import pandas as pd
import numpy as np

hourly = pd.date_range('1/1/2013 00:00:00', '1/3/2013 23:59:59', freq='H')  ①
print("Number of periods: ", len(hourly))

seconds = pd.date_range('1/1/2013 12:00:00', freq='S', periods=(60 * 60 * 18))  ②
print("Number of periods: ", len(seconds))
print("Last second: ", seconds[-1])

monthly = pd.date_range('1/1/2013', '12/31/2013', freq='M')  ③
print("Number of periods: {0} Seventh element: {1}".format(
    len(monthly),
    monthly[6]
))

NUM_DATA_POINTS = 1441  ④

dates = pd.date_range('4/1/2013 00:00:00', periods=NUM_DATA_POINTS, freq='T')  ⑤

data = np.random.random(NUM_DATA_POINTS)  ⑥

series = pd.Series(data, index=dates)  ⑦

time_slice = series['4/1/2013 10:00:00':'4/1/2013 10:30:00']  ⑧
print(time_slice)  # 31 values
```

① make time series — every hour for 3 days

② make time series — every second for 18 hours

③ every month for 1 year

④ number of minutes in a day

⑤ create range from starting point with specified number of points — one day’s worth of minutes

⑥ a day’s worth of data

⑦ series indexed by minutes

⑧ select the half hour of data from 10:00 to 10:30

pandas_time_slices.py

```
Number of periods:  72
Number of periods:  64800
Last second:  2013-01-02 05:59:59
Number of periods: 12 Seventh element: 2013-07-31 00:00:00
2013-04-01 10:00:00    0.466060
2013-04-01 10:01:00    0.984178
2013-04-01 10:02:00    0.501058
2013-04-01 10:03:00    0.858199
2013-04-01 10:04:00    0.357978
2013-04-01 10:05:00    0.370919
2013-04-01 10:06:00    0.352638
2013-04-01 10:07:00    0.207545
2013-04-01 10:08:00    0.811474
2013-04-01 10:09:00    0.703791
2013-04-01 10:10:00    0.538118
2013-04-01 10:11:00    0.262949
2013-04-01 10:12:00    0.011951
2013-04-01 10:13:00    0.249423
2013-04-01 10:14:00    0.239890
2013-04-01 10:15:00    0.765875
2013-04-01 10:16:00    0.712805
2013-04-01 10:17:00    0.370336
2013-04-01 10:18:00    0.126400
2013-04-01 10:19:00    0.395816
2013-04-01 10:20:00    0.191093
2013-04-01 10:21:00    0.712744
2013-04-01 10:22:00    0.905321
2013-04-01 10:23:00    0.072074
2013-04-01 10:24:00    0.683428
2013-04-01 10:25:00    0.286463
2013-04-01 10:26:00    0.906734
2013-04-01 10:27:00    0.315688
2013-04-01 10:28:00    0.605349
2013-04-01 10:29:00    0.720207
2013-04-01 10:30:00    0.667376
Freq: T, dtype: float64
```

Useful pandas methods

Table 32. Methods and attributes for fetching DataFrame/Series data

Method	**Description**
DF.columns()	Get or set column labels

DF.shape()
S.shape()
	Get or set shape (length of each axis)

DF.head(n)
DF.tail(n)
	Return n items (default 5) from beginning or end

DF.describe()
S.describe()
	Display statistics for dataframe

DF.info()	Display column attributes
DF.values S.values	Get the actual values from a data structure
DF.loc[row_indexer[1], col_indexer]	Multi-axis indexing by label (not by position)
DF.iloc[row_indexer[2], col_indexer]	Multi-axis indexing by position (not by labels)

[1] Indexers can be label, slice of labels, or iterable of labels.
[2] Indexers can be numeric index (0-based), slice of indexes, or iterable of indexes.

Table 33. Methods for Computations/Descriptive Stats (called from pandas)

Method	Returns
abs()	absolute values
corr()	pairwise correlations
count()	number of values
cov()	Pairwise covariance
cumsum()	cumulative sums
cumprod()	cumulative products
cummin(), cummax()	cumulative minimum, maximum
kurt()	unbiased kurtosis
median()	median
min(), max()	minimum, maximum values
prod()	products
quantile()	values at given quantile
skew()	unbiased skewness
std()	standard deviation
var()	variance

NOTE these methods return Series or DataFrames, as appropriate, and can be computed over rows (axis=0) or columns (axis=1). They generally skip NA/null values.

Example

pandas_read_csv.py

```
import pandas as pd

df = pd.read_csv('../DATA/sales_records.csv')  ①

print(df.describe())  ②
print()

print(df.info())  ③
print()

print(df.head())  ④
```

① Read CSV data into dataframe. Pandas automatically uses the first row as column names

② Get statistics on the numeric columns (use `df.describe(include='O')` for text columns)

③ Get information on all the columns ('object' means text/string)

④ Display first 5 rows of the dataframe (`df.describe(n)` displays n rows)

Even more pandas…

At this point, please load the following Jupyter notebooks for more pandas exploration:

- pandas_Demo.ipynb
- pandas_Input_Demo.ipynb
- pandas_Selection_Demo.ipynb

NOTE The instructor will explain how to start the Jupyter server.

Chapter 19 Exercises

Exercise 19-1 (add_columns.py)

Read in the file **sales_records.csv** as shown in the early part of the chapter. Add three new columns to the dataframe:

- Total Revenue (*units sold x unit price*)
- Total Cost (*units sold x unit cost*)
- Total Profit (*total revenue - total cost*)

Exercise 19-2 (parasites.py))

The file parasite_data.csv, in the DATA folder, has some results from analysis on some intestinal parasites (not that it matters for this exercise…). Read parasite_data.csv into a DataFrame. Print out all rows where the Shannon Diversity is >= 1.0.

Chapter 20: Introduction to Matplotlib

Objectives

- Understand what matplotlib can do
- Create many kinds of plots
- Label axes, plots, and design callouts

About matplotlib

- matplotlib is a package for making 2D plots
- Emulates MATLAB®, but not a drop-in replacement
- matplotlib’s philosophy: create simple plots simply
- Plots are publication quality
- Plots can be rendered in GUI applications

This chapter’s discussion of matplotlib will use the iPython notebook named **MatplotlibExamples.ipynb**. Please start the iPython notebook server and load this notebook, as directed by the instructor.

matplotlib architecture

- pylab/pyplot front end plotting functions
- API create/manage figures, text, plots
- backends device-independent renderers

matplotlib consists of roughly three parts: pylab/pyplot, the API, and and the backends.

pyplot is a set of functions which allow the user to quickly create plots. Pyplot functions are named after similar functions in MATLAB.

The API is a large set of classes that do all the work of creating and manipulating plots, lines, text, figures, and other graphic elements. The API can be called directly for more complex requirements.

pylab combines pyplot with numpy. This makes pylab emulate MATLAB more closely, and thus is good for interactive use, e.g., with iPython. On the other hand, pyplot alone is very convenient for scripting. The main advantage of pylab is that it imports methods from both pyplot and pylab.

There are many backends which render the in-memory representation, created by the API, to a video display or hard-copy format. For example, backends include PS for Postscript, SVG for scalable vector graphics, and PDF.

The normal import is

```
import matplotlib.pyplot as plt
```

Matplotlib Terminology

- Figure
- Axis
- Subplot

A Figure is one "picture". It has a border ("frame"), and other attributes. A Figure can be saved to a file.

A Plot is one set of values graphed onto the Figure. A Figure can contain more than one Plot.

Axes and Subplot are similar; the difference is how they get placed on the figure. Subplots allow multiple plots to be placed in a rectangular grid. Axes allow multiple plots to placed at any location, including within other plots, or overlapping.

matplotlib uses default objects for all of these, which are sufficient for simple plots. You can explicitly create any or all of these objects to fine-tune a graph. Most of the time, for simple plots, you can accept the defaults and get great-looking figures.

Matplotlib Keeps State

- Primary method is matplotlib.pyplot()
- The current figure can have more than one plot
- Calling show() displays the current figure

matplotlib.pyplot is the workhorse of figure drawing. It is usually aliased to "plt".

While Matplotlib is object oriented, and you can manually create figures, axes, subplots, etc., pyplot() will create a figure object for you automatically, and commands called from pyplot() (usually through the **plt** alias) will work on that object.

Calling **plt.plot()** plots one set of data on the current figure. Calling it again adds another plot to the same figure.

plt.show() displays the figure, although iPython may display each separate plot, depending on the current settings.

You can pass one or two datasets to plot(). If there are two datasets, they need to be the same length, and represent the x and y data.

What Else Can You Do?

- Multiple plots
- Control ticks on any axis
- Scatter plots
- Polar axes
- 3D Plots
- Quiver plots
- Pie Charts

There are many other types of drawings that matplotlib can create. Also, there are many more style details that can be tweaked. See http://matplotlib.org/gallery.html for dozens of sample plots and their source.

There are many extensions (AKA toolkits) for Matplotlib, including Seaborne, CartoPy, at Natgrid.

Matplotlib Demo

At this point, please open the notebook **MatPlotLibExamples.ipynb** for an instructor-led tour of MPL features.

Chapter 20 Exercises

Exercise 20-1 (energy_use_plot.py)

Using the file energy_use_quad.csv in the DATA folder, use matplotlib to plot the data for "Transportation", "Industrial", and "Residential and Commercial". Don't plot the "as a percent…".

You can do this in iPython, or as a standalone script. If you create a standalone script, save the figure to a file, so you can view it.

Use pandas to read the data. The columns are, in Python terms:

```
['Desc',"1960","1965","1970","1975","1980","1985","1990","1991","1992","1993","1994","199
5","1996","1997","1998","1999","2000","2001","2002","2003","2004","2005","2006","2007","2
008","2009","2010","2011"]
```

TIP See the script pandas_energy.py in the EXAMPLES folder to see how to load the data.

Appendix A: Where do I go from here?

Resources for learning Python

These are from Jessica Garson, who, among other things, teaches Python classes at NYU. (Used with permission).

Run the script **where_do_i_go.py** to display a web page with live links.

Resources for Learning Python [https://dev.to/jessicagarson/resources-for-learning-python-hd6]

Just getting started

Here are some resources that can help you get started learning how to code.

- Code Newbie Podcast [https://www.codenewbie.org/podcast]
- Dive into Python3 [http://www.diveintopython3.net]
- Learn Python the Hard Way [https://learnpythonthehardway.org/python3]
- Learn Python the Hard Way [https://learnpythonthehardway.org/python3]
- Automate the Boring Stuff with Python [https://automatetheboringstuff.com]
- Automate the Boring Stuff with Python [https://automatetheboringstuff.com]

So you want to be a data scientist?

- Data Wrangling with Python [https://www.amazon.com/Data-Wrangling-Python-Tools-Easier/dp/1491948817]
- Data Analysis in Python [http://www.data-analysis-in-python.org/index.html]
- Titanic: Machine Learning from Disaster [https://www.kaggle.com/c/titanic/discussion/5105]
- Deep Learning with Python [https://www.manning.com/books/deep-learning-with-python]
- How to do X with Python [https://chrisalbon.com/]
- Machine Learning: A Probabilistic Prospective [https://www.amazon.com/Machine-Learning-Probabilistic-Perspective-Computation/dp/0262018020]

So you want to write code for the web?

- Learn flask, some great resources are listed here [https://www.fullstackpython.com/flask.html]
- Django Polls Tutorial [https://docs.djangoproject.com/en/2.0/intro/tutorial01/]
- Hello Web App [https://www.amazon.com/Hello-Web-App-Learn-Build-ebook/dp/B00U5MMZ2E/ref=sr_1_1?ie=UTF8&qid=1510599119&sr=8-1&keywords=hello+web+app]
- Hello Web App Intermediate [https://www.amazon.com/Hello-Web-App-Intermediate-Concepts/dp/0986365920]

- Test-Driven-Development for Web Programming [https://www.obeythetestinggoat.com/pages/book.html#toc]
- 2 Scoops of Django [https://www.amazon.com/Two-Scoops-Django-1-11-Practices-ebook/dp/B076D5FKFX/ref=sr_1_1?s=books&ie=UTF8&qid=1510598897&sr=1-1&keywords=2+scoops+of+django]
- HTML and CSS: Design and Build Websites [https://www.amazon.com/HTML-CSS-Design-Build-Websites/dp/1118008189/ref=sr_1_1?ie=UTF8&qid=1510599157&sr=8-1&keywords=css+and+html]
- JavaScript and JQuery [https://www.amazon.com/JavaScript-JQuery-Interactive-Front-End-Development/dp/1118531647]

Not sure yet, that's okay!

Here are some resources for self guided learning. I recommend trying to be very good at Python and the rest should figure itself out in time.

- Python 3 Crash Course [https://www.amazon.com/Python-Crash-Course-Hands-Project-Based/dp/1593276036]
- Base CS Podcast [https://www.codenewbie.org/basecs]
- Writing Idiomatic Python [https://www.amazon.com/Writing-Idiomatic-Python-Jeff-Knupp-ebook/dp/B00B5VXMRG]
- Fluent Python [https://www.amazon.com/dp/1491946008?aaxitk=o7.Y1C9z7oJp87fs3ev30Q&pd_rd_i=1491946008&hsa_cr_id=1406361870001]
- Pro Python [https://www.amazon.com/Pro-Python-Marty-Alchin/dp/1484203356/ref=sr_1_1?s=books&ie=UTF8&qid=1510598874&sr=1-1&keywords=pro+python]
- Refactoring [https://www.amazon.com/Refactoring-Improving-Design-Existing-Code/dp/0201485672/ref=sr_1_1?ie=UTF8&qid=1510598784&sr=8-1&keywords=refactoring+martin+fowler]
- Clean Code [https://www.amazon.com/Clean-Code-Handbook-Software-Craftsmanship/dp/0132350882/ref=sr_1_1?s=books&ie=UTF8&qid=1510598926&sr=1-1&keywords=clean+code]
- Write music with Python, since that's my favorite way to learn a new language [https://github.com/reckoner165/soundmodular]

Appendix B: Virtual Environments

What are virtual environments?

Mary creates an app using spamlib and hamlib. She builds a distribution package and gives it to Paul. He installs spamlib and hamlib on his computer, which has a compatible Python interpreter, and then installs Mary's app. It starts to run, but then crashes with errors. What happened?

In the meantime, since Mary created her app, the author of spamlib removed a function "that almost noone used". When Paul installed spamlib, he installed the latest version, which does not have the function. The fix is for Paul to revert to an older version of spamlib, but suppose he has another app that uses the newer version? This can get very messy very quickly.

The solution to this problem is a **virtual environment**.

A virtual environment is a snapshot of a plain Python installation, before any other libraries are added. It is used to isolate a particular set of modules that will successfully run a given application.

Each application can have its own virtual environment, which ensures that it has the required versions of dependencies.

There are many tools for creating and using virtual environments, but the primary ones are **pip** and the **venv** module.

Preparing the virtual environment

Before creating a virtual environment, it is best to start with a "plain vanilla" Python installation of the desired release. You can use the base Python bundle from https://www.python.org/downloads, or the Anaconda bundle from https://www.anaconda.com/distribution.

You won’t use this installation directly — it will be more of a reference installation.

Creating the environment

The **venv** module provides the tools to create a new virtual environment. Basic usage is

```
python -m venv environment_name
```

This creates a virtual environment named *environment_name* in the current directory. It is a copy of the required parts of the original installation.

The virtual environment does not need to in the same location as your application. It is common to create a folder named *.envs* under your home folder to contain all your virtual environments.

Activating the environment

To use a virtual environment, it must be **activated**. This means that it takes precedence over any other installed Python version. This is is implemented by changing the PATH variable in your operating system's environment to point to the virtual copy.

venv will put the name of the environment in the terminal prompt.

Activating on Windows

To **activate** the environment on a Windows system, run the **activate.bat** script in the **Scripts** folder of the environment.

```
environment_name\Scripts\activate
```

Activating on non-Windows

To activate the environment on a Linux, Mac, or other Unix-like system, source the **activate** script in the **bin** folder of the environment. This must be *sourced*—run the script with the **source** builtin command, or the **.** shortcut

```
source environment_name/bin/activate
or
. environment_name/bin/activate
```

Deactivating the environment

When you are finished with an environment, you can deactivate it with the **deactivate** command. It does not need the leading path.

venv will remove the name of the environment from the terminal prompt.

Deactivating on Windows

Run the deactivate.bat script:

```
deactivate
```

Deactivating on non-Windows

Run the deactivate shell script:

```
deactivate
```

TIP To run an app with a particular environment, create a batch file or shell script that activates the environment, then runs the app with the environment's interpreter. When the script is finished, it should deactivate the environment.

Freezing the environment

When ready to share your app, specify the dependencies by running the **pip freeze** command. This will create a list of all the modules you have added to the virtual environments, and with their current versions. Since the output normally goes to *stdout*, it is conventional to redirect the output to a file named **requirements.txt**.

```
pip freeze > requirements.txt
```

Now you can provide your requirements.txt file to anyone who plans to run your app, and they can create a Python environment with the same versions of all required modules.

Duplicating an environment

When someone sends you an app with a requirements.txt file, it is easy to reproduce their environments. Install Python, then use pip to add the modules from requirements.txt. pip has a `-r` option, which says to read a file for a list of modules to be installed.

```
pip -r requirements.txt
```

That will add the module dependencies with the correct versions.

The pipenv/conda/virtualenv/PyCharm swamp

There are more tools to help with virtual environment management, and having them all available can be confusing. You can always just use pip and venv, as described above.

Here are a few of these tools, and what they do

`conda`
: A tool provided by Anaconda that replaces both pip and venv. It assumes you have the Anaconda bundle installed.

`pipenv`
: Another tool that replaces both pip and venv. It is very convenient, but has some annoying issues.

`virtualenv`
: The original name of the **venv** module.

`PyCharm`
: A Python IDE that will create virtual environments for you. It does not come with Python itself.

`virtualenvwrapper`
: A workflow manager that makes it more convenient to switch from one environment to another.

Multiple Python versions with `pyenv`

pyenv is a Python version controller.

It allows for multiple versions of Python to be installed for each user, by storing the installations in the user's home directory.

Those installations are added to the user's path, and managed through `pyenv`.

Installation requires a git clone and a one-time update to the user's shell.

```
> git clone https://github.com/pyenv/pyenv.git ~/.pyenv
> echo 'export PYENV_ROOT="~/.pyenv"' >>~/.bash_profile
> echo 'export PATH="$PYENV_ROOT/bin:$PATH"' >>~/.bash_profile
> echo -e 'if command -v pyenv 1>/dev/null 2>&1; then\n  eval "$(pyenv init -)"\nfi' >>
~/.bash_profile
> exec bash -l
```

Once set up, new versions can be installed to the user's home directory via the `pyenv install` command. Different versions can be switched between using the `local`, `shell`, and `global` commands to `pyenv`.

Because these python versions are installed in the user's home directory (under the `~/.pyenv` hidden directory), this can require more space if there are hundreds of users on the same machine, managing different versions of python. But for a dozen or fewer users on a single machine, `pyenv` does not take up significantly more space nor does it require elevated permissions.

As `pyenv` builds from source, it does require an adequate build environment. This varies from system to system, and from python version to python version (for instance, Python3.7 requires version 1.0.2+ of the SSL library). The `pyenv` page on GitHub has guidance on what libraries might need to be installed for a given environment.

Occasionally, `pyenv` will require an update to be made aware of newer python versions. Updating to the newest version on GitHub is sufficient.

```
> cd ~/.pyenv
> git pull
> cd -
```

Appendix C: Python Bibliography

Title	Author	Publisher
Data Science		
Building machine learning systems with Python	William Richert, Luis Pedro Coelho	Packt Publishing
High Performance Python	Mischa Gorlelick and Ian Ozsvald	O'Reilly Media
Introduction to Machine Learning with Python	Sarah Guido	O'Reilly & Assoc.
iPython Interactive Computing and Visualization Cookbook	Cyril Rossant	Packt Publishing
Learning iPython for Interactive Computing and Visualization	Cyril Rossant	Packt Publishing
Learning Pandas	Michael Heydt	Packt Publishing
Learning scikit-learn: Machine Learning in Python	Raúl Garreta, Guillermo Moncecchi	Packt Publishing
Mastering Machine Learning with Scikit-learn	Gavin Hackeling	Packt Publishing
Matplotlib for Python Developers	Sandro Tosi	Packt Publishing
Numpy Beginner's Guide	Ivan Idris	Packt Publishing
Numpy Cookbook	Ivan Idris	Packt Publishing
Practical Data Science Cookbook	Tony Ojeda, Sean Patrick Murphy, Benjamin Bengfort, Abhijit Dasgupta	Packt Publishing
Python Text Processing with NLTK 2.0 Cookbook	Jacob Perkins	Packt Publishing
Scikit-learn cookbook	Trent Hauck	Packt Publishing
Python Data Visualization Cookbook	Igor Milovanovic	Packt Publishing
Python for Data Analysis	Wes McKinney	O'Reilly & Assoc.
Design Patterns		
Design Patterns: Elements of Reusable Object-Oriented Software	Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides	Addison-Wesley Professional

Title	**Author**	**Publisher**
Head First Design Patterns	Eric Freeman, Elisabeth Robson, Bert Bates, Kathy Sierra	O'Reilly Media
Learning Python Design Patterns	Gennadiy Zlobin	Packt Publishing
Mastering Python Design Patterns	Sakis Kasampalis	Packt Publishing
General Python development		
Expert Python Programming	Tarek Ziadé	Packt Publishing
Fluent Python	Luciano Ramalho	O'Reilly & Assoc.
Learning Python, 2nd Ed.	Mark Lutz, David Asher	O'Reilly & Assoc.
Mastering Object-oriented Python	Stephen F. Lott	Packt Publishing
Programming Python, 2nd Ed.	Mark Lutz	O'Reilly & Assoc.
Python 3 Object Oriented Programming	Dusty Phillips	Packt Publishing
Python Cookbook, 3nd. Ed.	David Beazley, Brian K. Jones	O'Reilly & Assoc.
Python Essential Reference, 4th. Ed.	David M. Beazley	Addison-Wesley Professional
Python in a Nutshell	Alex Martelli	O'Reilly & Assoc.
Python Programming on Win32	Mark Hammond, Andy Robinson	O'Reilly & Assoc.
The Python Standard Library By Example	Doug Hellmann	Addison-Wesley Professional
Misc		
Python Geospatial Development	Erik Westra	Packt Publishing
Python High Performance Programming	Gabriele Lanaro	Packt Publishing
Networking		
Python Network Programming Cookbook	Dr. M. O. Faruque Sarker	Packt Publishing
Violent Python: A Cookbook for Hackers, Forensic Analysts, Penetration Testers and Security Engineers	T J O'Connor	Syngress
Web Scraping with Python	Ryan Mitchell	O'Reilly & Assoc.
Testing		

Title	Author	Publisher
Python Testing Cookbook	Greg L. Turnquist	Packt Publishing
Learning Python Testing	Daniel Arbuckle	Packt Publishing
Learning Selenium Testing Tools, 3rd Ed.	Raghavendra Prasad MG	Packt Publishing
Web Development		
Building Web Applications with Flask	Italo Maia	Packt Publishing
Django 1.0 Website Development	Ayman Hourieh	Packt Publishing
Django 1.1 Testing and Development	Karen M. Tracey	Packt Publishing
Django By Example	Antonio Melé	Packt Publishing
Django Design Patterns and Best Practices	Arun Ravindran	Packt Publishing
Django Essentials	Samuel Dauzon	Packt Publishing
Django Project Blueprints	Asad Jibran Ahmed	Packt Publishing
Flask Blueprints	Joel Perras	Packt Publishing
Flask by Example	Gareth Dwyer	Packt Publishing
Flask Framework Cookbook	Shalabh Aggarwal	Packt Publishing
Flask Web Development	Miguel Grinberg	O’Reilly & Assoc.
Full Stack Python (e-book only)	Matt Makai	Gumroad (or free download)
Full Stack Python Guide to Deployments (e-book only)	Matt Makai	Gumroad (or free download)
High Performance Django	Peter Baumgartner, Yann Malet	Lincoln Loop
Instant Flask Web Development	Ron DuPlain	Packt Publishing
Learning Flask Framework	Matt Copperwaite, Charles O Leifer	Packt Publishing
Mastering Flask	Jack Stouffer	Packt Publishing
Two Scoops of Django: Best Practices for Django 1.11	Daniel Roy Greenfeld, Audrey Roy Greenfeld	Two Scoops Press
Web Development with Django Cookbook	Aidas Bendoraitis	Packt Publishing

Appendix D: Chapter 21: Multiprogramming

Objectives

- Understand multiprogramming
- Differentiate between threads and processes
- Know when threads benefit your program
- Learn the limitations of the GIL
- Create a threaded application
- Implement a queue object
- Use the multiprocessing module
- Develop a multiprocessing application

Multiprogramming

- Parallel processing
- Three main ways to achieve it
  - threading
  - multiple processes
  - asynchronous communication
- All three supported in standard library

Computer programs spend a lot of their time doing nothing. This occurs when the CPU is waiting for the relatively slow disk subsystem, network stack, or other hardware to fetch data.

Some applications can achieve more throughput by taking advantage of this slack time by seemingly doing more than one thing at a time. With a single-core computer, this doesn't really happen; with a multicore computer, an application really can be executing different instructions at the same time. This is called multiprogramming.

The three main ways to implement multiprogramming are threading, multiprocessing, and asynchronous communication:

Threading subdivides a single process into multiple subprocesses, or threads, each of which can be performing a different task. Threading in Python is good for IO-bound applications, but does not increase the efficiency of compute-bound applications.

Multiprocessing forks (spawns) new processes to do multiple tasks. Multiprocessing is good for both CPU-bound and IO-bound applications.

Asynchronous communication uses an event loop to poll multiple I/O channels rather than waiting for one to finish. Asynch communication is good for IO-bound applications.

The standard library supports all three.

What Are Threads?

- Like processes (but lighter weight)
- Process itself is one thread
- Process can create one more more additional threads
- Similar to creating new processes with fork()

Modern operating systems (OSs) use time-sharing to manage multiple programs which appear to the user to be running simultaneously. Assuming a standard machine with only one CPU, that simultaneity is only an illusion, since only one program can run at a time, but it is a very useful illusion. Each program that is running counts as a process. The OS maintains a process table, listing all current processes. Each process will be shown as currently being in either Run state or Sleep state.

A thread is like a process. A thread might even be a process, depending on the implementation. In fact, threads are sometimes called “lightweight” processes, because threads occupy much less memory, and take less time to create, than do processes.

A process can create any number of threads. This is similar to a process calling the fork() function. The process itself is a thread, and could be considered the "main" thread.

Just as processes can be interrupted at any time, so can threads.

The Python Thread Manager

- Python uses underlying OS's threads
- Alas, the GIL – Global Interpreter Lock
- Only one thread runs at a time
- Python interpreter controls end of thread's turn
- Cannot take advantage of multiple processors

Python "piggybacks" on top of the OS's underlying threads system. A Python thread is a real OS thread. If a Python program has three threads, for instance, there will be three entries in the OS's thread list.

However, Python imposes further structure on top of the OS threads. Most importantly, there is a global interpreter lock, the famous (or infamous) GIL. It is set up to ensure that (a) only one thread runs at a time, and (b) that the ending of a thread's turn is controlled by the Python interpreter rather than the external event of the hardware timer interrupt.

The fact that the GIL allows only one thread to execute Python bytecode at a time simplifies the Python implementation by making the object model (including critical built-in types such as dict) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines. The takeaway is that Python does not currently take advantage of multi-processor hardware.

NOTE *GIL* is pronounced "jill", according to Guido__

For a thorough discussion of the GIL and its implications, see http://www.dabeaz.com/python/UnderstandingGIL.pdf.

The threading Module

- Provides basic threading services
- Also provides locks
- Three ways to use threads
    - Instantiate **Thread** with a function
    - Subclass **Thread**
    - Use pool method from **multiprocessing** module

The threading module provides basic threading services for Python programs. The usual approach is to subclass threading.Thread and provide a run() method that does the thread's work.

Threads for the impatient

- No class needed (created "behind the scenes")
- For simple applications

For many threading tasks, all you need is a run() method and maybe some arguments to pass to it.

For simple tasks, you can just create an instance of Thread, passing in positional or keyword arguments.

Example

thr_noclass.py

```
#!/usr/bin/env python

import threading
import random
import time


def doit(num):  ①
    time.sleep(random.randint(1, 3))
    print("Hello from thread {}".format(num))


for i in range(10):
    t = threading.Thread(target=doit, args=(i,))  ②
    t.start()  ③

print("Done.")  ④
```

① function to launch in each thread

② create thread

③ launch thread

④ "Done" is printed immediately — the threads are "in the background" *thr_noclass.py*

```
Done.
Hello from thread 7
Hello from thread 0
Hello from thread 1
Hello from thread 8
Hello from thread 5
Hello from thread 2
Hello from thread 3
Hello from thread 6
Hello from thread 4
Hello from thread 9
```

Creating a thread class

- Subclass Thread
- *Must* call base class's __init__()
- *Must* implement run()
- Can implement helper methods

A thread class is a class that starts a thread, and performs some task. Such a class can be repeatedly instantiated, with different parameters, and then started as needed.

The class can be as elaborate as the business logic requires. There are only two rules: the class must call the base class's __init__(), and it must implement a run() method. Other than that, the run() method can do pretty much anything it wants to.

The best way to invoke the base class __init__() is to use super().

The run() method is invoked when you call the start() method on the thread object. The start() method does not take any parameters, and thus run() has no parameters as well.

Any per-thread arguments can be passed into the constructor when the thread object is created.

Example

thr_simple.py

```
#!/usr/bin/env python

from threading import Thread
import random
import time


class SimpleThread(Thread):
    def __init__(self, num):
        super().__init__()  ①
        self._threadnum = num

    def run(self):  ②
        time.sleep(random.randint(1, 3))
        print("Hello from thread {}".format(self._threadnum))


for i in range(10):
    t = SimpleThread(i)  ③
    t.start()  ④

print("Done.")
```

① call base class constructor — REQUIRED

② the function that does the work in the thread

③ create the thread

④ launch the thread

thr_simple.py

```
Done.
Hello from thread 0
Hello from thread 3
Hello from thread 6
Hello from thread 9
Hello from thread 5
Hello from thread 7
Hello from thread 1
Hello from thread 4
Hello from thread 2
Hello from thread 8
```

Variable sharing

- Variables declared *before thread starts* are shared
- Variables declared *after thread starts* are local
- Threads communicate via shared variables

A major difference between ordinary processes and threads how variables are shared.

Each thread has its own local variables, just as is the case for a process. However, variables that existed in the program before threads are spawned are shared by all threads. They are used for communication between the threads.

Access to global variables is controlled by locks.

Example

thr_locking.py

```
#!/usr/bin/env python
import threading  ①
import random
import time

WORDS = 'apple banana mango peach papaya cherry lemon watermelon fig elderberry'.split()

MAX_SLEEP_TIME = 3
WORD_LIST = []  ②
WORD_LIST_LOCK = threading.Lock()  ③
STDOUT_LOCK = threading.Lock()  ③

class SimpleThread(threading.Thread):
    def __init__(self, num, word):  ④
        super().__init__()  ⑤
        self._word = word
        self._num = num

    def run(self):  ⑥
        time.sleep(random.randint(1, MAX_SLEEP_TIME))
        with STDOUT_LOCK:  ⑦
            print("Hello from thread {} ({})".format(self._num, self._word))

        with WORD_LIST_LOCK:  ⑦
            WORD_LIST.append(self._word.upper())

all_threads = []  ⑧
for i, random_word in enumerate(WORDS, 1):
    t = SimpleThread(i, random_word)  ⑨
    all_threads.append(t)  ⑩
    t.start()  ⑪

print("All threads launched...")

for t in all_threads:
    t.join()  ⑫

print(WORD_LIST)
```

① see multiprocessing.dummy.Pool for the easier way

② the threads will append words to this list

③ generic locks

④ thread constructor

⑤ be sure to call parent constructor

⑥ function invoked by each thread

⑦ acquire lock and release when finished

⑧ make list ("pool") of threads (but see Pool later in chapter)

⑨ create thread

⑩ add thread to "pool"

⑪ start thread

⑫ wait for thread to finish

thr_locking.py

```
All threads launched...
Hello from thread 6 (cherry)
Hello from thread 10 (elderberry)
Hello from thread 2 (banana)
Hello from thread 1 (apple)
Hello from thread 4 (peach)
Hello from thread 3 (mango)
Hello from thread 7 (lemon)
Hello from thread 8 (watermelon)
Hello from thread 5 (papaya)
Hello from thread 9 (fig)
['CHERRY', 'ELDERBERRY', 'BANANA', 'APPLE', 'PEACH', 'MANGO', 'LEMON', 'WATERMELON',
'PAPAYA', 'FIG']
```

Using queues

- Queue contains a list of objects
- Sequence is FIFO
- Worker threads can pull items from the queue
- Queue structure has builtin locks

Threaded applications often have some sort of work queue data structure. When a thread becomes free, it will pick up work to do from the queue. When a thread creates a task, it will add that task to the queue.

The queue must be guarded with locks. Python provides the Queue module to take care of all the lock creation, locking and unlocking, and so on, so that you don't have to bother with it.

Example

thr_queue.py

```
#!/usr/bin/env python
import random
import queue
from threading import Thread, Lock as tlock
import time

NUM_ITEMS = 25000
POOL_SIZE = 100

q = queue.Queue(0)  ①

shared_list = []
shlist_lock = tlock()  ②
stdout_lock = tlock()  ②


class RandomWord():  ③
    def __init__(self):
        with open('../DATA/words.txt') as words_in:
            self._words = [word.rstrip('\n\r') for word in words_in.readlines()]
        self._num_words = len(self._words)

    def __call__(self):
        return self._words[random.randrange(0, self._num_words)]
```

```
class Worker(Thread):  ④

    def __init__(self, name):  ⑤
        Thread.__init__(self)
        self.name = name

    def run(self):  ⑥
        while True:
            try:
                s1 = q.get(block=False)  ⑦
                s2 = s1.upper() + '-' + s1.upper()
                with shlist_lock:  ⑧
                    shared_list.append(s2)

            except queue.Empty:  ⑨
                break


⑩
random_word = RandomWord()
for i in range(NUM_ITEMS):
    w = random_word()
    q.put(w)

start_time = time.ctime()

⑪
pool = []
for i in range(POOL_SIZE):
    worker_name = "Worker {:c}".format(i + 65)
    w = Worker(worker_name)  ⑫
    w.start()  ⑬
    pool.append(w)

for t in pool:
    t.join()  ⑭

end_time = time.ctime()

print(shared_list[:20])

print(start_time)
print(end_time)
```

① initialize empty queue

② create locks

③ define callable class to generate words

④ worker thread

⑤ thread constructor

⑥ function invoked by thread

⑦ get next item from thread

⑧ acquire lock, then release when done

⑨ when queue is empty, it raises Empty exception

⑩ fill the queue

⑪ populate the threadpool

⑫ add thread to pool

⑬ launch the thread

⑭ wait for thread to finish

thr_queue.py

```
['INCONSEQUENTIAL-INCONSEQUENTIAL', 'CLIMBER-CLIMBER', 'SLANDEROUSNESSES-
SLANDEROUSNESSES', 'SUBTASK-SUBTASK', 'COVARIANCE-COVARIANCE', 'OVERT-OVERT', 'LIRIPIPE-
LIRIPIPE', 'REOBSERVES-REOBSERVES', 'BARNIER-BARNIER', 'SPEEDOS-SPEEDOS', 'DISSYMMETRY-
DISSYMMETRY', 'TITULARS-TITULARS', 'SWORDPLAYS-SWORDPLAYS', 'APPEARS-APPEARS', 'HELLOING-
HELLOING', 'ATHENEUM-ATHENEUM', 'CHURCHIANITIES-CHURCHIANITIES', 'MANUALS-MANUALS',
'LITERATURES-LITERATURES', 'GREATHEARTEDNESS-GREATHEARTEDNESS']
Wed Aug 18 13:44:18 2021
Wed Aug 18 13:44:18 2021
```

Debugging threaded Programs

- Harder than non-threaded programs
- Context changes abruptly
- Use pdb.trace
- Set breakpoint programmatically

Debugging is always tough with parallel programs, including threads programs. It's especially difficult with pre-emptive threads; those accustomed to debugging non-threads programs find it rather jarring to see sudden changes of context while single-stepping through code. Tracking down the cause of deadlocks can be very hard. (Often just getting a threads program to end properly is a challenge.)

Another problem which sometimes occurs is that if you issue a "next" command in your debugging tool, you may end up inside the internal threads code. In such cases, use a "continue" command or something like that to extricate yourself.

Unfortunately, threads debugging is even more difficult in Python, at least with the basic PDB debugger.

One cannot, for instance, simply do something like this:

```
pdb.py buggyprog.py
```

This is because the child threads will not inherit the PDB process from the main thread. You can still run PDB in the latter, but will not be able to set breakpoints in threads.

What you can do, though, is invoke PDB from within the function which is run by the thread, by calling pdb.set trace() at one or more points within the code:

```
import pdb
pdb.set_trace()
```

In essence, those become breakpoints.

For example, we could add a PDB call at the beginning of a loop:

```
import pdb
while True:
    pdb.set_trace() # app will stop here and enter debugger
    k = c.recv(1)
    if k == □□:
        break
```

You then run the program as usual, NOT through PDB, but then the program suddenly moves into debugging mode on its own. At that point, you can then step through the code using the n or s commands, query the values of variables, etc.

PDB's c ("continue") command still works. Can you still use the b command to set additional breakpoints? Yes, but it might be only on a one-time basis, depending on the context.

The multiprocessing module

- Drop-in replacement for the threading module
- Doesn't suffer from GIL issues
- Provides interprocess communication
- Provides process (and thread) pooling

The multiprocessing module can be used as a replacement for threading. It uses processes rather than threads to spread out the work to be done. While the entire module doesn't use the same API as threading, the multiprocessing.Process object is a drop-in replacement for a threading.Thread object. Both use run() as the overridable method that does the work, and both use start() to launch. The syntax is the same to create a process without using a class:

```
def myfunc(filename):
      pass

p = Process(target=myfunc, args=('/tmp/info.dat', ))
```

This solves the GIL issue, but the trade-off is that it's slightly more complicated for tasks (processes) to communicate. However, the module does the heavy lifting of creating pipes to share data.

The **Manager** class provided by multiprocessing allows you to create shared variables, as well as locks for them, which work across processes.

NOTE On windows, processes must be started in the "if __name__ == __main__" block, or they will not work.

Example

multi_processing.py

```
#!/usr/bin/env python
import sys
import random
from multiprocessing import Manager, Lock, Process, Queue, freeze_support
from queue import Empty
import time

NUM_ITEMS = 25000  ①
POOL_SIZE = 100
```

```
class RandomWord():  ②
    def __init__(self):
        with open('../DATA/words.txt') as words_in:
            self._words = [word.rstrip('\n\r') for word in words_in]
        self._num_words = len(self._words)

    def __call__(self):  ③
        return self._words[random.randrange(0, self._num_words)]


class Worker(Process):  ④

    def __init__(self, name, queue, lock, result):  ⑤
        Process.__init__(self)
        self.queue = queue
        self.result = result
        self.lock = lock
        self.name = name

    def run(self):  ⑥
        while True:
            try:
                word = self.queue.get(block=False)  ⑦
                word = word.upper()  ⑧
                with self.lock:
                    self.result.append(word)  ⑨

            except Empty:  ⑩
                break


if __name__ == '__main__':
    if sys.platform == 'win32':
        freeze_support()

    word_queue = Queue()  ⑪

    manager = Manager()  ⑫
    shared_result = manager.list()  ⑬
    result_lock = Lock()  ⑭

    random_word = RandomWord()  ⑮
    for i in range(NUM_ITEMS):
        w = random_word()
        word_queue.put(w)  ⑯

    start_time = time.ctime()
    pool = []  ⑰
    for i in range(POOL_SIZE):  ⑱
        worker_name = "Worker {:03d}".format(i)
        w = Worker(worker_name, word_queue, result_lock, shared_result)  ⑲
        #
        w.start()  ⑳
        pool.append(w)

    for t in pool:
        t.join()

    end_time = time.ctime()

    print((shared_result[-50:]))
    print(len(shared_result))
    print(start_time)
    print(end_time)
```

① set some constants

② callable class to provide random words

③ will be called when you call an instance of the class

④ worker class — inherits from Process

⑤ initialize worker process

⑥ do some work — will be called when process starts

⑦ get data from the queue

⑧ modify data

⑨ add to shared result

⑩ quit when there is no more data in the queue

⑪ create empty Queue object

⑫ create manager for shared data

⑬ create list-like object to be shared across all processes

⑭ create locks

⑮ create callable RandomWord instance

⑯ fill the queue

⑰ create empty list to hold processes

⑱ populate the process pool

⑲ create worker process

⑳ actually start the process — note: in Windows, should only call X.start() from main(), and may not work inside an IDE

add process to pool

wait for each queue to finish

print last 50 entries in shared result

multi_processing.py

```
['DESALINATING', 'FIPPLES', 'POLYENE', 'UNMARRIEDS', 'DISENDOWERS', 'SAREES', 'SHAW',
'VOCALIZATION', 'REQUALIFY', 'ONCIDIUM', 'REFELL', 'DISPATCHER', 'CORNUTOS',
'CONSULTANTS', 'BRIGANTINE', 'MACRONUTRIENTS', 'FOREDECKS', 'DIVAGATE', 'HUMMINGBIRD',
'FRAGMENTALLY', 'RUTHFUL', 'WRINGERS', 'CLOSETS', 'EGGHEADS', 'COMMISSARS',
'VITUPERATION', 'SUCCOTH', 'RETEXTURES', 'SUFFUSION', 'UNPLOWED', 'FAZE', 'HYPERARID',
'FANATICIZES', 'INDELICATENESSES', 'RACINGS', 'SYLVA', 'DACOIT', 'TEEN', 'NEURONAL',
'CORSAC', 'PAEANISMS', 'CUMULATIVE', 'APPRESSORIUM', 'ISSEI', 'AMICABLE', 'AWAITERS',
'PLURALISTIC', 'PURLOINERS', 'CHUCKLINGLY', 'GARGLE']
25000
Wed Aug 18 13:44:18 2021
Wed Aug 18 13:44:20 2021
```

Using pools

- Provided by **multiprocessing**
- Both thread and process pools
- Simplifies multiprogramming tasks

For many multiprocessing tasks, you want to process a list (or other iterable) of data and do something with the results. This is easily accomplished with the Pool object provided by the **multiprocessing** module.

This object creates a pool of *n* processes. Call the **.map()** method with a function that will do the work, and an iterable of data. map() will return a list the same size as the list that was passed in, containing the results returned by the function for each item in the original list.

For a thread pool, import **Pool** from **multiprocessing.dummy**. It works exactly the same, but creates threads.

Example

proc_pool.py

```
#!/usr/bin/env python

import random
from multiprocessing import Pool

POOL_SIZE = 30  ①

with open('../DATA/words.txt') as words_in:
    WORDS = [w.strip() for w in words_in]  ②

random.shuffle(WORDS)  ③


def my_task(word):  ④
    return word.upper()


if __name__ == '__main__':
    ppool = Pool(POOL_SIZE)  ⑤

    WORD_LIST = ppool.map(my_task, WORDS)  ⑥

    print(WORD_LIST[:20])  ⑦

    print("Processed {} words.".format(len(WORD_LIST)))
```

① number of processes

② read word file into a list, stripping off \n

③ randomize word list

④ actual task

⑤ create pool of POOL_SIZE processes

⑥ pass wordlist to pool and get results; map assigns values from input list to processes as needed

⑦ print last 20 words

proc_pool.py

```
['TARNS', 'PERDURABILITIES', 'COMAKES', 'LANGOUSTINE', 'ADOPTERS', 'REBUTTABLE',
'HOPELESS', 'TANGED', 'RESEEDING', 'TETRAMEROUS', 'UNCASES', 'RAMENS', 'NINEBARK',
'PLANETESIMAL', 'DIPTEROCARP', 'SENSUOUS', 'BERDACHE', 'MANDATOR', 'SHIKARRED', 'SKIDDY']
Processed 173466 words.
```

Example

thr_pool.py

```
#!/usr/bin/env python

import random
from multiprocessing.dummy import Pool ①

POOL_SIZE = 30 ②

with open('../DATA/words.txt') as words_in:
    WORDS = [w.strip() for w in words_in] ③

random.shuffle(WORDS) ④

def my_task(word):  ⑤
    return word.upper()

tpool = Pool(POOL_SIZE) ⑥

WORD_LIST = tpool.map(my_task, WORDS) ⑦

print(WORD_LIST[:20])  ⑧

print("Processed {} words.".format(len(WORD_LIST)))
```

① get the thread pool object

② set # of threads to create

③ get list of 175K words

④ shuffle the word list <5>

thr_pool.py

```
['SURVIVERS', 'REACQUIRING', 'PAVISE', 'INDUSTRIALLY', 'EPHORI', 'TRAIN', 'HETERODYNE',
'MULTIDIMENSIONALITY', 'BAHT', 'ANTEVERTING', 'PICTORIALISM', 'PROSPECTING',
'SUPERCURRENT', 'FOOTBALLER', 'SECERNED', 'FRIENDLILY', 'STEPFATHERS', 'MULTIPLICATION',
'PSYCHOLOGIZES', 'FEEBLENESS']
Processed 173466 words.
```

Example

thr_pool_mw.py

```
#!/usr/bin/env python
from multiprocessing.dummy import Pool  ①
from pprint import pprint
import requests

POOL_SIZE = 4

BASE_URL = 'https://www.dictionaryapi.com/api/v3/references/collegiate/json/'  ②

API_KEY = 'b619b55d-faa3-442b-a119-dd906adc79c8' ③

search_terms = [  ④
    'wombat',
    'frog', 'muntin', 'automobile', 'green', 'connect',
    'vial', 'battery', 'computer', 'sing', 'park',
    'ladle', 'ram', 'dog', 'scalpel'
]


def fetch_data(term):  ⑤
    try:
        response = requests.get(
            BASE_URL + term,
            params={'key': API_KEY},
        )  ⑥
    except requests.HTTPError as err:
        print(err)
        return []
    else:
        data = response.json()  ⑦
        parts_of_speech = []
        for entry in data: ⑧
            if isinstance(entry, dict):
                meta = entry.get("meta")
                if meta:
                    part_of_speech = entry.get("fl")
                    if part_of_speech:
                        parts_of_speech.append(part_of_speech)
        return sorted(set(parts_of_speech))  ⑨


p = Pool(POOL_SIZE)  ⑩

results = p.map(fetch_data, search_terms)  ⑪
```

```
for search_term, result in zip(search_terms, results):  ⑫
    print("{}:".format(search_term.upper()))
    if result:
        print(result)
    else:
        print("** no results **")
```

① .dummy has Pool for threads

② base url of site to access

③ credentials to access site

④ terms to search for; each thread will search some of these terms

⑤ function invoked by each thread for each item in list passed to map()

⑥ make the request to the site

⑦ convert JSON to Python structure

⑧ loop over entries matching search terms

⑨ return list of parsed entries matching search term

⑩ create pool of POOL_SIZE threads

⑪ launch threads, collect results

⑫ iterate over results, mapping them to search terms

…

Alternatives to multiprogramming

- asyncio
- Twisted

Threading and forking are not the only ways to have your program do more than one thing at a time. Another approach is asynchronous programming. This technique putting events (typically I/O events) in a list, or queue, and starting an event loop that processes the events one at a time. If the granularity of the event loop is small, this can be as efficient as multiprogramming.

Asynchronous programming is only useful for improving I/O throughput, such as networking clients and servers, or scouring a file system. Like threading (in Python), it will not help with raw computation speed.

The **asyncio** module in the standard library provides the means to write asynchronous clients and servers.

The **Twisted** framework is a large and well-supported third-party module that provides support for many kinds of asynchronous communication. It has prebuilt objects for servers, clients, and protocols, as well as tools for authentication, translation, and many others. Find Twisted at twistedmaxtrix.com/trac.

Chapter 21 Exercises

For each exercise, ask the questions: Should this be multi-threaded or multi-processed? Distributed or local?

Exercise 21-1 (pres_thread.py)

Using a thread pool (multiprocessing.dummy), calculate the age at inauguration of the presidents. To do this, read the presidents.txt file into an array of tuples, and then pass that array to the mapping function of the thread pool. The result of the map function will be the array of ages. You will need to convert the date fields into actual dates, and then subtract them.

Exercise 21-2 (folder_scanner.py)

Write a program that takes in a directory name on the command line, then traverses all the files in that directory tree and prints out a count of:

- how many total files
- how many total lines (count '\n')
- how many bytes (len() of file contents)

HINT: Use either a thread or a process pool in combination with **os.walk()**.

FOR ADVANCED STUDENTS

Exercise 21-3 (web_spider.py)

Write a website-spider. Given a domain name, it should crawl the page at that domain, and any other URLs from that page with the same domain name. Limit the number of parallel requests to the web server to no more than 4.

Exercise 21-4 (sum_tuple.py)

Write a function that will take in two large arrays of integers and a target. It should return an array of tuple pairs, each pair being one number from each input array, that sum to the target value.

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