Python

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About Python

What is Python?

- A programming language
- Open Source
  - Free; source code available
  - Download on your own system
- Written by Guido van Rossum
- Monty Python's Flying Circus…

- First release Feb 1991: 0.9.0
- Current version: 3.7
- Backward incompatibility issues are rare
  - But they do exist…
  - Largest change: from 2.0 to 3.0

Features of Python

- A script language
- Interpreted
  - No compile/link stage
  - Write and run
  - Slow compared to C, C++
- Elegant design; “tight”
- Designed for
  - Quick-and-dirty scripts
  - Reusable modules
  - Very large systems
- Object-oriented
  - Very well-designed
  - But you don’t have to use it
- Useful error messages
- Automatic memory handling
- Independent of operating system
  - Works on both Unix and Windows
  - Even file system code can be made os-independent
- Large library of standard modules
- Large number of third-party modules
- Integration with external C code
- Well documented

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'.*

Part 1:
Variables and built-in types

Basic data types

Object type	Example literals/creation
Numbers	1234, 3.1415, 3+4j
Strings	‘spam’, “Bob’s”
Lists	[1, [2, ‘three’], 4.5]
Dictionaries	{‘food’: ‘spam’, ‘taste’: ‘yum’}
Tuples	(1, ‘spam’, 4, ‘U’)
Files	open(‘eggs.txt’)
Sets	{‘a’, ‘b’, ‘c’}
Other core types	Boolean, None

Useful functions

- **type**(*object*) – returns type of an *object*
- **dir**(*object*) – returns a list of attributes for an *object*

```
>>> a = ‘Just a string’
>>> type(a)
<class ‘str’>

>>> dir(10)
[ '__abs__', '__add__', '__and__', '__bool__’, … , 'bit_length', 'conjugate',
'denominator', 'from_bytes', 'imag', 'numerator', 'real', 'to_bytes’ ]
```

Useful functions

- **help**(*object*) – returns description of an *object*

```
>>> help(int)

class int(object)
 |  int(x=0) -> integer
 |  int(x, base=10) -> integer
 |
 |  Convert a number or string to an integer, or return 0 if no arguments
 |  are given.  If x is a number, return x.__int__().  For floating point
 |  numbers, this truncates towards zero.
 |
 |  If x is not a number or if base is given, then x must be a string,
 |  bytes, or bytearray instance representing an integer literal in the
 |  given base.  The literal can be preceded by '+' or '-' and be surrounded
 |  by whitespace.  The base defaults to 10.  Valid bases are 0 and 2-36.
 |  Base 0 means to interpret the base from the string as an integer literal.
 |  >>> int('0b100', base=0)
 |  4
 |
```

Numeric types and literals

Object type	Example literals/creation
Integers (unlimited size)	1234, -24, 0, 99999999999
Floating-point numbers	1.23, 1., 3.14e-10
Octal, hex, binary	0**o**177, 0**x**9ff, 0**b**101010
Complex numbers	3+4j, 3j
Decimal and Fraction	Decimal('1.0'), Fraction(1,3)

Numeric tools

Expression operators:

+, -, *, /, >>, **, &, etc.

```
>>> 2 + 3
5

>>> 2 ** 19
524288

>>> 8 >> 2
2
```

```
>>> a = 1000001
>>> b = 29
>>> a % b
23

>>> a < ( 3 ** 14)
True
```

Numeric tools

Built-in mathematical functions:

pow, abs, round, int, hex, oct, bin, etc.

```
>>> pow(2, 19)
524288

>>> abs(-1.19)
1.19

>>> round(1.19)
1
```

```
>>> int(3.99)
3

>>> int('111', 2)
7

>>> hex(123)
'0x7b'

>>> bin(99999)
'0b11000011010011111'
```

Numeric tools

Utility modules

random, math, etc.

```
>>> import math
>>> math.pi
3.141592653589793

>>> math.factorial(10)
3628800

>>> math.hypot(3, 4)
5
```

```
>>> import random
3

>>> random.randint(1,10)
4

>>> random.choice(['me', 'you'])
'you'
```

Type mixing

Besides mixing operators in expressions we can also mix numeric types
Python ranks the complexity of given types and converts to a more complex type
Base ranking is: integer < float < complex

```
>>> 40 + 3.14                    # integer to float
43.14
>>> int(3.14)                    # Truncates float to integer
3
>>> float(4)                     # Converts integer to float
```

Division

True division – operator /
In Python 3.x operator / performs *true* division, always keeping reminders in floating-point results, regardless of types.

```
>>> 10 / 4
2.5

>>> 10 / 4.0
2.5
```

Floor division – operator //
Operator // always truncates fractional reminders down to their floor , regardless of types. Result type depends on the types of operands.

```
>>> 10 // 4
2

>>> 10 // 4.0
2.0
```

String

String
An ordered collection of characters used to store and represent text-based information.

Literal	Interpretation
S = ‘’	Empty string
S = “spam’s”	Double quotes, same as single
S = “”””….multiline…””” ”	Triple-quoted block strings

Escape sequences

Backslashes are used to introduce special character codings known as escape *sequences*. Escape sequences let us embed characters in string that cannot be easily typed on a keyboard.

```
>>> s = ‘a\nb\tc’                    # \n is a newline, \t is a tab
>>> print(s)
a
b      c
>>> path = ‘C:\new\text.dat’
>>> path2 = r ‘C:\new\text.dat”
'C:\\new\\text.dat‘
```

Basic operations

Function *len*, *concatenation*, *repetition* and operation *in*

```
>>> len('abc')                    # Length: number of items
3
>>> 'abc' + 'def'                 # Concatenation: a new string
'abcdef'
>>> 'Ni!' * 4                     # Repetition
'Ni!Ni!Ni!Ni!'
>>> 'k' in 'I hate lections on Saturday'
False
>>> 'lections' in 'I hate lections on Saturday'
True
```

Indexing and Slicing

Indexing let us to get a single character (returned as single character string) by numerical offset.
Slicing is a generalized form of indexing. Returns an entire section, not a single item.

```
>>> s = 'spam'
>>> s[0]
's'
>>> s[2]
'a'
>>> s[1:3]
'pa'
```

```
>>> s = 'slice of life'
>>> s[-1
'e'
>>> 'abc'[:]
'abc'
```

```
>>> 'hello'[::2]
'hlo'
>>> 'hello'[::-1]
'olleh'
```

Conversions

One of Python design mottos is it refuses the temptation to guess. As a prime example you cannot add a string and a number together in Python even if string looks like a number.

```
>>> “42” + 1
Traceback (most important call last):
   File “<stdin>”, line 1, in <module>
TypeError: must be str, not int

>>>  “42” + str(1)
‘421’

>>> int(“42”) + 1
43’
```

```
>>> ord(“s”)
115

>> chr(115)
‘s’
```

String methods

```
>>> ‘BIG’.lower()
'big’
>>> ‘small’.upper()
'SMALL’
>>> ‘SMALL AnD big’.swapcase()
'small aNd BIG’
```

```
>>> ‘Saturday’.startswith(‘coffe’)
False
>>> ‘Saturday’.endswith(‘ay’)
True
>>> ‘Hi my name is Hillary’.count(‘Hi’)
2
>>> ‘try to find me in such a long long string’.find(‘me’)
12
>>> ‘a-b-c-d’.replace(‘-’,’PEW’)
'aPEWbPEWcPEWd’
```

```
>>> ‘,’.join([‘words’, ‘separated’, ‘by’, ‘commas’])
'words,separated,by,commas'
>>> ‘                    spaces around     \t \n’.strip()
'spaces around’
>>> ‘%%$%$%garbade will be gone(()()(#’.strip(‘%$()#’)
'garbade will be gone’
>>> ‘aaa bbb ccc 12 123 1’.split()
['aaa', 'bbb', 'ccc', '12', '123', '1']
```

Lists

Ordered collections of arbitrary objects
Lists are just places to collect other objects which maintain a left-to-right positional ordering among the items they contain

Accessed by offset
Lists are ordered by their positions, so you can fetch objects by index (position) and also do tasks such as slicing, concatenation.

Variable-length, heterogeneous, and arbitrarily nestable
Lists can grow and shrink in place. They can contain any sort of object including other complex objects.
Lists also support arbitrary nesting.

List creation

Literal/expression	Interpretation
a = []; a = list()	Empty list
a = [1, 2, ‘abc’, 1.5]	Heterogeneous list
a = [‘Vasiliy’, 21, [‘python’, ‘metaheuristics’]]	Nested list
a = list(‘list me’)	List from iterable
a = [int(x) ** 2 for x in ‘123’]	List comprehension

Basic operations

```
>>> len([1,2,3,4])                    # Length: number of items
4
>>> list(‘abc’) + list(‘def’)         # Concatenation: a new list
['a', 'b', 'c', 'd', 'e', 'f’]
>>>  ‘Ni!’] * 4                       # Repetition
['Ni', 'Ni', 'Ni', 'Ni’]
>>> ‘needle’ in [‘haystack’, 1, 0.99999, [1,2,3], ‘needle’]
True
>>> [‘first’, ‘second’, ‘third’][1]   # Indexing
'second'
>>> [1, 2, 3, 4, 5, 6, 7, 8][-2::-2]  # Slicing
[7, 5, 3, 1]
```

Changes

List are **mutable,** so we can change them without creating new lists using some operators and methods.

```
>>> a = [1, 2, 3, 4, 5]
>>> a[-1] = 100 # Assigning by index - [1, 2, 3, 4, 100]
>>> a[::2] = [100, 100, 100] # Assigning a slice  - [100, 2, 100, 4, 100]
>>> a[3:] = [1, 1, 1, 1, 1] # [100, 2, 100, 1, 1, 1, 1, 1]
>>> [1, 2, 3, 4, 5].append(6) # Add new element
>>> [1, 2, 3, 4, 5].extend([6,7,8]) # Add elements from second list
– result is [1, 2, 3, 4, 5, 6, 7, 8]
>>> [1, 2, 4, 5].insert(2, 3) # Insert element 3 in position 2 – result is [1, 2, 3, 4, 5]
```

Changes

```
>>> a = [1, 2, 3, 4, 5, 4]
>>> a.remove(4) # Removes the first occurrence of element 4 – result is [1, 2, 3, 5, 4]
>>> del (a[0]) # Built-in function del also can be used, result is [2, 3, 5, 4]
>>> del (a[1:3]) # del for slices, result is [2, 4]
>>> first_element = a.pop(0) # Delete element with index 0` and return it
>>> first_element
2
```

Lists sorting

```
>>> a = ['abc’, 1, 0.99]
>>> a.sort()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: '<' not supported between instances of 'int' and 'str'

>>> a = ['abc', 'ABD', 'aBe']
>>> sorted(a, key=str.lower, reverse=True)  # Using built-in function sorted
['ABD', 'aBe', 'abc']

>>> a = ['abc', 'ABD', 'aBe']
>>> a.sort() # Sort with mixed case
>>> a
['ABD', 'aBe', 'abc']
```

Other methods

```
>>> a = [1, 2, 3, 4]
>>> a.reverse()  # Reverse order
>>> a
[4, 3, 2, 1]
>>> a = [1, 2, 3, 4, 3, 2, 1]
>>> a.index(3)  # We already know this method – it is common for all 'sequence' classes
2
>>> a.count(1)  # We already know this method – it is common for all 'sequence' classes
2
```

List comprehensions

Python supports a concept called *list comprehensions*. It can be used to construct lists in a very natural, easy way.

```
>>> result = []
>>> for c in ‘SPAM’:
...         result.append(c * 4)
...
>>> result
['SSSS', 'PPPP', 'AAAA', 'MMMM’]
>>> a = [1, 2, 3, 4, 5]
>>> b = [x + 10 for x in a] # Create a new list using list comprehension
>>> b
[21, 22, 23, 24, 25]
```

List comprehensions

Extended list comprehensions syntax

```
>>> test = [21, 1, 9123, 323, 112]
>>> [x for x in test if x % 7 == 0]
[21, 112]

>>> alpha_test = ‘alpha’, ’12hi’, ‘c’, ‘100%’, ‘last_word’]
>>> [x for x in alpha_test if x.isalpha()]
['alpha', 'c']
```

Tuple

Tuples work exactly like lists, except that tuples **can't be changed** in place (they are **immutable**).

Ordered collections of arbitrary objects

Accessed by offset

Of the category "immutable sequence"
Like strings and lists, tuples are sequences; they support many of the same operations. However, like strings, tuples are immutable; they don't support any of the in-place change operations applied to lists.
Fixed-length, heterogeneous, and arbitrarily nestable

Tuple creation

Literal/expression	Interpretation
()	Empty tuple
t = (0,)	A one-item tuple (not an expression)
t = (0, ‘Ni’, 1.2)	A three-item tuple
t = 0, ‘Ni’, 1.2	Another three-item tuple
t = (‘Vasiliy’, 21, (‘python’, ‘metaheuristics’))	Nested tuple
t = tuple(‘spam’)	Tuple from iterable

Basic operations

Function *len*, *concatenation*, *repetition*, operation *in*, *slicing*

```
>>> len((1,2,3,4))                    # Length: number of items
4
>>> tuple('abc') + tuple('def')    # Concatenation: a new list
('a', 'b', 'c', 'd', 'e', 'f')
>>> ('Ni!',) * 4                      # Repetition
('Ni', 'Ni', 'Ni', 'Ni')
>>> 'needle' in ('haystack', 1, 0.99999, [1,2,3], 'needle')
True
>>> ('first', 'second', 'third')[1]   # Indexing
'second'
>>> (1, 2, 3, 4, 5, 6, 7, 8)[-2::-2]  # Slicing
(7, 5, 3, 1)
```

Other methods

```
>>> a = (1, 2, 3, 4, 3, 2, 1)
>>> a.index(3)  # We already know this method – it is common for all ‘sequence’ classes
2
>>> a.count(1)  # We already know this method – it is common for all ‘sequence’ classes
2
>>> t = (‘cc’, ‘aa’, ‘dd’, ‘bb’) # Lets sort this
>>> tmp = list(t) # Cast this to a list
>>> tmp.sort() # Sort the list
>>> t = tuple(tmp) # Finally get back to tuple
('aa', 'bb', 'cc', 'dd')
>>> t = (‘cc’, ‘aa’, ‘dd’, ‘bb’) # Lets sort this
>>> sorted(t) # Or use built-in sorted function
 'aa', 'bb', 'cc', 'dd']
```

Dictionaries

In dictionaries, items are stored and fetched by a *key*, instead of by positional offset. Dictionaries can replace many of the searching algorithms and data structures you might have to implement manually in lower-level languages.

Accessed by key, not offset position

Unordered collections of arbitrary objects

Variable-length, heterogeneous, and arbitrarily nestable

Of the category "mutable mapping"

Tables of object references (hash tables)

Dicts creation

Literal/expression	Interpretation
d = {}; d = dict()	Empty dict
d = {‘name’: ‘Vasiliy’, ‘age’: 21}	Two-item dict
d = {‘lector’:{‘name’: ‘Vasiliy’, ‘age’: ‘21’}}	Nested dicts
d = dict(name=‘Vasiliy’, age=21)	Another two-item dict
d = dict([(‘name’, Vasiliy’), (‘age’, 21)])	Dict from list of tuples
d = dict.fromkeys([‘name’, ‘age’], ‘Empty’)	Dict from keys

Basic operations

Indexing, function *len*, membership operator, getting keys/values

```
>>> d = {‘spam’:2, ‘eggs’: 3, ‘ham’: 1}   # Create a simple dict
>>> d[‘eggs’]  # Fetch a value by a key
3
>>> len(d)
3
>>> ‘ham’ in d, 2 in d
(True, False)
>>> list(d.keys())  # Create list of all dict keys
['spam', 'eggs', 'ham']
```

In-place changes

```
>>> d = {‘spam’:2, ‘eggs’: 3, ‘ham’: 1}   # Create a simple dict
>>> d[‘ham’] = [‘grill’, ‘bake’, ‘fry’]  # Change entry
>>> d
{'spam': 2, 'eggs': 3, 'ham': ['grill', 'bake', 'fry’]}

>>> del d(‘eggs’)  # Delete entry
>>> d
{'spam': 2, 'ham': ['grill', 'bake', 'fry’]}
>>> d[‘brunch’] = (1,2,3) # Create a new entry
>>> d
{'spam': 2, 'ham': ['grill', 'bake', 'fry'], 'brunch': (1, 2, 3)}
```

Other dict methods

```
>>> d = {‘spam’:2, ‘eggs’: 3, ‘ham’: 1}   # Create a simple dict
>>> list(d.values())
[2, 3, 1]
>>> list(d.items())  # Fetch all items as tuples with key-value
[('spam', 2), ('eggs', 3), ('ham', 1)]
>>> d.get(‘spam’) # Key exists
2
>>> print(d.get('wurf’), 88) # Key is missing
88
>>> d2 = {'toast':4, 'muffin': 5}
>>> d.update(d2) # update with new keys
>>> d
{'spam': 2, 'eggs': 3, 'ham': 1, 'toast': 4, 'muffin': 5}
```

Other dict methods

```
>>> d.pop('muffin') # Delete and return object
5
>>> d.pop('strange key') # Operating with missing key
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'strange key'

>>> d.setdefault('strange key', 'strange value') # Fetch a value by a key and create a new key if it is missing
'strange value'
>>> d.clear() # Remove all items from dictionary
>>> d
{}
```

Dict comprehensions

```
>>> d = { x: x**2 for x in (2, 4, 6)} # Dict comprehension
>>> d
{2: 4, 4: 16, 6: 36}

>>>source_string = ‘string for vowels search’
>>> all_vowels = [‘a’, ‘e’, ‘i’, ‘o’, ‘u’, ‘y’]
>>> d = { x: source_string.count(x) for x in source_string if x in all_vowels }
# Extended dict comprehension

>>> d
{'i': 1, 'o': 2, 'e': 2, 'a': 1}
```

Sets

A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference

```
>>> basket = {'apple', 'orange', 'apple', 'pear', 'orange'} # simple set
>>> basket
{'pear', 'apple', 'orange'}
>>> set('abracadabra')
{'c', 'b', 'a', 'd', 'r'}
```

Basic operations

Function len, fast membership testing, equality test

```
>>> basket = {'apple', 'orange', 'apple', 'pear', 'orange'} # simple set
>>> len(basket)
3
>>> 'orange' in basket  # fast membership testing
True

>>> set('spam') == set('asmp') #Order-neutral equality tests
True
```

Set operations

```
>>> a = set('abracadabra')
>>> b = set('alacazam')
>>> a - b                     # letters in a but not in b
{'r', 'd', 'b'}
>>> a | b                     # letters in a or b or both
{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}
>>> a & b                     # letters in both a and b
{'a', 'c'}
>>> a > b                     # b is a superset
False
>>> {1,2} < {5,4,3,2,1}       # subset test
True
```

Set methods

In place change methods, set comprehensions

```
>>> basket = {'apple', 'orange', 'apple', 'pear', 'orange'}
>>> basket.add('pineapple') # add element to a set
>>> basket.remove('orange') # remove element from a set
>>> basket
{'pear', 'pineapple', 'apple'}
>>> basket.update(['pen', 'pineapple', 'apple', 'pen']) # update set with some elements
>>> basket
{'pear', 'apple', 'pen', 'pineapple'}
>>> a = {x for x in 'abracadabra' if x not in 'abc'} # set comprehensions
>>> a
{'r', 'd'}
```

Files

File objects are Python code's main interface to external files on your computer. Files are a core type, but there is no specific literal syntax for creating them. To create a file object, you call the built-in open function, passing in an external filename and an optional processing mode as strings.

```
>>> f = open('data.txt', 'w') # Open/create a file in 'w' – write mode
>>> f.write('Hello\n') # Returns number of characters written
6
>>> f.close() # Close to flush output buffer to disk
```

Files

It is good practice to use the with keyword when dealing with file objects. The advantage is that the file is properly closed after its suite finishes.

```
>>> with open('file.txt') as f:  # f = open('file.txt')
...         first_row = f.readline()   # read a single line
```

```
>>> full_file = f.read() # read all file content
```

```
>>> for line in f:  # iterate over file lines
...         print(line, end='')
```

Boolean

Python today has an explicit Boolean data type called bool, with the values True and False. Internally, the names True and False are instances of bool, which is in turn just a subclass of the built-in integer type int. True and False behave exactly like the integers 1 and 0, except that they have customized printing logic- they print themselves as the words True and False.

```
>>> type(True)
<class 'bool'>
>>> True == 1 # Same value
True
>>> True or False # Same as: 1 or 0
True
```

NoneType

The sole value of the type NoneType is None. None is frequently used to represent the absence of a value. Assignments to None are illegal and raise a SyntaxError.

```
>>> a = [1,2,3].sort()
>>> type(a)
<class 'NoneType'>
>>> a is None
True
>>> a == None
True
>>> a = [None] * 10
>>> a
[None, None, None, None, None, None, None, None, None, None]
```

Interview

1. Reverse the number using list
2. Reverse the number using string
3. Reverse the number using only basic operations

Assignment Statement Forms

Dicts creation

Dicts creation

Dicts creation

Boolean expressions

- ‘True’ and ‘ False’ are predefined values; actually integers 1 and 0
- Value 0 is considered False, all other values True
- The usual Boolean expression operators: not, and, or

```
>>> True or False
True
>>> not ((True and False) or True)
False
>>> True * 12
12
>>> 0 and 1
0
```

- Comparison operators produce Boolean values
- The usual suspects: <, <=, >, >=, ==, !=

```
>>> 12<13
True
>>> 12>13
False
>>> 12<=12
True
>>> 12!=13
True
```

String

```
>>> a = 'Hello world!'
>>> b = "Hello world!"
>>> a == b
True
```

```
>>> a = "Per's lecture"
>>> print a
Per's lecture
```

- Single quotes <u>or</u> double quotes can be used for string literals
- Produces exactly the same value
- Special characters in string literals: \n newline, \t tab, others
- Triple quotes useful for large chunks of text in program code

```
>>> a = "One line.\nAnother line."
>>> print a
One line.
Another line.
```

```
>>> b = """One line,
another line."""
>>> print b
One line,
another line.
```

String conversions

```
>>> a = "58"
>>> type(a)
<type 'str'>
>>> b=int(a)
>>> b
58
>>> type(b)
<type 'int'>
```

```
>>> f = float('1.2e-3')
>>> f                    # uses 'repr'
0.0011999999999999999
>>> print f              # uses 'str'
0.0012
>>> eval('23-12')
11
```

- Convert data types using functions ‘str’, ‘int’, ‘float’
- ‘repr’ is a variant of ‘str’
  - intended for strict, code-like representation of values
  - ‘str’ usually gives nicer-looking representation
- Function ‘eval’ interprets a string as a Python expression

```
>>> c = int('blah')            # what happens when something illegal is done?
Traceback (most recent call last):
  File "<pyshell#34>", line 1, in -toplevel-
    c = int('blah')
ValueError: invalid literal for int(): blah
```

String operations

- Common string operations on page 75 in ‘Learning Python’

```
>>> a = "Part 1"
>>> b = "and part 2"
>>> a + ' ' + b            # concatenation, adding strings
'Part 1 and part 2'
>>> s = a * 2              # repeat and concatenate string
>>> print s
Part 1Part 1
```

```
>>> s[0]                   # index: one single character, offset 0 (zero)
'P'
>>> s[0:4]                 # slice: part of string
'Part‘
>>> s[5:]                  # leave out one boundary: to the end
'1Part 1'
>>> >>> s[6:-1]            # negative index counts from the end
'Part '
```

```
>>> len(s)                 # function ‘len’ to get length of string
12
>>> 'p' in s               # membership test
False
>>> 'P' in s
True
>>> 'Part' in s            # also works for substrings (new feature)
True
```

Changing strings. Not!

```
>>> s[0] = 'B'
Traceback (most recent call last):
  File "<pyshell#68>", line 1, in -toplevel-
    s[0] = 'B'
TypeError: object doesn't support item assignment
```

- A string cannot be changed in Python! Immutable
- Good reasons for this; more later
- Create new strings from bits and pieces of old

```
>>> s = 'B' + s[1:]
>>> s
'Bart 1Part 1'
```

- Recreating strings may use a lot of computing power
- If you need to create many new strings, learn string formatting (more later)
- List processing can often be used to make string handling more efficient

String methods

- Strings have a set of built-in methods
- No method ever changes the original string!
- Several methods produce new strings
- A list on page 91 in ‘Learning Python’

```
>>> s = 'a string, with stuff'
>>> s.count('st')                    # how many substrings?
2
>>> s.find('stu')                    # give location of substring, if any
15
>>> three = '3'
>>> three.isdigit()                  # only digit characters in string?
True
```

```
>>> supper = s.upper()               # convert to upper case
>>> supper
'A STRING, WITH STUFF'
>>> s.rjust(30)                      # right justify by adding blanks
'          a string, with stuff'
>>> "newlines\n\n\n".strip()         # a string literal also has methods!
'newlines'
```

```
>>> s.replace('stuff', 'characters') # replace substring (all occurrences)
'a string, with characters'
>>> s.replace('s', 'X', 1)           # replace only once
'a Xtring, with stuff'
```

List

- Ordered collection of objects; array
- Heterogenous; may contain mix of objects of any type

```
>>> r = [1, 2.0, 3, 5]        # list literal; different types of values
>>> r
[1, 2.0, 3, 5]
>>> type(r)
<type 'list'>
```

```
>>> r[1]                      # access by index; offset 0 (zero)
2.0
>>> r[-1]                     # negative index counts from end
5
```

```
>>> r[1:3]                    # a slice out of a list; gives another list
[2.0, 3]
```

```
>>> w = r + [10, 19]          # concatenate lists; gives another list
>>> w
[1, 2.0, 3, 5, 10, 19]
>>> r                         # original list unchanged; w and r are
different
[1, 2.0, 3, 5]
```

```
>>> t = [0.0] * 10            # create an initial vector using repetition
>>> t
[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
```

List operations

- Lists are mutable; can be changed in-place
- Lists are dynamic; size may be changed

```
>>> r = [1, 2.0, 3, 5]
>>> r[3] = 'word'            # replace an item by index
>>> r
[1, 2.0, 3, 'word']
```

```
>>> r[0] = [9, 8]            # lists can be nested
>>> r
[[9, 8], 2.0, 3, 'word']
```

```
>>> r[0:3] = [1, 2, 5, 6]    # change a slice of list; may change list
length
>>> r
[1, 2, 5, 6, 'word']
>>> r[1:3] = []              # remove items by setting slice to empty list
>>> r
[1, 6, 'word']
```

```
>>> len(r)                   # length of list; number of items
3
```

```
>>> 6 in r                   # membership test
True
>>> r.index(6)               # search for position; bombs if item not in
list
1
```

List methods, part 1

- Lists have a set of built-in methods
- Some methods change the list in-place

```
>>> r = [1, 2.0, 3, 5]
>>> r.append('thing')              # add a single item to the end
>>> r
[1, 2.0, 3, 5, 'thing']
>>> r.append(['another', 'list'])  # list treated as a single item
>>> r
[1, 2.0, 3, 5, 'thing', ['another', 'list']]
```

```
>>> r = [1, 2.0, 3, 5]
>>> r.extend(['item', 'another'])  # list items appended one by one
>>> r
[1, 2.0, 3, 5, 'item', 'another']
```

```
>>> k = r.pop()                    # remove last item from list and return
>>> k
'another'
>>> r
[1, 2.0, 3, 5, 'item']
```

- Methods 'append' and 'pop' can be used to implement a stack

List methods, part 2

- Use the built-in 'sort' method: efficient
- The list is sorted in-place; a new list is <u>not</u> produced!

```
>>> r = [2, 5, -1, 0, 20]
>>> r.sort()
>>> r
[-1, 0, 2, 5, 20]
```

```
>>> w = ['apa', '1', '2', '1234']
>>> w.sort()                        # strings: lexical sort using ASCII order
>>> w
['1', '1234', '2', 'apa']
```

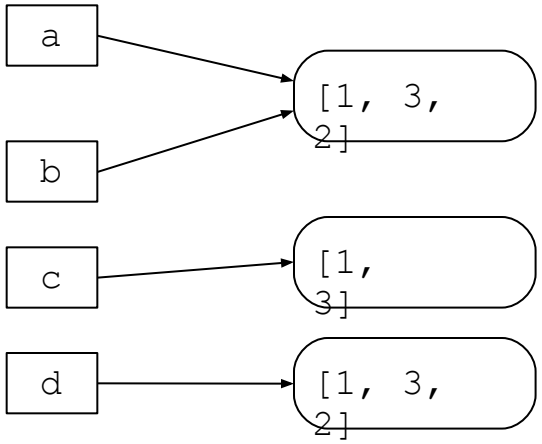
```
>>> w.reverse()                     # how to flip a list; in-place!
>>> w
['apa', '2', '1234', '1']
```

```
>>> v = w[:]                        # first create a copy of the list
>>> v.reverse()                     # then reverse the copy
>>> v                               # use same technique for sort
['1', '1234', '2', 'apa']
>>> w
['apa', '2', '1234', '1']
```

Objects, names and references

- All values are objects
- A variable is a name referencing an object
- An object may have several names referencing it
- Important when modifying objects in-place!
- You may have to make proper copies to get the effect you want
- For immutable objects (numbers, strings), this is never a problem

```
>>> a = [1, 3, 2]
>>> b = a
>>> c = b[0:2]
>>> d = b[:]
```




```
>>> b.sort()    # 'a' is affected!
>>> a
[1, 2, 3]
```

Dictionary

- An unordered collection of key/value pairs
- Each key maps to a value
- Also called "mapping", "hash table" or "lookup table"

```
>>> h = {'key': 12, 'nyckel': 'word'}
>>> h['key']                                    # access by key
12
>>> h.has_key('nyckel')
True
```

```
>>> h['Per'] = 'Kraulis'                        # adding a key/value
>>> h
{'nyckel': 'word', 'Per': 'Kraulis', 'key': 12}  # the output order is
random
>>> h['Per'] = 'Johansson'                      # replaces the value
>>> h
{'nyckel': 'word', 'Per': 'Johansson', 'key': 12}
```

- The key is
  - Usually an integer or a string
  - Should (must!) be an immutable object
  - May be any object that is 'hashable' (more later)
  - Any key occurs at most once in a dictionary!
- The value may be any object
  - Values may occur many times

Forgetting things: garbage collection

- What happens to the object when its name is ’del’ed, or reassigned to another object?
- Don’t worry, be happy!
- The Python systems detects when an object is ’lost in space’
  - It keeps track of the number of references to it
- The object’s memory gets reclaimed; garbage collection
- A few problematic special cases; cyclical references

Dictionary methods, part 1

```
>>> h = {'key': 12, 'nyckel': 'word'}
>>> 'Per' in h                          # test if key in dictionary
False
>>> h['Per']
Traceback (most recent call last):
  File "<pyshell#192>", line 1, in -toplevel-
    h['Per']
KeyError: 'Per'
```

```
>>> h.get('Per', 'unknown')             # return value, or default if not found
'unknown'
>>> h.get('key', 'unknown')
12
```

```
>>> h.keys()                    # all keys in a list; unordered
['nyckel', 'key']
>>> h.values()                  # all values in a list; unordered
['word', 12]
```

```
>>> len(h)                      # number of keys in dictionary
2
```

Dictionary methods, part 2

```
>>> g = h.copy()              # a separate copy of the dictionary
>>> del h['key']
>>> h
{'nyckel': 'word'}
>>> g
{'nyckel': 'word', 'key': 12}
```

```
>>> h['Per'] = 'Johansson'
>>> h
{'nyckel': 'word', 'Per': 'Johansson'}
>>> h.update(g)                          # add or update all key/value from
g
>>> h
{'nyckel': 'word', 'key': 12, 'Per': 'Johansson'}
```

Tuple

- Same as list, except immutable
- Once created, can't be changed
- Some functions return tuples

```
>>> t = (1, 3, 2)
>>> t[1]                          # access by index; offset 0 (zero)
3
```

```
>>> (a, b, c) = t                 # tuple assignment (unpacking)
>>> a
1
>>> b
3
>>> a, b, c                       # actually a tuple expression!
(1, 3, 2)
```

```
>>> a, b = b, a                   # neat trick to swap values
>>> a, b
(3, 1)
```

```
>>> r = list(t)                   # convert tuple to a list
>>> r
[1, 3, 2]
>>> tuple(r)                      # convert list to a tuple
(1, 3, 2)
```

String formatting

- String formatting operator '%'
- Usually the best way to create new strings
- C-like formatting: Slightly tricky, but powerful
- Many string formatting codes
  - %s: string (uses function 'str')
  - %r: string (uses function 'repr')
  - %f, %e, %g: float

```
>>> w = "Number %i won!" % 12     # string formatting operator %
>>> w
'Number 12 won!'
```

- Tuples are used as operands in string formatting when >1 items
- The length of the tuple must match the number of format codes in the string
- Lists won't do!

```
>>> c = 'Python'
>>> n = 11
>>> "This is a %s course with %i students." % (c, n)
'This is a Python course with 11 students.'
```

Part 2: Statements

'if' statement; block structure

- The Python feature that one either loves or hates
- Block structure is determined by indentation

- Edit a new script file 't2.py'
  - In window 't1.py' do 'File', 'New Window', then 'Save As…
- Use the 'if' statement:

```
"file t2.py"

person = 'Luke'

if person == 'Per':
    status = 'Pythonist'
elif person == 'Luke':
    status = 'Jedi knight'
else:
    status = 'unknown'

print person, status
```

- Note that the IDLE editor helps with indentation
- Run the script (F5)

Dictionary often better than if… elif…

- Particularly with many hardcoded choices (elif's)…

```
"file t3.py"

status_map = {'Luke': 'Jedi Knight',
              'Per': 'Pythonist'}

person = 'Luke'

print person, status_map.get(person, 'unknown')
```

- More compact, and more efficient
- This pattern is very useful

Built-in types and their Boolean interpretations

int	0	False
	-1	True
	124	True
float	0.0	False
str	""	False
	"False"	True !
dict	{ }	False
	{'key': 'val'}	True
list	[ ]	False
	[False]	True !

- All built-in types can be used directly in 'if' statements

- Zero-valued numbers are False
- All other numbers are True

- Empty containers (str, list, dict) are False
- All other container values are True

- Use function 'bool' to get explicit value

'for' statement

- Repetition of a block of statements
- Iterate through a sequence (list, tuple, string, iterator)

```
"file t4.py"

s = 0
for i in [0, 1, 2, 3, 4, 5, 6, 7, 8]:     # walk through list, assign to i
    s = s + i
    if s > 10:
        break                             # quit 'for' loop, jump to after
it

print "i=%i, s=%i" % (i, s)
```

```
"file t5.py"

r = []
for c in 'this is a string with blanks':  # walks through string, char by
char
    if c == ' ': continue                 # skip rest of block, continue
loop
    r.append(c)

print ''.join(r)
```

Built-in functions 'range' and 'xrange'

- Built-in functions 'range' and 'xrange' useful with 'for'
- 'range' creates a list
- Warning: may use lots of memory; inefficient!

```
>>> range(9)                        # start=0, step=1 by default
[0, 1, 2, 3, 4, 5, 6, 7, 8]
>>> range(1, 12, 3)                 # explicit start, end, step
[1, 4, 7, 10]
>>> range(10**9)                    # MemoryError!
```

- 'xrange' creates an iterator, which works like a list
- Very memory-efficient!

```
"file t6.py"

s = 0
for i in xrange(100000):
    if i % 19 == 0:                 # remainder: evenly divisible with 19?
        s = s + i

print s
```

'while' statement

- Repetition of a block of statements
- Loop until test becomes false, or 'break'

```
"file t7.py"

r = []
n = 0
last = 20

while n <= last:            # any expression interpretable as Boolean
    r.append(str(n))
    n += 3

print ', '.join(r)
```

Optional 'else' block in loops

- 'else' block executed if no 'break' encountered
- May often replace success/failure flags
- Valid in 'for' and 'while' loops

```
"file t8.py"

r = [1, 3, 10, 98, -2, 48]

for i in r:
    if i < 0:
        print 'input contains negative value!'
        break                   # this skips out of loop, including 'else'
    else:
        pass                    # do-nothing statement
else:                           # do if loop ended normally
    print 'input is OK'
```

- 'pass' statement does absolutely nothing
- May be useful as placeholder for unwritten code
- A few cases where required (more later)

Error handling: ’try’ and ’except’

- Run-time error normally causes execution to bomb
- The error message gives type of error
- Use a ’try’, ’except’ blocks to catch and handle errors

```
"file t9.py"

numbers = []
not_numbers = []

for s in ['12', '-4.1', '1.0e2', 'e3']:
    try:
        n = float(s)
        numbers.append(s)
    except ValueError, msg:
        not_numbers.append(str(msg))

print 'numbers:', numbers
print 'not numbers:', not_numbers
```

```
numbers: ['12', '-4.1', '1.0e2']
not numbers: ['invalid literal for float(): e3']
```

How to split up long lines

- Sometimes a source code line needs splitting up
- Indentation rule means we do not have free-format!

```
"illegal syntax example"

if a_complicated_expression and
   another_complicated_expression:
    print 'this is illegal syntax; it will not work'
```

- Alt 1: Use continuation character '\' as the very last

```
"valid syntax example 1"

if a_complicated_expression and \
    another_complicated_expression:
    print 'this is valid syntax'
```

- Alt 2: Enclose the expression in parenthesis
  - Lines within parenthesis can be broken up
  - Also true for [ ] and { }

```
"valid syntax example 2"

if (a_complicated_expression and
    another_complicated_expression):
    print 'this is valid syntax'
```

Statements not covered in this course

- 'finally': used with 'try', 'except'
- 'raise': causes an exception
- 'yield': in functions
- 'global': within functions
- 'exec': execute strings as code

- **There is no 'goto' statement!**

Part 3: Functions

How to define your own function

- Use the 'def' statement
- Function body follows; indented!
- This is a statement like others
  - Can be placed basically anywhere
  - Required: Define the function before calling it

```
"file t10.py"

def all_items_positive(r):                              # function definition
    "Check that all values in list r are positive."  # documentation string
    for i in r:
        if i <= 0: return False                         # return a result value
    return True

sequences = [[1, 5, 6, -0.01], [0.01, 1, 2]]

for seq in sequences:
    if not all_items_positive(seq):                     # call the function
        print 'invalid: ', seq
```

Function features

- The value of an argument is not checked for type
  - Often very useful; overloading without effort
  - Of course, the function may still bomb if invalid value is given
- The documentation string is <u>not</u> required (more later)
  - But strongly encouraged!
  - Make a habit of writing one (before writing the function code)
- A user-defined function has exactly the same status as a built-in function, or a function from another module

Function arguments: fixed

- Fixed number of arguments
- Associated by order

```
"file t11.py"

def fixed_args(a, c, b):                                # note!: order of args
    "Format arguments into a string and return."        # doc string
    return "a=%s, b=%s, c=%s" % (a, b, c)               # '%s' converts to
string

print fixed_args('stuff', 1.2, [2, 1])
```

Function arguments: variable

- List of any number of arguments
- Useful when unknown number of arguments needed
- The argument values collected into a tuple
  - Called 'args', by convention
  - The '*' is the magical part

```
"file t12.py"

def unspec_args(a, *args):                    # name 'args' is a convention
    return "a=%s, others=%s" % (a, args)

print unspec_args('bla', 'qwe', 23, False)
```

```
a=bla, others=('qwe', 23, False)
```

Function arguments: default values

- Arguments may have default values
- When argument not given in a call, default value is used
- If no default value, and not given when called: bombs
- Use explicit names to override argument order

```
"file t13.py"

def default_args(a, b='bar', c=13):
    return "a=%s, b=%s, c=%s" % (a, b, c)

print default_args('apa')                    # uses all default values
print default_args('s', b='py')              # overrides one default value
print default_args(c=-26, a='apa')           # override argument order
```

```
a=apa, b=bar, c=13
a=s, b=py, c=13
a=apa, b=bar, c=-26
```

Function arguments: keywords

- Keyword/value arguments
- The argument values collected into a dictionary
  - Called 'kwargs', by convention
  - The '**' is the magical part
  - First attempts to match existing argument names

```
"file t14.py"

def keyword_args(a, b='bla', **kwargs):
    return "a=%s, b=%s, kwargs=%s" % (a, b, str(kwargs))

print keyword_args('stuff', c='call')
print keyword_args('stuff', c='call', b='apa')
print keyword_args(c='call', d=12, a='gr')
```

```
a=stuff, b=bla, kwargs={'c': 'call'}
a=stuff, b=apa, kwargs={'c': 'call'}
a=gr, b=bla, kwargs={'c': 'call', 'd': 12}
```

Function arguments: local variables

- Arguments become local variables
  - Immutable values are copied, in effect
  - Mutable values may still be changed: be careful
- Variables created within 'def' block are local
  - Forgotten on return

```
"file t16.py"

def test_local(a, r):
    print 'local original ', a, r
    a = 12
    r[1] = 999
    print 'local changed  ', a, r

a = -5
r = [0, 1, 2]
print 'global original', a, r
test_local(a, r)
print 'global changed ', a, r
```

```
global original -5 [0, 1, 2]
local original  -5 [0, 1, 2]
local changed   12 [0, 999, 2]
global changed  -5 [0, 999, 2]
```

Function without 'return': value None

- A function does not have to use the 'return' statement
- If not, then same as a 'procedure' in other languages
- Actually returns a value anyway: 'None'
- A 'return' without value is OK: returns 'None'
- 'None' is a special value meaning 'nothing'
  - Useful in many contexts
  - Particularly in object-oriented programming (more later)

```
"file t17.py"

def concat_strings(a, b):
    str_type = type('')                                # save a type value!
    if type(a) == str_type and type(b) == str_type:
        return a + ' ' + b

print 'strings:', concat_strings('first', 'second')
print 'integers:', concat_strings(1, 2)
```

```
strings: first second
integers: None
```

The 'math' module: functions and constants

- A peek at modules
- Math functions available in a separate module

```
"file t18.py"

from math import *              # import everything from module 'math'

print e, pi
print cos(radians(180.0))
print log(10.0)
print exp(-1.0)
```

```
2.71828182846 3.14159265359
-1.0
2.30258509299
0.367879441171
```

Functions are objects; names are references

- A function is just another kind of object
- Nothing magical about their names; can be changed

```
"file t19.py"

from math import *

def print_calc(f):
    print "log(%s)=%s, exp(%s)=%s" % (f, log(f), f, exp(f))

print_calc(1.0)
log, exp = exp, log        # evil code! swap the objects the names refer to
print_calc(1.0)
```

```
log(1.0)=0.0, exp(1.0)=2.71828182846
log(1.0)=2.71828182846, exp(1.0)=0.0
```

- A function can be passed as any argument to another function
- A function can assigned to a variable

Built-in function 'map'

- Built-in function that works on a list
- 'map' takes a function and a list
  - The function must take only one argument, and return one value
  - The function is applied to each value of the list
  - The resulting values are returned in a list

```
>>> from math import *
>>> r = [0, 1, 2, 3, 4, 5, 6]
>>> map(cos, r)
[1.0, 0.54030230586813977, -0.41614683654714241, -0.98999249660044542,
 -0.65364362086361194, 0.28366218546322625, 0.96017028665036597]
```

Built-in function 'reduce'

- Built-in function that works on a list
- 'reduce' takes a function and a list
- It boils down the list into one value using the function
  - The function must take only two arguments, and return one value
  - 'reduce' applies the function to the first two values in the list
  - The function is then applied to the result and the next value in the list
  - And so on, until all values in the list have been used

```
>>> r = [0, 1, 2, 3, 4, 5, 6]
>>> def sum(x, y): return x+y

>>> reduce(sum, r)                    #  (((((1+2)+3)+4)+5)+6)
21
```

Built-in function 'filter'

- Built-in function that works on a list
- 'filter' takes a function and a list
- It uses the function to decide which values to put into the resulting list
  - Each value in the list is given to the function
  - If the function return True, then the value is put into the resulting list
  - If the function returns False, then the value is skipped

```
>>> r = [0, 1, 2, 3, 4, 5, 6]
>>> def large(x): return x>3

>>> filter(large, r)
[4, 5, 6]
```

Files: reading

- A file object is created by the built-in function 'open'
- The file object has a set of methods
- The 'read' methods get data sequentially from the file
  - 'read': Get the entire file (or N bytes) and return as a single string
  - 'readline': Read a line (up to and including newline)
  - 'readlines': Read all lines and return as a list of strings

```
>>> f = open('test.txt')       # by default: read-only mode
>>> line = f.readline()        # read a single line
>>> line
'This is the first line.\n'
>>> lines = f.readlines()      # read all remaining lines
>>> lines
['This is the second.\n', 'And third.\n']
```

- Several modules define objects that are file-like, i.e. have methods that make them behave as files

Files: writing

- The 'write' method simply outputs the given string
- The string does not have to be ASCII; binary contents allowed

```
>>> w = open('output.txt', 'w')          # write mode (text by default)
>>> w.write('stuff')                     # does *not* add newline
automatically
>>> w.write('\n')
>>> w.write('more\n and even more\n')
>>> w.close()
```

```
stuff
more
 and even more
```

Part 4:
Modules

Example: Reverse complement NT sequence

- Given a nucleotide sequence, produce reverse complement
  - Use available features

```
"file t21.py"

complement_map = {'c': 'g', 'g': 'c', 'a': 't', 't': 'a'}

seq = 'cgtaacggtcaggttatattt'

complist = map(complement_map.get, seq)
complist.reverse()
revseq = ''.join(complist)

print seq
print revseq
```

```
cgtaacggtcaggttatattt
aaatataacctgaccgttacg
```

Make a module of the code

- How to make the code even more reusable?
- Step 2: Make a module out of it
- Is actually already a module!
- Let's simply rename it to 'ntseq.py'

```
"""file ntseq.py

Module 'ntseq': operations on NT sequences.
"""

complement_map = {'c': 'g', 'g': 'c', 'a': 't', 't': 'a'}

def reverse_complement(seq):
    "Return the reverse complement of an NT sequence."
    complist = map(complement_map.get, seq)
    complist.reverse()
    return ''.join(complist)

seq = 'cgtaacggtcaggttatattt'
print seq
print reverse_complement(seq)
```

How to use the module: ’import’ statement

- The ’import’ statement makes a module available
- The module name (not the file name) is imported: skip the ’.py’
- Access module features through the ’dot’ notation

```
"file t23.py"

import ntseq

seq = 'aaaccc'
print seq
print ntseq.reverse_complement(seq)
```

```
cgtaacggtcaggttatattt
aaatataacctgaccgttacg
aaaccc
gggttt
```

- Huh?! We got more than we wanted!
- First two lines: The test code in the module was also executed

Module self-test code: the '__name__' trick

- The 'import' statement executes all code in the module file
- How to 'hide' self-test code?
- Use the predefined variable '__name__':
  - If executed as the main program: value '__main__'
  - If executed as a module: some other value

```
"""file ntseq_mod.py

Module 'ntseq_mod': operations on NT sequences.
"""

complement_map = {'c': 'g', 'g': 'c', 'a': 't', 't': 'a'}

def reverse_complement(seq):
    "Return the reverse complement of an NT sequence."
    complist = map(complement_map.get, seq)
    complist.reverse()
    return ''.join(complist)

if __name__ == '__main__':          # code to test the function
    seq = 'cgtaacggtcaggttatattt'
    print seq
    print reverse_complement(seq)
```

Now, the ’import’ statement behaves

```
"file t24.py"

import ntseq_mod                          # note: ntseq_mod!

seq = 'aaaccc'
print seq
print ntseq_mod.reverse_complement(seq)  # note: ntseq_mod!
```

```
aaaccc
gggttt
```

Modules are easy, fun, and powerful

- The module feature is the basis for Python's ability to scale to really large software systems
- Easy to create: every Python source code file is a module!
- Features to make a module elegant:
  - Doc strings
  - '__name__' trick
  - Namespace concept
- Be sure to browse the standard library modules!
  - You will find extremely useful stuff there
  - You will learn good coding habits
- Packages are directories of several associated modules
  - Not covered in this course. A few minor interesting points

Namespaces

- A namespace is a bag of names
- A module is a namespace
- Use the built-in function ’dir’ to list the names in a namespace
- ’import’ statement modifies the namespace

```
"file t26.py"

for name in dir():
    print "%r: %r" % (name, eval(name))
print
print 'virgin namespace:', dir()

import ntseq_mod
print 'after import:', dir()

from ntseq_mod import *
print 'after from:', dir()
```

```
'__builtins__': <module '__builtin__' (built-in)>
'__doc__': 'file t26.py'
'__name__': '__main__'

virgin namespace: ['__builtins__', '__doc__', '__name__', 'name']
after import: ['__builtins__', '__doc__', '__name__', 'name', 'ntseq_mod']
after from: ['__builtins__', '__doc__', '__name__', 'complement_map',
'name',
             'ntseq_mod', 'reverse_complement']
```

Avoiding clutter in your namespace

- Using ’from module import *’ can create clutter
- Fine-tuning of import; bring in only selected things
- Rename things from a module
  - Avoid name collisions
  - Make it clearer

```
"file t27.py"

print 'virgin namespace:', dir()

from math import exp
from math import log as natural_logarithm

print 'selective import:', dir()
print 'exp(1.0)=', exp(1.0)
print 'natural_logarithm(10.0)=', natural_logarithm(10.0)
```

```
virgin namespace: ['__builtins__', '__doc__', '__name__']
selective import: ['__builtins__', '__doc__', '__name__',
                   'exp', 'natural_logarithm']
exp(1.0)= 2.71828182846
natural_logarithm(10.0)= 2.30258509299
```

Doc strings: ’__doc__’

- We have mentioned documentation strings before
  - The first string in a module
  - The first string after a ’def’ statement
- Accessed through variable ’__doc__’
- Feature to facilitate creation of documentation
  - Used by tools to produce documentation, such as ’pydoc’
  - See ’Module Docs’ in ’Start’ > ’Programs’ > ’Python 2.3’

```
>>> import ntseq_mod
>>> print ntseq_mod.__doc__
file ntseq_mod.py

Module 'ntseq': operations on NT sequences.

>>> print ntseq_mod.reverse_complement.__doc__
Return the reverse complement of an NT sequence.
```

Part 5:
Object-oriented programming, classes

Classes *vs.* objects (instances)

- A class is like a
  - Prototype
  - Blue-print ("ritning")
  - An object creator
- A class defines potential objects
  - What their structure will be
  - What they will be able to do
- Objects are instances of a class
  - An object is a container of data: attributes
  - An object has associated functions: methods

A class example: Geometrical shapes

- Let's define classes for geometrical shapes
  - With data; position, etc
  - With functions: compute area, etc

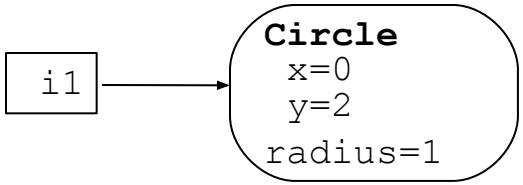
```
"file geom1.py: Module with classes for geometrical shapes, 1st try"

import math

class Circle:                           # class definition statement
    "A 2D circle."                      # documentation string

    def __init__(self, x, y, radius=1): # initialization method
        self.x = x                      # set the attributes of this
instance
        self.y = y
        self.radius = radius

    def area(self):
        "Return the area of the shape."
        return math.pi * self.radius**2
```

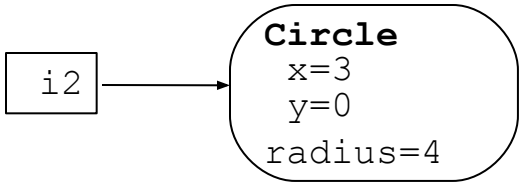
Instances of classes

- Let's create some instances of the Circle class
- Look at attribute 'radius'
- Use the method 'area'

```
"file t28.py"

from geom1 import *

i1 = Circle(0, 2)                # '__init__' is called automatically
i2 = Circle(3, 0, 4)

print 'i1:', i1.radius, i1.area()
print 'i2:', i2.radius, i2.area()
print str(i1)
```

```
i1: 1 3.14159265359
i2: 4 50.2654824574
<geom1.Circle instance at 0x009CEA08>
```

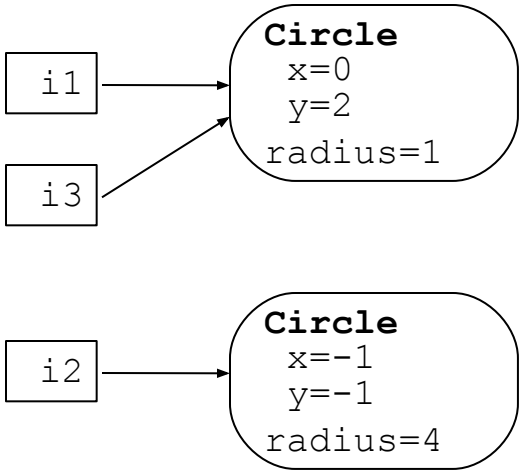




Changing an instance: references

- Variables may reference the same object
- Changing an attribute changes the object, not the reference

```
"file t30.py"

from geom1 import *

i1 = Circle(0, 2)
i2 = Circle(-1, -1, 4)
i3 = i1

i1.radius = 1.75
print 'i1:', i1.radius
print 'i2:', i2.radius
print 'i3:', i3.radius
```




```
i1: 1.75
i2: 4
i3: 1.75
```

Changing an instance: attribute add/delete

- An attribute can be added!
- And deleted!

```
"file t32.py"

from geom1 import *

i1 = Circle(0, 2)

i1.colour = 'red'                                # add an instance attribute
print 'i1:', i1.radius, i1.colour

del i1.radius                                    # delete an instance
attribute
print 'has i1 radius?', hasattr(i1, 'radius')    # built-in function
print 'i1:', i1.area()
```

```
i1: 1 red
has i1 radius? False
i1:
Traceback (most recent call last):
  File "M:/My Documents/Python course/tests/t32.py", line 11, in -toplevel-
    print 'i1:', i1.area()
  File "M:/My Documents/Python course/tests\geom1.py", line 15, in area
    return math.pi * self.radius**2
AttributeError: Circle instance has no attribute 'radius'
```

Equality between objects

- Two kinds of equality:
  - Are the two objects similar in value?
  - Are the two references actually pointing to the same object?

```
>>> a = [1, 2]
>>> b = [1, 2]
>>> a == b              # test whether values are equal
True
>>> a is b              # test whether objects are identical
False
>>> a.append(3)
>>> a == b              # test values again
False
```

Special methods in classes

- Special methods '__xxx__' in classes
- Define custom-made behaviour
- See page 327 in 'Learning Python'

```
"file geom2.py: Module with classes for geometrical shapes, 2nd try"

import math

class Circle:
    # ...some code removed here, for clarity...

    def __repr__(self):                 # better string representation
        return "Circle(%g, %g, radius=%g)" % (self.x, self.y, self.radius)

    def __nonzero__(self):              # is a true circle? else point
        return self.radius != 0

    def __cmp__(self, other):           # compare with other: larger or not?
        return cmp(self.radius, other.radius)
```

Using the special methods, part 1

- Special method definitions are detected by Python
- Built-in functions use them; see documentation

```
"file t33.py"

from geom2 import *

i1 = Circle(0, 2.5)
i2 = Circle(3, 4.02, 0)

print str(i1)
print 'is i1 a circle?:', bool(i1)
print 'is i2 a circle?:', bool(i2)
print 'i1 larger than i2?', i1 > i2        # uses __cmp__, if defined
```

```
Circle(0, 2.5, radius=1)
is i1 a circle?: True
is i2 a circle?: False
i1 larger than i2? True
```

Using the special methods, part 2

- Defining special methods may clarify code tremendously
- But: Stay reasonable 'natural'!

```
"file t34.py"

from geom2 import *

circles = [Circle(1, 3),
           Circle(0, 0, 0.2),
           Circle(-1, -1, 10.0)]
print circles                    # this uses 'repr', which calls __repr__

circles.sort()                   # this uses 'cmp', which calls __cmp__
print circles
```

```
[Circle(1, 3, radius=1), Circle(0, 0, radius=0.2), Circle(-1, -1,
radius=10)]
[Circle(0, 0, radius=0.2), Circle(1, 3, radius=1), Circle(-1, -1,
radius=10)]
```

Inheritance: Class hierarchies

- Let's define a general 'Shape' class
- 'Circle' is a special case of 'Shape'
- 'Blob' is also a special case of 'Shape'
- Notice: redefinition of 'is_round' in 'Blob'

```
"file geom3.py: Module with classes for geometrical shapes, 2nd try"

import math

class Shape:                                # This is a base class
    "General geometrical shape."

    def is_round(self):
        return True


class Circle(Shape):                        # Circle inherits Shape
    # ...same code as in geom2.py...


class Blob(Shape):
    "An undefined blob."

    def is_round(self):                     # overrides method from Shape
        return False
```

Instances of classes using inheritance

- Which method is called by which instance?
- Polymorphism
  - Selection of method depends on actual class of the instance
  - Extremely powerful, if properly designed class hierarchy

```
"file t35.py"

from geom3 import *

shapes = [Shape(),
          Circle(1, -2),
          Blob()]

for s in shapes:
    print s, 'round?', s.is_round()
```

```
<geom3.Shape instance at 0x009CEF80> round? True
Circle(1, -2, radius=1) round? True
<geom3.Blob instance at 0x009CEF58> round? False
```

Part 6:
Standard library modules

Module 're', part 1

Regular expressions: advanced string patterns

- Define a pattern
  - The pattern syntax is very much like Perl or grep
- Apply it to a string
- Process the results

```
"file t37.py"

import re

seq = "MAKEVFSKRTCACVFHKVHAQPNVGITR"

zinc_finger = re.compile('C.C..H..H')     # compile regular expression
pattern
print zinc_finger.findall(seq)

two_charged = re.compile('[DERK][DERK]')
print two_charged.findall(seq)
```

```
['CACVFHKVH']
['KE', 'KR']
```

Module 'sys', part 1

Variables and functions for the Python interpreter

- sys.argv
  - List of command-line arguments; sys.argv[0] is script name
- sys.path
  - List of directory names, where modules are searched for
- sys.platform
  - String to identify type of computer system

```
>>> import sys
>>> sys.platform
'win32'
```

Module 'sys', part 2

- sys.stdout, sys.stdin, sys.stderr
  - Predefined file objects for input/output
  - 'print' stuff goes to 'sys.stdout'
  - May be set to other files
- sys.exit(n)
  - Force exit from Python execution
  - 'n' is an integer error code, normally 0

```
>>> import sys
>>> sys.stdout.write('the hard way')
the hard way
```

Module 'os', part 1

Portable interface to operating-system services

- os.getcwd()
  - Returns the current directory

```
>>> os.getcwd()
'M:\\My Documents\\Python course\\tests'
```

- os.environ
  - Dictionary containing the current environment variables

```
>>> for k, v in os.environ.items(): print k, v

TMP C:\DOCUME~1\se22312\LOCALS~1\Temp
COMPUTERNAME WS101778
USERDOMAIN BIOVITRUM
COMMONPROGRAMFILES C:\Program Files\Common Files
PROCESSOR_IDENTIFIER x86 Family 6 Model 9 Stepping 5, GenuineIntel
PROGRAMFILES C:\Program Files
PROCESSOR_REVISION 0905
HOME C:\emacs
...
```

Module 'os', part 2

- os.chdir(path)
  - Changes the current working directory to 'path'
- os.listdir(path)
  - Return a list of the contents of the directory 'path'
- os.mkdir(path)
  - Create the directory 'path'
- os.rmdir(path)
  - Remove the directory 'path'
- os.remove(path)
  - Remove the file named 'path'

Module 'os', part 3

- os.system(command)
  - Execute the shell command (string) in a subprocess
  - Return the error code as integer
- os.popen(command, mode='r')
  - Run the shell command (string)
  - Open a pipe to the command, return as a file object
  - Mode is either read, or write; not both
- os.popen2, os.popen3, os.popen4
  - Variants of os.popen, with different file objects
- os.getpid()
  - Return the process ID as integer

Module 'os.path', part 1

Portable path name handling

- os.path.abspath(path)
  - Returns the absolute path for the given relative 'path'

```
>>> d = os.path.abspath('.')
>>> d
'M:\\My Documents\\Python course\\tests'
```

- os.path.dirname(path)
  - Returns the directory name part of 'path'

```
>>> os.path.dirname(d)
'M:\\My Documents\\Python course'
```

Module 'os.path', part 2

- os.path.join(path, path, …)
  - Joint together the path parts intelligently into a valid path name

```
>>> d = os.path.join(os.getcwd(), 't1.py')
>>> d
'M:\\My Documents\\Python course\\tests\\t1.py'
```

- os.path.split(path)
  - Splits up the path into directory name and filename
  - Reverse of 'os.path.join'

```
>>> os.path.split(d)
('M:\\My Documents\\Python course\\tests', 't1.py')
```

- os.path.splitext(path)
  - Splits up the path into base filename and the extension (if any)

```
>>> >>> os.path.splitext(d)
('M:\\My Documents\\Python course\\tests\\t1', '.py')
```

Module 'os.path', part 3

- os.path.exists(path)
  - Does the 'path' exist? File, or directory

```
>>> d = os.path.join(os.getcwd(), 't1.py')
>>> os.path.exists(d)
True
```

- os.path.isfile(path)
  - Is 'path' the name of a file?
- os.path.isdir(path)
  - Is 'path' the name of a directory?

```
>>> os.path.isfile(d)
True
>>> os.path.isdir(d)
False
```

- os.path.walk(path, func, arg)
  - Used to process an entire directory tree
  - Visits each subdirectory
  - Calls the function 'func' with a list of the filenames in that directory

Some other useful modules

shutil	'shell utilities': copy files, remove entire directories
StringIO cStringIO	String-like objects that behave as files
gzip, zipfile	Handle compressed files
dbm, gdbm	Files that behave as dictionaries; simple databases
time	Time handling and formatting
random	Random number generator
urlparse urllib, urllib2 ftplib	URL address manipulation URL data fetching, using file-like objects FTP handling
cgi	CGI script operations
Tkinter	Interface to Tk/Tcl; graphical user interface (GUI) module
xml	Package for handling XML files