Python

CSE 307 – Principles of Programming Languages
Stony Brook University

http://www.cs.stonybrook.edu/~cse307
Python’s History

• Created by Guido van Rossum in Netherlands in 1990

• Open source: http://www.python.org
Python 2.7x vs. Python 3.x

- Python 3.x is a newer version, but it is not backward compatible with Python 2.7x
- That means if you write a program using Python 2, it may not work on Python 3.x
Launch Python

C:\>python
Python 3.1.2 (r312:79149, Mar 21 2010, 00:41:52) [MSC v.1500 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> print("Welcome to Python")
Welcome to Python
>>> print("Python is fun")
Python is fun
>>> ^Z
C:}\n
(c) Paul Fodor (CS Stony Brook) and Pearson
Launch Python IDLE

Editor, Command line interface, Debugger

Many other IDEs.
# Display two messages
print("Welcome to Python")
print("Python is fun")

# Comment in Python
Run Python Script

```
c:\pybook>python Welcome.py
Welcome to Python
Python is fun
```
Python Example

# Assign a radius
radius = 20  # radius is now 20
# Compute area
area = radius * radius * 3.14159
# Display results
print("The area for the circle of radius " +
    str(radius) + " is " + str(area))
Reading Input from the Console

1. Use the input function

   ```python
   variable = input("Enter a string: ");
   ```

2. Use the eval function

   ```python
   variable = eval("51 + (54 * (3 + 2))");
   
   print(variable);
   321
   ```
# Compute the first area
radius = 1.0
area = radius * radius * 3.14159
print("The area is ", area, " for radius ", radius)

# Compute the second area
radius = 2.0
area = radius * radius * 3.14159
print("The area is ", area, " for radius ", radius)
Expression

```python
x = 1           # Assign 1 to variable x
radius = 1.0    # Assign 1.0 to variable radius

# Assign the value of the expression to x
x = 5 * (3 / 2) + 3 * 2
print(x)
    13.5

x = 5 * (3 // 2) + 3 * 2
print(x)
    11
```
Overflow

● When a variable is assigned a value that is too large (in size) to be stored, it causes overflow. For example, executing the following statement causes overflow:

```python
>>> 245.0 ** 1000
OverflowError: 'Result too large'
```
Type Conversion and Rounding

- `datatype(value) :
  int(4.5) => 4
  float(4) => 4.0
  str(4) => '4'
  round(4.6) => 5
  round(4.5) => 4
  round(4.5) => 5  # in Python 2
  round(4.5) => 4  # in Python 3

https://docs.python.org/2/library/functions.html#round
https://docs.python.org/3/library/functions.html#round

Note: 2 vs 3
Built-in Functions and math Module

```python
>>> max(2, 3, 4)  # Returns a maximum number
4
>>> min(2, 3, 4)  # Returns a minimum number
2
>>> round(3.51)  # Rounds to its nearest integer
4
>>> round(3.4)   # Rounds to its nearest integer
3
>>> abs(-3)      # Returns the absolute value
3
>>> pow(2, 3)    # Same as 2 ** 3
8
```
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>fabs(x)</td>
<td>Returns the absolute value of the argument.</td>
<td>fabs(-2) is 2</td>
</tr>
<tr>
<td>ceil(x)</td>
<td>Rounds x up to its nearest integer and returns this integer.</td>
<td>ceil(2.1) is 3</td>
</tr>
<tr>
<td>floor(x)</td>
<td>Rounds x down to its nearest integer and returns this integer.</td>
<td>floor(2.1) is 2</td>
</tr>
<tr>
<td>exp(x)</td>
<td>Returns the exponential function of x (e^x).</td>
<td>exp(1) is 2.71828</td>
</tr>
<tr>
<td>log(x)</td>
<td>Returns the natural logarithm of x.</td>
<td>log(2.71828) is 1.0</td>
</tr>
<tr>
<td>log(x, base)</td>
<td>Returns the logarithm of x for the specified base.</td>
<td>log10(10, 10) is 1</td>
</tr>
<tr>
<td>sqrt(x)</td>
<td>Returns the square root of x.</td>
<td>sqrt(4.0) is 2.0</td>
</tr>
<tr>
<td>sin(x)</td>
<td>Returns the sine of x. x represents an angle in radians.</td>
<td>sin(3.14159 / 2) is 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sin(3.14159) is 0</td>
</tr>
<tr>
<td>asin(x)</td>
<td>Returns the angle in radians for the inverse of sine.</td>
<td>asin(1.0) is 1.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>asin(0.5) is 0.523599</td>
</tr>
<tr>
<td>cos(x)</td>
<td>Returns the cosine of x. x represents an angle in radians.</td>
<td>cos(3.14159 / 2) is 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cos(3.14159) is -1</td>
</tr>
<tr>
<td>acos(x)</td>
<td>Returns the angle in radians for the inverse of cosine.</td>
<td>acos(1.0) is 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>acos(0.5) is 1.0472</td>
</tr>
<tr>
<td>tan(x)</td>
<td>Returns the tangent of x. x represents an angle in radians.</td>
<td>tan(3.14159 / 4) is 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tan(0.0) is 0</td>
</tr>
<tr>
<td>fmod(x, y)</td>
<td>Returns the remainder of x/y as double.</td>
<td>fmod(2.4, 1.3) is 1.1</td>
</tr>
<tr>
<td>degrees(x)</td>
<td>Converts angle x from radians to degrees</td>
<td>degrees(1.57) is 90</td>
</tr>
<tr>
<td>radians(x)</td>
<td>Converts angle x from degrees to radians</td>
<td>radians(90) is 1.57</td>
</tr>
</tbody>
</table>
Strings and Characters

A string is a sequence of characters. *String* literals can be enclosed in matching *single quotes* (') or *double quotes* ("'). Python does not have a data type for characters. A single-character string represents a character.

```python
letter = 'A'    # Same as letter = "A"
numChar = '4'   # Same as numChar = "4"
message = "Good morning"
    # Same as message = 'Good morning'
```
Functions ord and chr

```python
>>> ch = 'a'
>>> ord(ch)
97
>>> chr(98)
'b'
```
The `str` function can be used to convert a number into a string. For example,

```python
>>> s = str(3.4)  # Convert a float to string
>>> s
'3.4'
>>> s = str(3)   # Convert an integer to string
>>> s
'3'
```
The String Concatenation Operator

You can use the + operator to add two numbers. The + operator can also be used to concatenate (combine) two strings. Here are some examples:

```python
>>> message = "Welcome " + "to " + "Python"
>>> message
'Welcome to Python'
>>> chapterNo = 1
>>> s = "Chapter " + str(chapterNo)
>>> s
'Chapter 1'
>>> s = "Chapter " + chapterNo
TypeError: Can't convert 'int' object to str implicitly
```
In Python, all data—including numbers and strings—are actually objects.

An object is an entity. Each object has an id and a type. Objects of the same kind have the same type. You can use the `id` function and `type` function to get these information for an object.
Object Types and Ids

The **id** and **type** functions are rarely used in programming, but they are good pedagogical tools for understanding objects.

```python
>>> n = 3  # n is an integer
>>> id(n)
505408904
>>> type(n)
<class 'int'>

>>> f = 3.0  # f is a float
>>> id(f)
26647120
>>> type(f)
<class 'float'>

>>> s = "Welcome"
>>> id(s)
36201472
>>> type(s)
<class 'str'>
```
str Object Methods

```python
>>> s = "Welcome"
>>> s1 = s.lower() # Invoke the lower method
>>> s1
'welcome'

>>> s2 = s.upper() # Invoke the upper method
>>> s2
'WELCOME'
```
Formatting Floating-Point Numbers

```python
print(format(57.467657, '10.2f'))
print(format(12345678.923, '10.2f'))
print(format(57.4, '10.2f'))
print(format(57, '10.2f'))
```

- **field width**: 10
- **precision**: 2
- **conversion code**: f
- **format specifier**: `10.2f`

```
57.47
12345678.9
57.40
57.00
```
Blocks

- Python 3 uses indentation of 4 spaces for blocks

- Tabs should be used solely to remain consistent with code that is already indented with tabs

[https://www.python.org/dev/peps/pep-0008/#tabs-or-spaces](https://www.python.org/dev/peps/pep-0008/#tabs-or-spaces)

"Python 3 disallows mixing the use of tabs and spaces for indentation."
from math import pi

if radius >= 0:
    area = radius * radius * pi
    print("The area for the ", "circle of radius ", radius, " is ", area)
else:
    print("Negative input")
Multiple Alternative if Statements

if score >= 90.0:
    grade = 'A'
else:
    if score >= 80.0:
        grade = 'B'
    else:
        if score >= 70.0:
            grade = 'C'
        else:
            if score >= 60.0:
                grade = 'D'
            else:
                grade = 'F'

(b) This is better

if score >= 90.0:
    grade = 'A'
elif score >= 80.0:
    grade = 'B'
elif score >= 70.0:
    grade = 'C'
elif score >= 60.0:
    grade = 'D'
else:
    grade = 'F'

Equivalent

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Loops

# Initialize loop-control variable

i = initialValue

while i < endValue:
    # Loop body
    ...
    i++ # Adjust loop-control variable

for i in range(initialValue, endValue):
    # Loop body
range(a, b)

for i in range(4, 8):
    print(i)

4
5
6
7
range(b)

for i in range(4):
    print(i)

0
1
2
3
range(a, b, step)

for v in range(3, 9, 2):
    print(v)

3
5
7
def sum(i1, i2):
    ''' This is the doc '''
    result = 0
    for i in range(i1, i2):
        result += i
    return result

def main():
    print("Sum from 1 to 10 is", sum(1, 10))
    print("Sum from 20 to 37 is", sum(20, 37))
    print("Sum from 35 to 49 is", sum(35, 49))
main() # Call the main function
Classes

import math
class Circle:
    # Construct a circle object
    def __init__(self, radius = 1):
        self.radius = radius
    def getPerimeter(self):
        return 2 * self.radius * math.pi
    def getArea(self):
        return self.radius * self.radius * math.pi
    def setRadius(self, radius):
        self.radius = radius
    def __str__(self):
        return "Circle: radius=" + str(radius)
from Circle import Circle

def main():
    # Create a circle with radius 1
    circle1 = Circle()
    print("The area of the circle of radius", circle1.radius, "is", circle1.getArea())
    # Create a circle with radius 25
    circle2 = Circle(25)
    print("The area of the circle of radius", circle2.radius, "is", circle2.getArea())
    # Create a circle with radius 125
    circle3 = Circle(125)
    print("The area of the circle of radius", circle3.radius, "is", circle3.getArea())
    # Modify circle radius
    circle2.radius = 100
    print("The area of the circle of radius", circle2.radius, "is", circle2.getArea())

main() # Call the main function
from GeometricObject import GeometricObject

import math
class Circle(GeometricObject):
    def __init__(self, radius):
        super().__init__()
        self.__radius = radius
    def getRadius(self):
        return self.__radius
    def setRadius(self, radius):
        self.__radius = radius
    def getArea(self):
        return self.__radius * self.__radius * math.pi
    def getDiameter(self):
        return 2 * self.__radius
    def getPerimeter(self):
        return 2 * self.__radius * math.pi
    def printCircle(self):
        print(self.__str__() + " radius: " + str(self.__radius))
class Employee:
    pass

# Create an empty employee record
john = Employee()

# Add the fields of the record
john.name = 'John Doe'
john.dept = 'computer lab'
john.salary = 1000
from GeometricObject import GeometricObject
import math

class Circle(GeometricObject):
    def __init__(self, radius):
        super().__init__()
        self.setRadius(radius)
    def setRadius(self, self, radius):
        if radius < 0:
            raise RuntimeError("Negative radius")
        else:
            self.__radius = radius
The str Class

Creating Strings

```python
s1 = str()  # Create an empty string
s2 = str("Welcome")  # Create a string Welcome
```

Python provides a simple syntax for creating string using a string literal. For example,

```python
s1 = ""  # Same as s1 = str()
s2 = "Welcome"  # Same as s2 = str("Welcome")
```
Strings are Immutable

A string object is immutable. Once it is created, its contents cannot be changed. To optimize performance, Python uses one object for strings with the same contents.

- both s1 and s2 refer to the same string object.

```python
>>> s1 = "Welcome"
>>> s2 = "Welcome"
>>> id(s1)
505408902
>>> id(s2)
505408902
```
Functions for str

```
>>> s = "Welcome"
>>> len(s)
7
>>> max(s)
'o'
>>> min(s)
'W'
```
The +, *, [ : ], and in Operators

```python
>>> s1 = "Welcome"
>>> s2 = "Python"
>>> s3 = s1 + " to " + s2
>>> s3
'Welcome to Python'
>>> s4 = 2 * s1
>>> s4
'WelcomeWelcome'
>>> s1[3 : 6]
'com'
>>> 'W' in s1
True
>>> 'X' in s1
False
```
Negative Index

```python
>>> s1 = "Welcome"
>>> s1[-1]
'e'
>>> s1[-3 : -1]
'om'
```
The in and not in Operators

```python
>>> s1 = "Welcome"
>>> "come" in s1
True
>>> "come" not in s1
False
```
Foreach Loops

```python
for ch in string:
    print(ch)

for i in range(0, len(s), 2):
    print(s[i])
```
Comparing Strings

```python
>>> s1 = "green"
>>> s2 = "glow"
>>> s1 == s2
False
>>> s1 != s2
True
>>> s1 > s2
True
>>> s1 >= s2
True
>>> s1 < s2
False
>>> s1 <= s2
False
```
Testing Characters in a String

<table>
<thead>
<tr>
<th>str</th>
</tr>
</thead>
<tbody>
<tr>
<td>isalnum(): bool</td>
</tr>
<tr>
<td>isalpha(): bool</td>
</tr>
<tr>
<td>isdigit(): bool</td>
</tr>
<tr>
<td>isidentifier(): bool</td>
</tr>
<tr>
<td>islower(): bool</td>
</tr>
<tr>
<td>isupper(): bool</td>
</tr>
<tr>
<td>isspace(): bool</td>
</tr>
</tbody>
</table>

Return True if all characters in this string are alphanumeric and there is at least one character.

Return True if all characters in this string are alphabetic and there is at least one character.

Return True if this string contains only number characters.

Return True if this string is a Python identifier.

Return True if all characters in this string are lowercase letters and there is at least one character.

Return True if all characters in this string are uppercase letters and there is at least one character.

Return True if this string contains only whitespace characters.
Searching for Substrings

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<tr>
<th>str</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>str</td>
<td></td>
</tr>
<tr>
<td>endswith(s1: str): bool</td>
<td>Returns True if the string ends with the substring s1.</td>
</tr>
<tr>
<td>startswith(s1: str): bool</td>
<td>Returns True if the string starts with the substring s1.</td>
</tr>
<tr>
<td>find(s1): int</td>
<td>Returns the lowest index where s1 starts in this string, or -1 if s1 is not found in this string.</td>
</tr>
<tr>
<td>rfind(s1): int</td>
<td>Returns the highest index where s1 starts in this string, or -1 if s1 is not found in this string.</td>
</tr>
<tr>
<td>count(substring): int</td>
<td>Returns the number of non-overlapping occurrences of this substring.</td>
</tr>
</tbody>
</table>
## Converting Strings

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>str capitalize()</td>
<td>Returns a copy of this string with only the first character capitalized.</td>
</tr>
<tr>
<td>str lower()</td>
<td>Returns a copy of this string with all characters converted to lowercase.</td>
</tr>
<tr>
<td>str upper()</td>
<td>Returns a copy of this string with all characters converted to uppercase.</td>
</tr>
<tr>
<td>str title()</td>
<td>Returns a copy of this string with the first letter capitalized in each word.</td>
</tr>
<tr>
<td>str swapcase()</td>
<td>Returns a copy of this string in which lowercase letters are converted to uppercase and uppercase to lowercase.</td>
</tr>
<tr>
<td>str replace(old, new)</td>
<td>Returns a new string that replaces all the occurrence of the old string with a new string.</td>
</tr>
</tbody>
</table>
### Stripping Whitespace Characters

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>str</code></td>
<td></td>
</tr>
<tr>
<td><code>lstrip(): str</code></td>
<td>Returns a string with the leading whitespace characters removed.</td>
</tr>
<tr>
<td><code>rstrip(): str</code></td>
<td>Returns a string with the trailing whitespace characters removed.</td>
</tr>
<tr>
<td><code>strip(): str</code></td>
<td>Returns a string with the starting and trailing whitespace characters removed.</td>
</tr>
</tbody>
</table>
### Formatting Strings

<table>
<thead>
<tr>
<th>str</th>
</tr>
</thead>
<tbody>
<tr>
<td>center(width): str</td>
</tr>
<tr>
<td>Returns a copy of this string centered in a field of the given width.</td>
</tr>
<tr>
<td>ljust(width): str</td>
</tr>
<tr>
<td>Returns a string left justified in a field of the given width.</td>
</tr>
<tr>
<td>rjust(width): str</td>
</tr>
<tr>
<td>Returns a string right justified in a field of the given width.</td>
</tr>
</tbody>
</table>
from tkinter import * # Import tkinter

root = Tk() # Create a root window

# Create a label
label = Label(root, text = "Welcome to Python")

# Create a button
button = Button(root, text = "Click Me")

label.pack() # Display the label in the window
button.pack() # Display the button in the window

root.mainloop() # Create an event loop
Creating Lists

Creating list using the list class

```
list1 = list()  # Create an empty list
list2 = list([2, 3, 4])  # Create a list with elements 2, 3, 4
list3 = list(['red', 'green', 'blue'])  # Create a list with strings
list4 = list(range(3, 6))  # Create a list with elements 3, 4, 5
list5 = list('abcd')  # Create a list with characters a, b, c, d
```

For convenience, you may create a list using the following syntax:

```
list1 = []  # Same as list()
list2 = [2, 3, 4]  # Same as list([2, 3, 4])
list3 = ['red', 'green']  # Same as list(['red', 'green'])
```
## list Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>append(x: object): None</td>
<td>Add an item x to the end of the list.</td>
</tr>
<tr>
<td>insert(index: int, x: object): None</td>
<td>Insert an item x at a given index. Note that the first element in the list has index 0.</td>
</tr>
<tr>
<td>remove(x: object): None</td>
<td>Remove the first occurrence of the item x from the list.</td>
</tr>
<tr>
<td>index(x: object): int</td>
<td>Return the index of the item x in the list.</td>
</tr>
<tr>
<td>count(x: object): int</td>
<td>Return the number of times item x appears in the list.</td>
</tr>
<tr>
<td>sort(): None</td>
<td>Sort the items in the list.</td>
</tr>
<tr>
<td>reverse(): None</td>
<td>Reverse the items in the list.</td>
</tr>
<tr>
<td>extend(l: list): None</td>
<td>Append all the items in L to the list.</td>
</tr>
<tr>
<td>pop([i]): object</td>
<td>Remove the item at the given position and return it. The square bracket denotes that parameter is optional. If no index is specified, list.pop() removes and returns the last item in the list.</td>
</tr>
</tbody>
</table>
Functions for lists

```python
>>> list1 = [2, 3, 4, 1, 32]
>>> len(list1)
5
>>> max(list1)
32
>>> min(list1)
1
>>> sum(list1)
42
>>> import random
>>> random.shuffle(list1) # Shuffle the items in the list
>>> list1
[4, 1, 2, 32, 3]
```
The +, *, [ : ], and in Operators

```python
>>> list1 = [2, 3]
>>> list2 = [1, 9]
>>> list3 = list1 + list2
>>> list3
[2, 3, 1, 9]
>>> list3 = 2 * list1
>>> list3
[2, 3, 2, 3]
>>> list4 = list3[2 : 4]
>>> list4
[2, 3]
```
The +, *, [ : ], and in Operators

```python
>>> list1 = [2, 3, 5, 2, 33, 21]
>>> list1[-1]
21
>>> list1[-3]
2
>>> list1 = [2, 3, 5, 2, 33, 21]
>>> 2 in list1
True
>>> list1 = [2, 3, 5, 2, 33, 21]
>>> 2.5 in list1
False
```
Comparing Lists

```python
>>> list1 = ["green", "red", "blue"]
>>> list2 = ["red", "blue", "green"]
>>> list2 == list1
False
>>> list2 != list1
True
>>> list2 >= list1
True
>>> list2 > list1
True
>>> list2 < list1
False
>>> list2 <= list1
False
```
items = "Welcome to the US".split()
print(items)
['Welcome', 'to', 'the', 'US']

items = "34#13#78#45".split("#")
print(items)
['34', '13', '78', '45']
def main():
    x = 1 # x represents an int value
    y = [1, 2, 3] # y represents a list
    m(x, y) # Invoke f with arguments x and y
    print("x is " + str(x))
    print("y[0] is " + str(y[0]))

def m(number, numbers):
    number = 1001 # Assign a new value to number
    numbers[0] = 5555 # Assign a new value to numbers[0]
main()
# Use binary search to find the key in the list

def binarySearch(lst, key):
    low = 0
    high = len(lst) - 1
    while high >= low:
        mid = (low + high) // 2
        if key < lst[mid]:
            high = mid - 1
        elif key == lst[mid]:
            return mid
        else:
            low = mid + 1
    # Now high < low, key not found
    return -low - 1
def selectionSort(lst):
    for i in range(0, len(lst) - 1):
        # Find the minimum in the lst[i..len(lst)-1]
        currentMin = lst[i]
        currentMinIndex = i
        for j in range(i + 1, len(lst)):
            if currentMin > lst[j]:
                currentMin = lst[j]
                currentMinIndex = j
        # Swap lst[i] with lst[currentMinIndex] if necessary
        if currentMinIndex != i:
            lst[currentMinIndex] = lst[i]
            lst[i] = currentMin
    return lst
Write to a File

outfile = open("test.txt", "w")
outfile.write("Welcome to Python")

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>read([number: int]): str</td>
<td>Returns the specified number of characters from the file. If the argument is omitted, the entire remaining contents are read.</td>
</tr>
<tr>
<td>readline(): str</td>
<td>Returns the next line of file as a string.</td>
</tr>
<tr>
<td>readlines(): list</td>
<td>Returns a list of the remaining lines in the file.</td>
</tr>
<tr>
<td>write(s: str): None</td>
<td>Writes the string to the file.</td>
</tr>
<tr>
<td>close(): None</td>
<td>Closes the file.</td>
</tr>
</tbody>
</table>
import os.path

if os.path.isfile("Presidents.txt"):
    print("Presidents.txt exists")
Write/Read in/from File

```python
def main():
    # write
    w = open("a.txt", "w")
    w.write("de")
    w.close()
    # read
    r = open("a.txt", "r")
    for line in r:
        print(line)
    r.close()
main()
```
Tuples

t1 = ()  # Create an empty tuple
t2 = (1, 3, 5)  # Create a set with three elements
# Create a tuple from a list
# Create a tuple from a string
# t3 = tuple([2*x for x in range(1,5)])  # Create a tuple from a list
# t4 = tuple("abac")  # t4 is ['a', 'b', 'a', 'c']

- Tuples vs. lists: you cannot modify a tuple!
List Comprehensions

- List comprehensions are a concise way to create lists

```python
>>> squares = [x**2 for x in range(10)]
>>> squares
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

same with:

```python
>>> squares = []
>>> for x in range(10):
...     squares.append(x**2)
```

but shorter
List Comprehensions

```python
>>> vec = [-4, -2, 0, 2, 4]
# create a new list with the values doubled
>>> [x*2 for x in vec]
[-8, -4, 0, 4, 8]
# filter the list to exclude negative numbers
>>> [x for x in vec if x >= 0]
[0, 2, 4]
# apply a function to all the elements
>>> [abs(x) for x in vec]
[4, 2, 0, 2, 4]
```
List Comprehensions

• A list comprehension consists of brackets containing an expression followed by a `for` clause, then zero or more `for` or `if` clauses

• the result will be a new list resulting from evaluating the expression in the context of the `for` and `if` clauses which follow it

• example: combines the elements of two lists if they are not equal

```python
>>> [(x, y) for x in [1,2,3] for y in [3,1,4] if x != y]
[((1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4))]
```
List Comprehensions

```python
>>> [(x, y) for x in [1,2,3] for y in [3,1,4] if x != y]
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]
```

is the same with:

```python
>>> combs = []
>>> for x in [1,2,3]:
...     for y in [3,1,4]:
...         if x != y:
...             combs.append((x, y))
```
List Comprehensions

# create a list of 2-tuples like (number, square)
>>> [(x, x**2) for x in range(6)]
[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

# flatten a list using a listcomp with two 'for'
>>> vec = [[1, 2, 3], [4, 5, 6], [7, 8, 9]]
>>> [num for elem in vec for num in elem]
[1, 2, 3, 4, 5, 6, 7, 8, 9]
# Nested List Comprehensions

```python
>>> matrix = [
    [1, 2, 3, 4],
    [5, 6, 7, 8],
    [9, 10, 11, 12],
]

>>> [[row[i] for row in matrix] for i in range(len(matrix[0]))]
[[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```
all and any

- **all(iterable)** returns True if all elements of the iterable are true (or if the iterable is empty)
  - The internal implementation:

```python
def all(iterable):
    for element in iterable:
        if not element:
            return False
    return True
```
all and any

• `any(iterable)` returns True if any element of the iterable is true. If the iterable is empty, return False.
  • The internal implementation:

```python
def any(iterable):
    for element in iterable:
        if element:
            return True
    return False
```
all and any

- **all** and **any** will short-circuit the execution the moment they know the result.
  - that is, the entire iterable need not be consumed.
def is_prime(element):
    if element == 2:
        return True
    elif element <= 1 or element % 2 == 0:
        return False
    else:
        return all(element % i for i in range(3, element, 2))

myList = [4, 5, 9, 12]
if not any(is_prime(x) for x in myList):
    print("The list did not contain a prime")
else:
    print("The list contains a prime")
Sets

\[ s1 = \text{set}() \] # Create an empty set

\[ s2 = \{1, 3, 5\} \] # Create a set with three elements

\[ s3 = \text{set}([1, 3, 5]) \] # Create a set from a list

# Create a set from a list
\[ s4 = \text{set}([x \times 2 \text{ for } x \text{ in range}(1, 10)]) \]

# Create a set from a string
\[ s5 = \text{set}("abac") \] # s5 is \{'a', 'b', 'c'\}
Manipulating and Accessing Sets

```python
>>> s1 = {1, 2, 4}
>>> s1.add(6)
>>> s1
{1, 2, 4, 6}
>>> len(s1)
4
>>> max(s1)
6
>>> min(s1)
1
>>> sum(s1)
13
>>> 3 in s1
False
>>> s1.remove(4)
>>> s1
{1, 2, 6}
>>> 
```
Subset and Superset

```python
>>> s1 = {1, 2, 4}
>>> s2 = {1, 4, 5, 2, 6}
>>> s1.issubset(s2) # s1 is a subset of s2
True

>>> s2.issuperset(s1) # s2 is a superset of s1
True
```
Equality Test

```python
>>> s1 = {1, 2, 4}
>>> s2 = {1, 4, 2}
>>> s1 == s2
True
>>> s1 != s2
False
```
Comparison Operators

Note that it makes no sense to compare the sets using the conventional comparison operators (> , >=, <=, <), because the elements in a set are not ordered. However, these operators have special meaning when used for sets.

s1 > s2 returns true if s1 is a proper superset of s2.

s1 >= s2 returns true if s1 is a superset of s2.

s1 < s2 returns true if s1 is a proper subset of s2.

s1 <= s2 returns true if s1 is a subset of s2.
Set Operations (union, |)

```python
>>> s1 = {1, 2, 4}
>>> s2 = {1, 3, 5}
>>> s1.union(s2)
{1, 2, 3, 4, 5}

>>> s1 | s2
{1, 2, 3, 4, 5}
```
Set Operations (intersection, &)

```python
>>> s1 = {1, 2, 4}
>>> s2 = {1, 3, 5}
>>> s1.intersection(s2)
{1}
```

```python
>>> s1 & s2
{1}
```
Set Operations (difference, -)

>>> s1 = {1, 2, 4}
>>> s2 = {1, 3, 5}
>>> s1.difference(s2)
{2, 4}

>>> s1 - s2
{2, 4}
Creating a Dictionary

# Create an empty dictionary
dictionary = {}

# Create a dictionary
dictionary = {"john":40, "peter":45}
for key in dictionary:
    print(key + "::" + str(dictionary[key])))
Lambda Expressions

• Small anonymous functions
• a function can return a function

```python
>>> def make_incrementor(n):
...     return lambda x: x + n
...     return lambda x: x + n

>>> f = make_incrementor(42)
>>> f(0)
42
>>> f(1)
43
```
• Operating System Interface:

```python
>>> import os

# Return the current working directory
>>> os.getcwd()
'C:\\Python35'

# Run the command mkdir
>>> os.system('mkdir today')
0
```
Operating System Interface:

```python
>>> import shutil

>>> shutil.copyfile('data.db', 'archive.db')
'archive.db'

>>> shutil.move('/build/executables', 'installdir')
'installdir'
```
String Pattern Matching Interface:

```python
>>> import re

>>> re.findall(r'\bf[a-z]*',
               'which foot or hand fell fastest')

['foot', 'fell', 'fastest']
```
Mathematics:

```python
>>> import random

>>> random.choice(['apple', 'pear', 'banana'])
'apple'

# sampling without replacement

>>> random.sample(range(100), 10)
[30, 83, 16, 4, 8, 81, 41, 50, 18, 33]

>>> random.random()  # random float
0.17970987693706186
```
Mathematics:

```python
>>> import statistics

>>> data = [2.75, 1.75, 1.25, 0.25, 0.5, 1.25, 3.5]
>>> statistics.mean(data)
1.6071428571428572

>>> statistics.median(data)
1.25

>>> statistics.variance(data)
1.3720238095238095
```
Standard Library

• Internet Access:

```python
>>> from urllib.request import urlopen

>>> with urlopen('http://www.cs.stonybrook.edu') as response:
    for line in response:
        print(line)
```
Standard Library

• Dates and Times:

```python
>>> from datetime import date

>>> now = date.today()
>>> now

>>> birthday = date(2000, 5, 23)

>>> age = now - birthday

>>> age.days
```
Data Compression:

```python
>>> import zlib
>>> s = b'data archiving and compression'
# A prefix of 'b' means that the chars are encoded in byte type
# may only contain ASCII characters

>>> t = zlib.compress(s)
>>> zlib.decompress(t)
b'data archiving and compression'
>>> zlib.crc32(s)
3701065259
```
• Testing:
  • doctest: scans a module and validate tests embedded in a program’s
docstrings

def average(values):
    """Computes the arithmetic mean of a list of numbers.
    >>> print(average([20, 30, 70]))
    40.0
    """
    return sum(values) / len(values)

import doctest
doctest.testmod()  # automatically validate the embedded tests
Testing:

- unittest: comprehensive set of tests to be maintained in a separate file

```python
import unittest
class TestStatisticalFunctions(unittest.TestCase):
    def test_average(self):
        self.assertEqual(average([20, 30, 70]), 40.0)
        self.assertEqual(round(average([1, 5, 7]), 1), 4.3)
        with self.assertRaises(ZeroDivisionError):
            average([])
        with self.assertRaises(TypeError):
            average(20, 30, 70)

unittest.main()  # Calling from the command line invokes all tests
```
Standard Library

- Logging:
  - by default, informational and debugging messages are suppressed

<table>
<thead>
<tr>
<th>Level</th>
<th>Numeric value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRITICAL</td>
<td>50</td>
</tr>
<tr>
<td>ERROR</td>
<td>40</td>
</tr>
<tr>
<td>WARNING</td>
<td>30</td>
</tr>
<tr>
<td>INFO</td>
<td>20</td>
</tr>
<tr>
<td>DEBUG</td>
<td>10</td>
</tr>
<tr>
<td>NOTSET</td>
<td>0</td>
</tr>
</tbody>
</table>

```python
import logging
logging.debug('Debugging information')
logging.info('Informational message')
logging.warning('Warning: config file %s not found', 'server.conf')
logging.error('Error occurred')
logging.critical('Critical error -- shutting down')
logging.getLogger().setLevel('INFO')
```
What else?

- The Python Standard Library: built-in functions, collections, and many modules: [https://docs.python.org/3/library/index.html#library-index](https://docs.python.org/3/library/index.html#library-index)
- Installing Python Modules: pip, virtual environments [https://docs.python.org/3/installing/index.html#installing-index](https://docs.python.org/3/installing/index.html#installing-index)