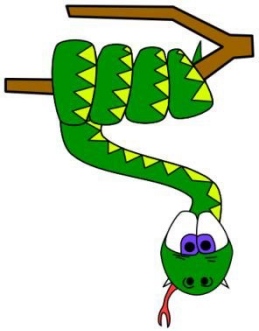
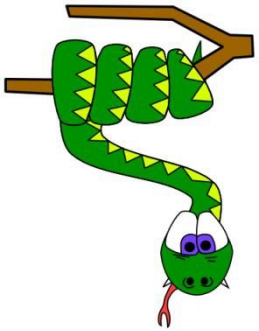


Introduction to Programming with Python

Credit: Robert Sedgewick, Kevin Wayne, Marty Stepp and Moshe Goldstein

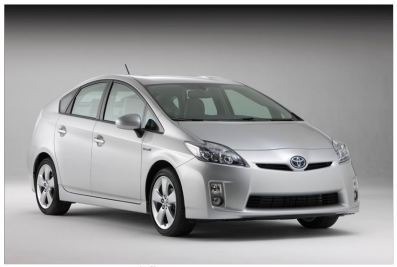
Outline

- Overview
- Python basics
- Repetition and selection (loops and if/else)
- More data types

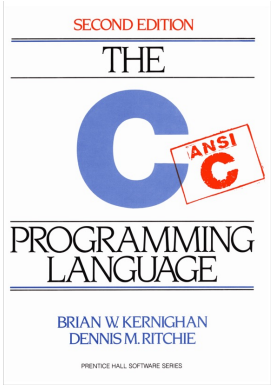


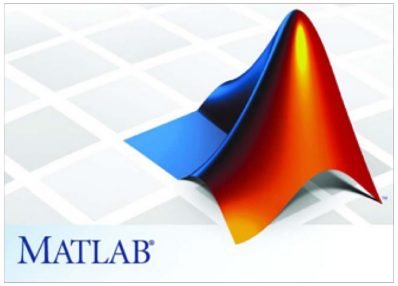
Overview

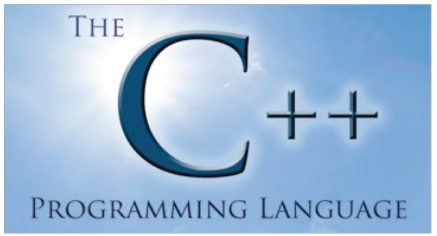
Several ways to solve a transportation problem



Several ways to solve a programming problem







Java

You can write Java code.

3-sum

- Read `int` values from `StdIn`.
- Print triples that sum to 0.
- [See *Performance* lecture]

ThreeSum.java

```
public class ThreeSum
{
   public static void main(String[] args)
   {
      int N = Integer.parseInt(args[0]);
      int[] a = new int[N];
      for (int i = 0; i < N; i++)
         a[i] = StdIn.readInt();
      for (int i = 0; i < N; i++)
         for (int j = i+1; j < N; j++)
            for (int k = j+1; k < N; k++)
               if (a[i] + a[j] + a[k] == 0)
                  StdOut.println(a[i] + " " + a[j] + " " + a[k]);
   }
}
```

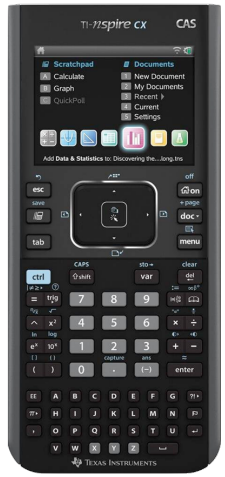
```
% more 8ints.txt
30 -30 -20 -10 40 0 10 5
% javac ThreeSum.java
% java ThreeSum 8 < 8ints.txt
 30 -30 0
 30 -20 -10
-30 -10 40
-10 0 10
```

Python

You can *also* use Python.

Example 1. Use Python like a calculator.


```
% python3
Python 3.9.6 (default, Sep 26 2022, 11:37:49)
[Clang 14.0.0 (clang-1400.0.29.202)] on darwin
Type "help", "copyright", "credits" or "license" for more
>>> 2+2
4
>>> (1+sqrt(5))/2
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'sqrt' is not defined
>>> import math
>>> (1+math.sqrt(5))/2
1.618033988749895
```



Python

You can *also* write Python code.

Example 2. Use Python like Java.

Noticeable differences

- No braces (indents instead).
- No type declarations.
- Array creation idiom.
- I/O idioms.
- for (iterable) idiom.

threesum.py


```
import sys

N = int(sys.argv[1])
a = [0]*N
for i in range(N):
   a[i] = int(sys.stdin.readline().strip())
for i in range(N):
   for j in range(i+1, N):
      for k in range(j+1, N):
         if (a[i] + a[j] + a[k]) == 0:
              print(a[i], a[j], a[k])
```

range(8) is [0,1,2,3,4,5,6,7]

```
% python threesum.py 8 < 8ints.txt
 30 -30 0
 30 -20 -10
-30 -10 40
-10 0 10
```

Compilation vs. Interpretation

Definition. A compiler translates your entire program to (virtual) machine code.

Definition. An interpreter simulates the operation of a (virtual) machine running your code.

A big difference between Python and Java

NO COMPILE-TIME TYPE CHECKING

- No need to declare types of variables.
- System checks for type errors *only* at RUN time.

Implications

- Easier to write small programs.
- More difficult to debug large programs.

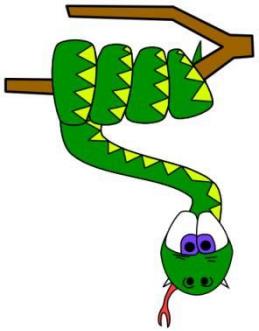
Using Python for large problems is playing with fire.

Typical (nightmare) scenario

- Scientist/programmer makes a small type error in a big program.
- Program runs for hours or days (because Python might be 10-100 times slower than Java).
- Program crashes without writing results.

Reasonable approaches

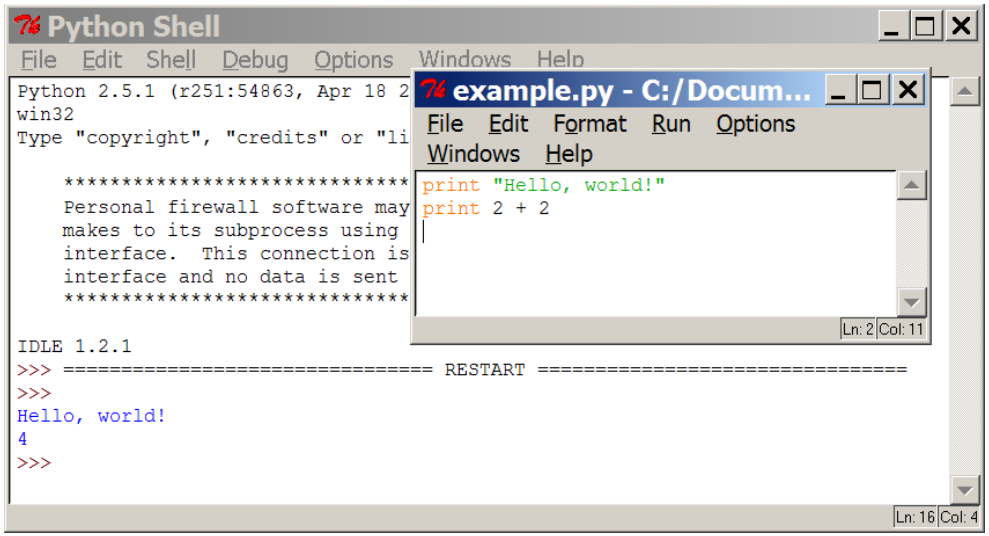
- Throw out your calculator; use Python.
- Prototype in Python, then convert to Java for "production" use.

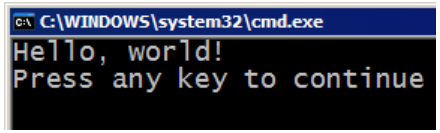


Python basics

Programming basics

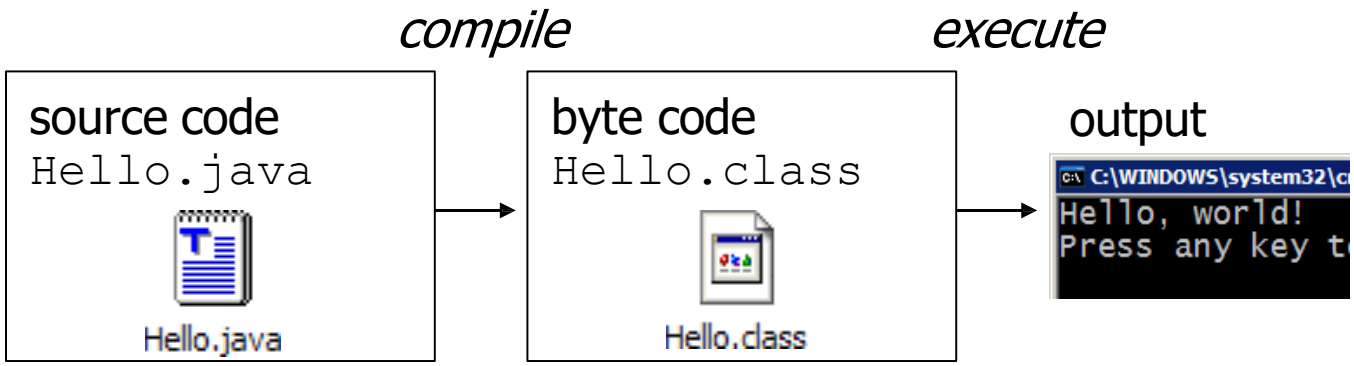
- **code** or **source code**: The sequence of instructions in a program.
- **syntax**: The set of legal structures and commands that can be used in a particular programming language.
- **output**: The messages printed to the user by a program.
- **console**: The text box onto which output is printed.
  - Some source code editors pop up the console as an external window, and others contain their own console window.



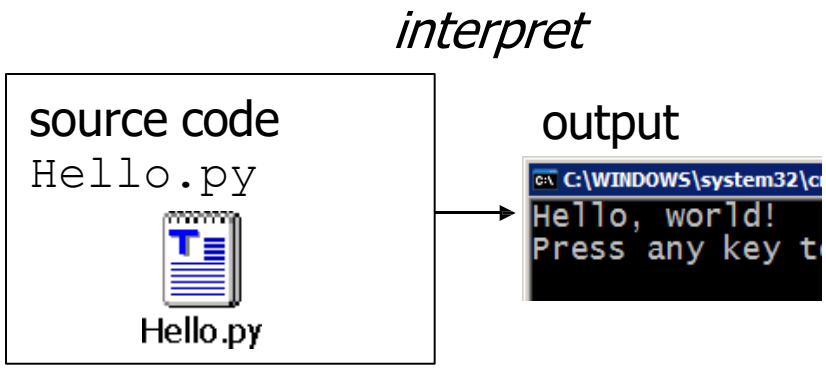


Compiling and interpreting

- Many languages require you to *compile* (translate) your program into a form that the machine understands.



- Python is instead directly *interpreted* into machine instructions.



The Python Interpreter

- Python is an interpreted language
- The interpreter provides an interactive environment to play with the language
- Results of expressions are printed on the screen

```
>>> 3 + 7
10
>>> 3 < 15
True
>>> 'print me'
'print me'
>>> print('print me')
print me
>>>
```

Expressions

- **expression**: A data value or set of operations to compute a value.

  Examples:
  ```
  1 + 4 * 3
  42
  ```

- Arithmetic operators we will use:

`+ - * / //`	addition, subtraction/negation, multiplication, division
`%`	modulus, a.k.a. remainder
`**`	exponentiation

- **precedence**: Order in which operations are computed.
  - `**` has a higher precedence than `* / // % + -`
  - `* / // %` have a higher precedence than `+ -`

  `1 + 3 * 4` is `13`

  - Parentheses can be used to force a certain order of evaluation.

  `(1 + 3) * 4` is `16`

Float division

- When we divide numbers with `/` , the quotient is always a float number

```
>>>5/5
1.0
>>>10/2
5.0
>>>-10/2
-5.0
>>>20.0/2
10.0
```

Integer division (floor)

- When we divide integers with `//` , the quotient is also an integer.
- If any of the numbers is float, it returns output in float.
  - Examples:
    - `35 // 5` is `7`
    - `84 // 10` is `8`
    - `156 // 100` is `1`
    - `35 // 5.0` is `7.0`
    - `84 // 10.0` is `8.0`

```
   3
4 ) 14
   12
    2
```

```
   52
27 ) 1425
   135
    75
    54
    21
```

- The `%` operator computes the remainder from an integer division.

```
   3
4 ) 14
   12
    2
```

```
   43
5 ) 218
   20
    18
    15
     3
```

Math commands

- Python has useful commands (or called functions) for performing calculations.

Command name	Description
`abs(`***value***`)`	absolute value
`ceil(`***value***`)`	rounds up
`cos(`***value***`)`	cosine, in radians
`floor(`***value***`)`	rounds down
`log(`***value***`)`	logarithm, base *e*
`log10(`***value***`)`	logarithm, base 10
`max(`***value1***`, `***value2***`)`	larger of two values
`min(`***value1***`, `***value2***`)`	smaller of two values
`round(`***value***`)`	nearest whole number
`sin(`***value***`)`	sine, in radians
`sqrt(`***value***`)`	square root

Constant	Description
`e`	2.7182818...
`pi`	3.1415926...

- To use many of these commands, you must write the following at the top of your Python program:

```
from math import *
```

Numbers: Floating Point

- int(x) converts x to an integer
- float(x) converts x to a floating point
- can use `type()` to see the type of a variable

```
>>> 1.23232
1.2323200000000001
>>> print(1.23232)
1.23232
>>> 1.3E7
13000000.0
>>>int(2.0)
2
>>> float(2)
2.0
>>> type(2.0)
float
```

Variables

- **variable**: A named piece of memory that can store a value.
  - Usage:
    - Compute an expression's result,
    - store that result into a variable,
    - and use that variable later in the program.

- **assignment statement**: Stores a value into a variable.
  - Syntax:

    name = ***value***

  - Examples:

```
x = 5
gpa = 3.14
```

  - A variable that has been given a value can be used in expressions.

    `x + 4` is `9`

- **Exercise:** Evaluate the quadratic equation for a given *a*, *b*, and *c*.

Exercise: Quadratic equation

Quadratic Formula

cuemath
THE MATH EXPERT

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Example

```
>>> x = 7
>>> x
7
>>> x+7
14
>>> x = 'hello'
>>> x
'hello'
>>>
```

print

- `print()` : Produces text output on the console.
- Syntax:

```
print("Message")

print(Expression)
```

  - Prints the given text message or expression value on the console, and moves the cursor down to the next line.

```
print(Item1, Item2, ..., ItemN)
```

  - Prints several messages and/or expressions on the same line.

- Examples:

```
print("Hello, world!")
age = 45
print("You have", 65 - age, "years until retirement")
```

Output:

```
Hello, world!
You have 20 years until retirement
```

Example: print Statement

- Elements separated by commas print with a space between them

```
>>> print('hello')
hello
>>> print('hello', 'there')
hello there
```

- To print without newline: `print('hello', end ='')`

```
>>> print('hello', end = '')
hello>>>
```

input

- `input` : Reads a string from user input.
  - You can assign (store) the result of `input` into a variable.
  - Example:

```
age = int(input("How old are you? "))
print("Your age is", age)
print("You have", 65 - age, "years until retirement")
```

Output:

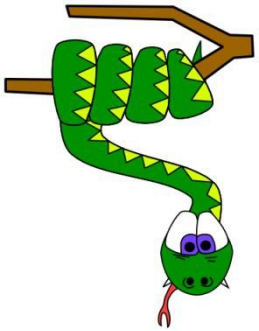
```
How old are you? 53
Your age is 53
You have 12 years until retirement
```

- **Exercise:** Write a Python program that prompts the user for his/her amount of money, then reports how many Nintendo Switches the person can afford, and how much more money he/she will need to afford an additional Switch.

Input: Example

```
print("What's your name?")
name = input("> ")

print("What year were you born?")
birthyear = int(input("> "))

print("Hi ", name, "!", "You are ", 2022 - birthyear)
```

```
% python3 input.py
What's your name?
> Michael
What year were you born?
>1980
Hi Michael! You are 42
```



Repetition (loops) and Selection (if/else)

The `for` loop

- **`for` loop**: Repeats a set of statements over a group of values.
  - Syntax:

    `for` ***variableName*** `in` ***groupOfValues***`:`
    statements

    - We indent the statements to be repeated with tabs or spaces.
    - ***variableName*** gives a name to each value, so you can refer to it in the ***statements***.
    - ***groupOfValues*** can be a range of integers, specified with the `range` function.

  - Example:

```
for x in range(1, 6):
    print(x, "squared is", x * x)
```

Output:

```
1 squared is 1
2 squared is 4
3 squared is 9
4 squared is 16
5 squared is 25
```

range

- The `range` function specifies a range of integers:
  - `range(`***start***`, `***stop***`)` - the integers between ***start*** (inclusive) and ***stop*** (exclusive)
- It can also accept a third value specifying the change between values.
  - `range(`***start***`, `***stop***`, `***step***`)` - the integers between ***start*** (inclusive) and ***stop*** (exclusive) by ***step***
- Example:

```
for x in range(5, 0, -1):
    print(x)
print("Blastoff!")
```

Output:

```
5
4
3
2
1
Blastoff!
```

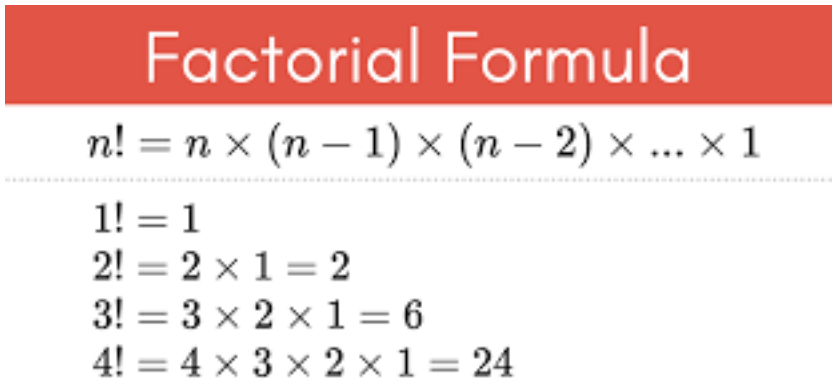
- **Exercise:** How would we print the "99 Bottles of Beer" song?

Cumulative loops

- Some loops incrementally compute a value that is initialized outside the loop. This is sometimes called a *cumulative sum*.

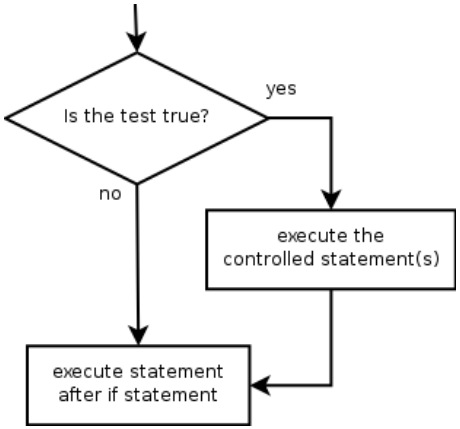
```
sum = 0
for i in range(1, 11):
    sum = sum + (i * i)
print("sum of first 10 squares is", sum)

Output:
sum of first 10 squares is 385
```

- **Exercise:** Write a Python program that computes the factorial of an integer.



if

- **`if` statement**: Executes a group of statements only if a certain condition is true. Otherwise, the statements are skipped.
  - Syntax:
    ```
    if condition:
        statements
    ```



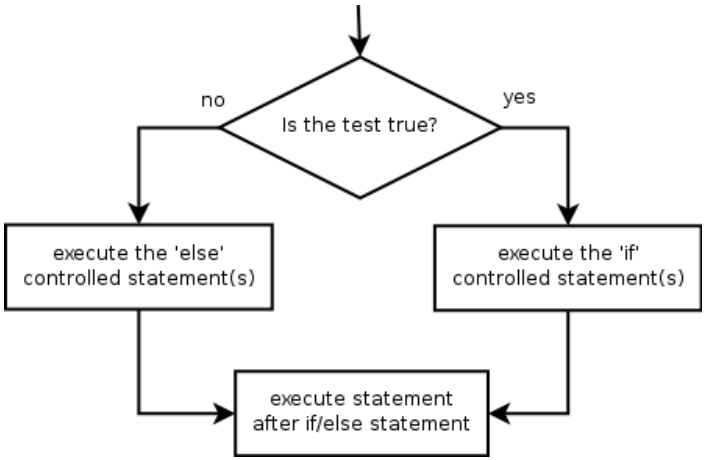
- Example:

```
gpa = 3.4
if gpa > 2.0:
    print("Your application is accepted.")
```

if/else

- **`if/else` statement**: Executes one block of statements if a certain condition is True, and a second block of statements if it is False.
  - Syntax:

```
if condition:
    statements
else:
    statements
```

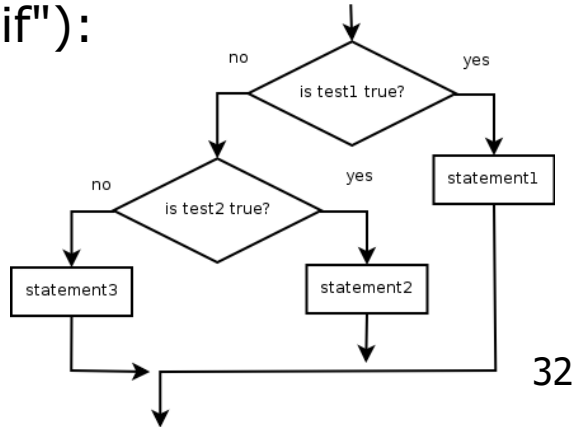


- Example:

```
gpa = 1.4
if gpa > 2.0:
    print("Welcome to Mars University!")
else:
    print("Your application is denied.")
```

- Multiple conditions can be chained with `elif` ("else if"):

```
if condition1:
    statements1
elif condition2:
    statements2
else:
    statements3
```



Example of If Statements

```
x = 30
if x <= 15:
        y = x + 15
elif x <= 30:
        y = x + 30
else:
        y = x

print('y =', y)
```

In file ifstatement.py

```
% python3 ifstatement.py
y = 60
```

In terminal

while

- **`while` loop**: Executes a group of statements as long as a condition is True.
  - good for *indefinite loops* (repeat an unknown number of times)

- Syntax:

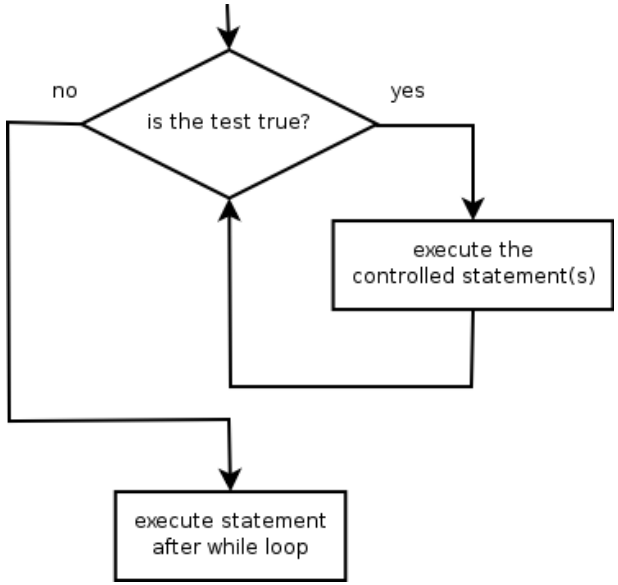
```
while condition:
    statements
```

- Example:

```
number = 1
while number < 200:
    print(number, end = " ")
    number = number * 2
```

  - Output:

```
1 2 4 8 16 32 64 128
```



While Loops

```
x = 1
while x < 10 :
   print(x)
   x = x + 1
```

- In whileloop.py

```
% python3 whileloop.py
1
2
3
4
5
6
7
8
9
```

- In terminal

Logic

- Many logical expressions use *relational operators*:

Operator	Meaning	Example	Result
==	equals	`1 + 1 == 2`	`True`
!=	does not equal	`3.2 != 2.5`	`True`
<	less than	`10 < 5`	`False`
>	greater than	`10 > 5`	`True`
<=	less than or equal to	`126 <= 100`	`False`
>=	greater than or equal to	`5.0 >= 5.0`	`True`

- Logical expressions can be combined with *logical operators*:

Operator	Example	Result
`and`	`9 != 6 and 2 < 3`	`True`
`or`	`2 == 3 or -1 < 5`	`True`
`not`	`not 7 > 0`	`False`

- **Exercise:** Write code to display and count the factors of a number.

Loop Control Statements

break	Jumps out of the closest enclosing loop
continue	Jumps to the top of the closest enclosing loop
pass	Does nothing, empty statement placeholder

More Examples For Loops

- Iterating through a list of values

forloop1.py

```
for x in [1,7,13,2]:
    print(x)
```

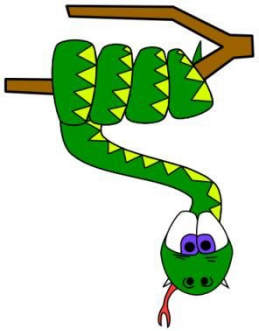
```
% python forloop1.py
1
7
13
2
```

forloop2.py

```
for x in range(5) :
    print(x)
```

```
% python forloop2.py
0
1
2
3
4
```

range(N) generates a list of numbers [0,1, …, n-1]



More Data Types

Everything is an object

- Everything means everything, including functions and classes
- Data type is a property of the object and not of the variable

```
>>> x = 7
>>> x
7
>>> x = 'hello'
>>> x
'hello'
>>>
```

Numbers: Integers

- Integers have unlimited precision.

```
>>> 132224
132224
>>> 132323 ** 2
17509376329
>>>
```

Numbers: Floating Point

- int(x) converts x to an integer
- float(x) converts x to a floating point
- The interpreter shows a lot of digits

```
>>> 1.23232
1.23232
>>> print(1.23232)
1.23232
>>> 1.3E7
13000000.0
>>> int(2.0)
2
>>> float(2)
2.0
```

Numbers: Complex

- Built into Python
- Same operations are supported as integer and float

```
>>> x = 3 + 2j
>>> y = -1j
>>> x + y
(3+1j)
>>> x * y
(2-3j)
```

String Literals

- + is overloaded to do concatenation

```
>>> x = 'hello'
>>> x = x + ' there'
>>> x
'hello there'
```

String Literals

- Can use single or double quotes

```
>>> 'I am a string'
'I am a string'
>>> "So am I!"
'So am I!'
```

Substrings and Methods

```
>>> s = '012345'
>>> s[3]
'3'
>>> s[1:4]
'123'
>>> s[2:]
'2345'
>>> s[:4]
'0123'
>>> s[-2]
'4'
```

suffix

prefix

- **len**(String) – returns the number of characters in the String

- **str**(Object) – returns a String representation of the Object

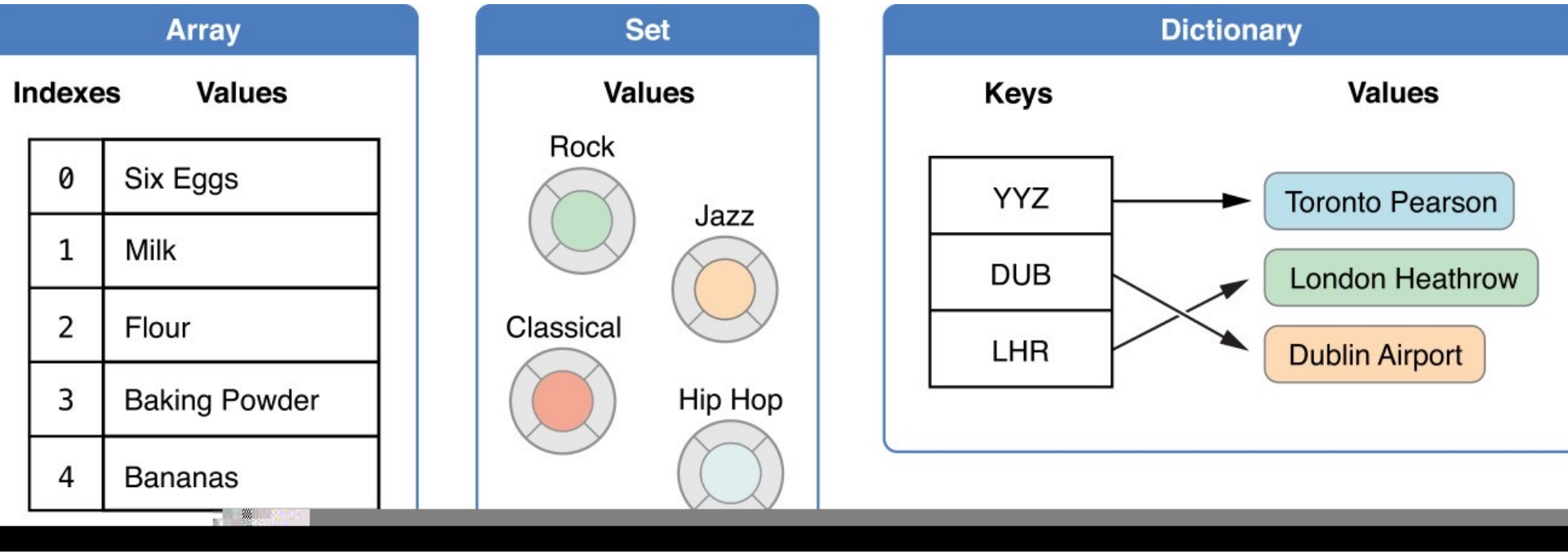
```
>>> len(s)
6
>>> str(10.3)
'10.3'
```

String Formatting

- Similar to Java's printf
- <formatted string> % <elements to insert>
- Can usually just use `%s` for everything, it will convert the object to its String representation.

```
>>> "One, %d, three" % 2
'One, 2, three'
>>> "%d, two, %s" % (1,3)
'1, two, 3'
>>> "%s two %s" % (1, 'three')
'1 two three'
>>>
```

Types for Data Collection List, Set, and Dictionary



List (ordered)

Set (Unordered list)

Dict (Pairs of values)

List Functions

- `list.append(x)`
  - Add item at the end of the list.
- `list.insert(i,x)`
  - Insert item at a given position.
  - Similar to `a[i:i]=[x]`
- `list.remove(x)`
  - Removes first item from the list with value `x`
- `list.pop(i)`
  - Remove item at position i and return it. If no index i is given then remove the last item in the list.
- `list.index(x)`
  - Return the index in the list of the first item with value x.
- `list.count(x)`
  - Return the number of time x appears in the list
- `list.sort()`
  - Sorts items in the list in ascending order
- `list.reverse()`
  - Reverses items in the list

Lists: Modifying Content

- **x[i] = a** reassigns the ith element to the value a
- Since x and y point to the same list object, *both* are changed
- The method **append** also modifies the list

```
>>> x = [1,2,3]
>>> y = x
>>> x[1] = 15
>>> x
[1, 15, 3]
>>> y
[1, 15, 3]
>>> x.append(12)
>>> y
[1, 15, 3, 12]
```

Lists: Modifying Contents

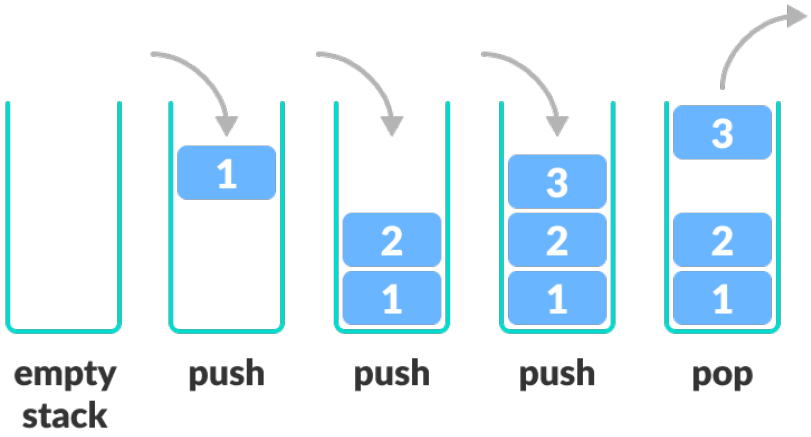
- The method **append** modifies the list and returns **None**
- List addition (**+**) returns a new list

```
>>> x = [1,2,3]
>>> y = x
>>> z = x.append(12)
>>> z == None
True
>>> y
[1, 2, 3, 12]
>>> x = x + [9,10]
>>> x
[1, 2, 3, 12, 9, 10]
>>> y
[1, 2, 3, 12]
>>>
```

Using Lists as Stacks

- You can use a list as a stack

```
>>> a = ["a", "b", "c“,”d”]
>>> a
['a', 'b', 'c', 'd']
>>> a.append("e")
>>> a
['a', 'b', 'c', 'd', 'e']
>>> a.pop()
'e'
>>> a.pop()
'd'
>>> a
["a", "b", "c"]
>>>
```



Tuples

- Tuples are *immutable* versions of lists
- One strange point is the format to make a tuple with one element:

  ',' is needed to differentiate from the mathematical expression (2)

```
>>> x = (1,2,3)
>>> x[1:]
(2, 3)
>>> y = (2,)
>>> y
(2,)
>>>
```

Sets

- A set is another python data structure that is an unordered collection with no duplicates.

```
>>> setA=set(["a","b","c","d"])
>>> setB=set(["c","d","e","f"])
>>> "a" in setA
True
>>> "a" in setB
False
```

Sets

```
>>> setA - setB
{'a', 'b'}
>>> setA | setB
{'a', 'c', 'b', 'e', 'd', 'f'}
>>> setA & setB
{'c', 'd'}
>>> setA ^ setB
{'a', 'b', 'e', 'f'}
>>>
```

Dictionaries

- A set of key-value pairs
- Dictionaries are *mutable*

```
>>> d= {'one' : 1, 'two' : 2, 'three' : 3}
>>> d[‘three’]
3
```

Dictionaries: Add/Modify

- Entries can be changed by assigning to that entry

```
>>> d
{1: 'hello', 'two': 42, 'blah': [1, 2, 3]}
>>> d['two'] = 99
>>> d
{1: 'hello', 'two': 99, 'blah': [1, 2, 3]}
```

- Assigning to a key that does not exist adds an entry

```
>>> d[7] = 'new entry'
>>> d
{1: 'hello', 7: 'new entry', 'two': 99, 'blah': [1, 2, 3]}
```

Dictionaries: Deleting Elements

- The **del** method deletes an element from a dictionary

```
>>> d
{1: 'hello', 2: 'there', 10: 'world'}
>>> del(d[2])
>>> d
{1: 'hello', 10: 'world'}
```

Iterating over a dictionary

```
>>>address={'Wayne': 'Young 678', 'John': 'Oakwood 345',
  'Mary': 'Kingston 564'}
 >>>for k in address.keys():
            print(k,":", address[k])

Wayne : Young 678
John : Oakwood 345
Mary : Kingston 564
>>>

>>> for k in sorted(address.keys()):
  print(k,":", address[k])

John : Oakwood 345
Mary : Kingston 564
Wayne : Young 678
>>>
```

Copying Dictionaries and Lists

- The built-in **list** function will copy a list
- The dictionary has a method called **copy**

```
>>> l1 = [1]
>>> l2 = list(l1)
>>> l1[0] = 22
>>> l1
[22]
>>> l2
[1]
```

```
>>> d = {1 : 10}
>>> d2 = d.copy()
>>> d[1] = 22
>>> d
{1: 22}
>>> d2
{1: 10}
```

Data Type Summary

Integers: 2323

Floating Point: 32.3, 3.1E2

Complex: 3 + 2j, 1j

Lists: l = [1,2,3]

Tuples: t = (1,2,3)

Dictionaries: d = {'hello' : 'there', 2 : 15}

- Lists, Tuples, and Dictionaries can store any type (including other lists, tuples, and dictionaries!)
- Only lists and dictionaries are mutable
- All variables are references