
Introduction to Python

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...

Python

- Open source general-purpose language.
 - Object Oriented, Procedural, Functional
 - Easy to interface with C/ObjC/Java/Fortran
 - Easy-ish to interface with C++ (via SWIG)
 - Great interactive environment
-
- Downloads: <http://www.python.org>
 - Documentation: <http://www.python.org/doc/>
 - Free book: <http://www.diveintopython.org>

2.5.x / 2.6.x / 3.x ???

- “Current” version is 2.6.x
- “Mainstream” version is 2.5.x
- The new kid on the block is 3.x

You probably want 2.5.x unless you are starting from scratch. Then maybe 3.x

Technical Issues

Installing & Running Python

Binaries

- Python comes pre-installed with Mac OS X and Linux.
- Windows binaries from <http://python.org/>
- You might not have to do anything!

The Python Interpreter

- **Interactive interface to Python**

```
% python
```

```
Python 2.5 (r25:51908, May 25 2007, 16:14:04)
```

```
[GCC 4.1.2 20061115 (prerelease) (SUSE Linux)] on linux2
```

```
Type "help", "copyright", "credits" or "license" for more information.
```

```
>>>
```

- **Python interpreter evaluates inputs:**

```
>>> 3*(7+2)
```

```
27
```

- **Python prompts with ‘>>>’.**
- **To exit Python:**
 - CTRL-D

Running Programs on UNIX

```
% python filename.py
```

You could make the *.py file executable and add the following `#!/usr/bin/env python` to the top to make it runnable.

Batteries Included

- Large collection of proven modules included in the standard distribution.

<http://docs.python.org/modindex.html>

numpy

- Offers Matlab-ish capabilities within Python
 - Fast array operations
 - 2D arrays, multi-D arrays, linear algebra etc.
-
- Downloads: <http://numpy.scipy.org/>
 - Tutorial: http://www.scipy.org/Tentative_NumPy_Tutorial

matplotlib

- High quality plotting library.

```
#!/usr/bin/env python
import numpy as np
import matplotlib.mlab as mlab
import matplotlib.pyplot as plt

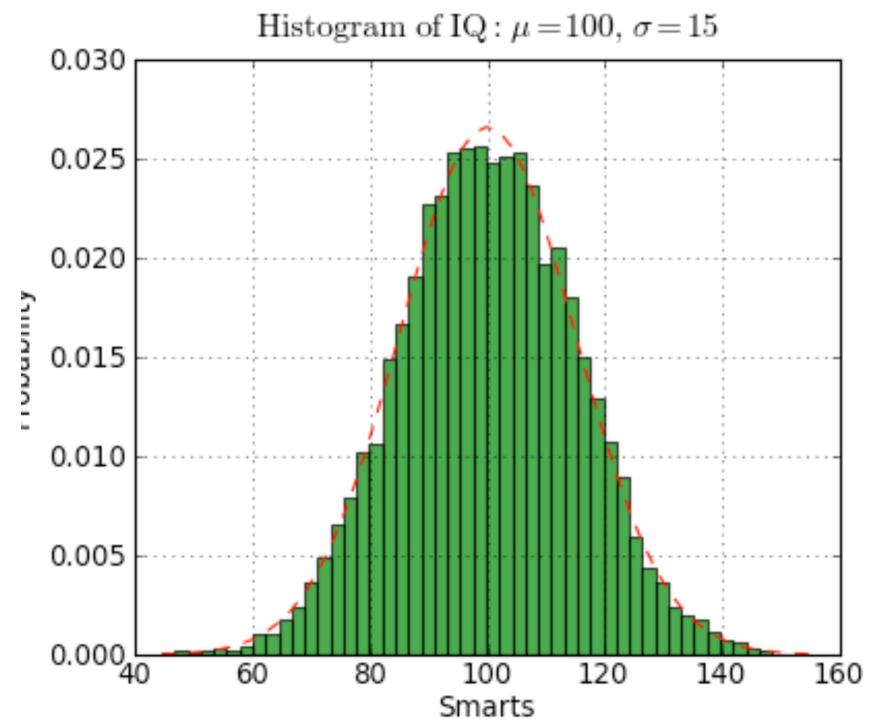
mu, sigma = 100, 15
x = mu + sigma*np.random.randn(10000)

# the histogram of the data
n, bins, patches = plt.hist(x, 50, normed=1, facecolor='green',
                            alpha=0.75)

# add a 'best fit' line
y = mlab.normpdf(bins, mu, sigma)
l = plt.plot(bins, y, 'r--', linewidth=1)

plt.xlabel('Smarts')
plt.ylabel('Probability')
plt.title(r'$\mathrm{Histogram\ of\ IQ:}\ \mu=100,\ \sigma=15$')
plt.axis([40, 160, 0, 0.03])
plt.grid(True)

plt.show()
```



- Downloads: <http://matplotlib.sourceforge.net/>

PyFITS

- **FITS I/O made simple:**

```
>>> import pyfits
>>> hdulist = pyfits.open('input.fits')
>>> hdulist.info()
Filename: test1.fits
No. Name Type Cards Dimensions Format
0 PRIMARY PrimaryHDU 220 () Int16
1 SCI ImageHDU 61 (800, 800) Float32
2 SCI ImageHDU 61 (800, 800) Float32
3 SCI ImageHDU 61 (800, 800) Float32
4 SCI ImageHDU 61 (800, 800) Float32
>>> hdulist[0].header['targname']
'NGC121'
>>> scidata = hdulist[1].data
>>> scidata.shape
(800, 800)
>>> scidata.dtype.name 'float32'
>>> scidata[30:40,10:20] = scidata[1,4] = 999
```

- **Downloads:** [http://www.stsci.edu/resources/
software_hardware/pyfits](http://www.stsci.edu/resources/software_hardware/pyfits)

pyds9 / python-sao

- **Interaction with DS9**
 - **Display Python 1-D and 2-D arrays in DS9**
 - **Display FITS files in DS9**
-
- **Downloads:** Ask Eric Mandel :-)
 - **Downloads:** <http://code.google.com/p/python-sao/>

Wrappers for Astronomical Packages

- **CasaPy (Casa)**
- **PyGILDAS (GILDAS)**
- **ParseiTongue (AIPS)**
- **PyRAF (IRAF)**
- **PyMIDAS (MIDAS)**
- **PyIMSL (IMSL)**

Custom Distributions

- **Python(x,y):** <http://www.pythonxy.com/>
 - Python(x,y) is a free scientific and engineering development software for numerical computations, data analysis and data visualization
- **Sage:** <http://www.sagemath.org/>
 - Sage is a free open-source mathematics software system licensed under the GPL. It combines the power of many existing open-source packages into a common Python-based interface.

Extra Astronomy Links

- iPython (better shell, distributed computing):
<http://ipython.scipy.org/>
- SciPy (collection of science tools): <http://www.scipy.org/>
- Python Astronomy Modules: <http://astlib.sourceforge.net/>
- Python Astronomer Wiki: <http://macsingularity.org/astrowiki/tiki-index.php?page=python>
- AstroPy: <http://www.astro.washington.edu/users/rowen/AstroPy.html>
- Python for Astronomers: <http://www.iac.es/sieinvens/siepedia/pmwiki.php?n=HOWTOs.EmpezandoPython>

The Basics

A Code Sample

```
x = 34 - 23                      # A comment.  
y = "Hello"                        # Another one.  
z = 3.45  
if z == 3.45 or y == "Hello":  
    x = x + 1  
    y = y + " World"    # String concat.  
print x  
print y
```

Enough to Understand the Code

- Assignment uses `=` and comparison uses `==`.
- For numbers `+ - * / %` are as expected.
 - Special use of `+` for string concatenation.
 - Special use of `%` for string formatting (as with `printf` in C)
- Logical operators are words (`and`, `or`, `not`)
not symbols
- The basic printing command is `print`.
- The first assignment to a variable creates it.
 - Variable types don't need to be declared.
 - Python figures out the variable types on its own.

Basic Datatypes

- **Integers (default for numbers)**

```
z = 5 / 2      # Answer is 2, integer division.
```

- **Floats**

```
x = 3.456
```

- **Strings**

- Can use "" or " to specify.

```
"abc"  'abc' (Same thing.)
```

- Unmatched can occur within the string.

```
"matt's"
```

- Use triple double-quotes for multi-line strings or strings than contain both ' and " inside of them:

```
"""a'b"c""""
```

Whitespace

Whitespace is meaningful in Python: especially indentation and placement of newlines.

- **Use a newline to end a line of code.**
 - Use \ when must go to next line prematurely.
- **No braces { } to mark blocks of code in Python... Use *consistent* indentation instead.**
 - The first line with *less* indentation is outside of the block.
 - The first line with *more* indentation starts a nested block
- **Often a colon appears at the start of a new block. (E.g. for function and class definitions.)**

Comments

- Start comments with # – the rest of line is ignored.
- Can include a “documentation string” as the first line of any new function or class that you define.
- The development environment, debugger, and other tools use it: it’s good style to include one.

```
def my_function(x, y):  
    """This is the docstring. This  
    function does blah blah blah."""  
    # The code would go here...
```

Assignment

- **Binding a variable in Python means setting a *name* to hold a *reference* to some *object*.**
 - Assignment creates references, not copies
- **Names in Python do not have an intrinsic type. Objects have types.**
 - Python determines the type of the reference automatically based on the data object assigned to it.
- **You create a name the first time it appears on the left side of an assignment expression:**
`x = 3`
- **A reference is deleted via garbage collection after any names bound to it have passed out of scope.**

Accessing Non-Existent Names

- If you try to access a name before it's been properly created (by placing it on the left side of an assignment), you'll get an error.

```
>>> y  
  
Traceback (most recent call last):  
  File "<pyshell#16>", line 1, in -toplevel-  
    y  
NameError: name 'y' is not defined  
>>> y = 3  
>>> y  
3
```

Multiple Assignment

- You can also assign to multiple names at the same time.

```
>>> x, y = 2, 3  
>>> x  
2  
>>> y  
3
```

Naming Rules

- **Names are case sensitive and cannot start with a number.
They can contain letters, numbers, and underscores.**

bob Bob _bob _2_bob_ bob_2 BoB

- **There are some reserved words:**

and, assert, break, class, continue, def, del, elif,
else, except, exec, finally, for, from, global, if,
import, in, is, lambda, not, or, pass, print, raise,
return, try, while

Understanding Reference Semantics in Python

Understanding Reference Semantics

- **Assignment manipulates references**
 - $x = y$ does not make a copy of the object y references
 - $x = y$ makes x reference the object y references

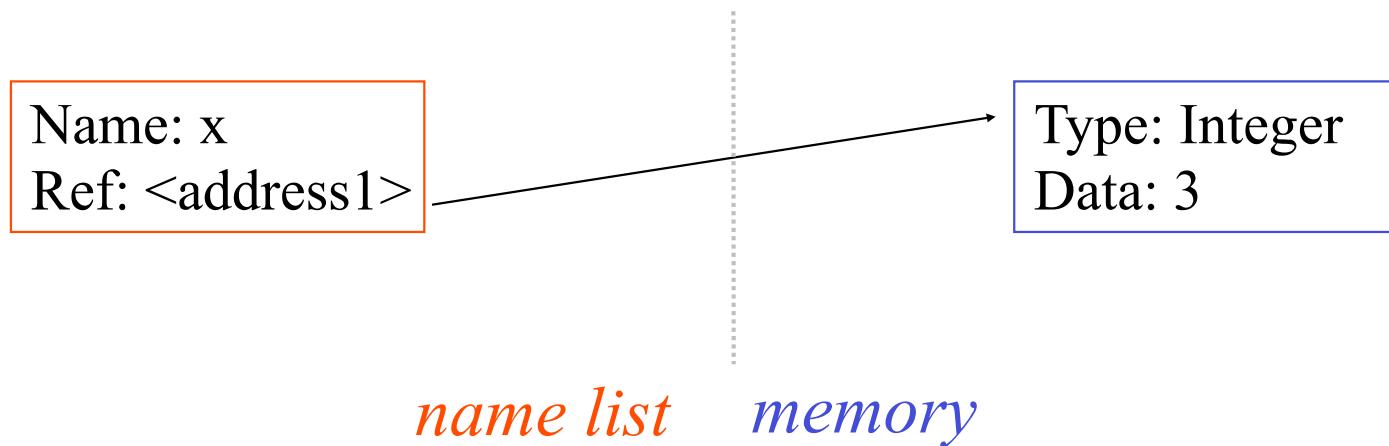
- **Very useful; but beware!**
- **Example:**

```
>>> a = [1, 2, 3]      # a now references the list [1, 2, 3]
>>> b = a              # b now references what a references
>>> a.append(4)        # this changes the list a references
>>> print b            # if we print what b references,
[1, 2, 3, 4]           # SURPRISE! It has changed...
```

Why??

Understanding Reference Semantics II

- There is a lot going on when we type:
 $x = 3$
- First, an integer **3** is created and stored in memory
- A name **x** is created
- An **reference** to the memory location storing the **3** is then assigned to the name **x**
- So: When we say that the value of **x** is **3**
- we mean that **x** now refers to the integer **3**



Understanding Reference Semantics III

- The data 3 we created is of type integer. In Python, the datatypes integer, float, and string (and tuple) are “immutable.”
- This doesn’t mean we can’t change the value of x, i.e. *change what x refers to* ...
- For example, we could increment x:

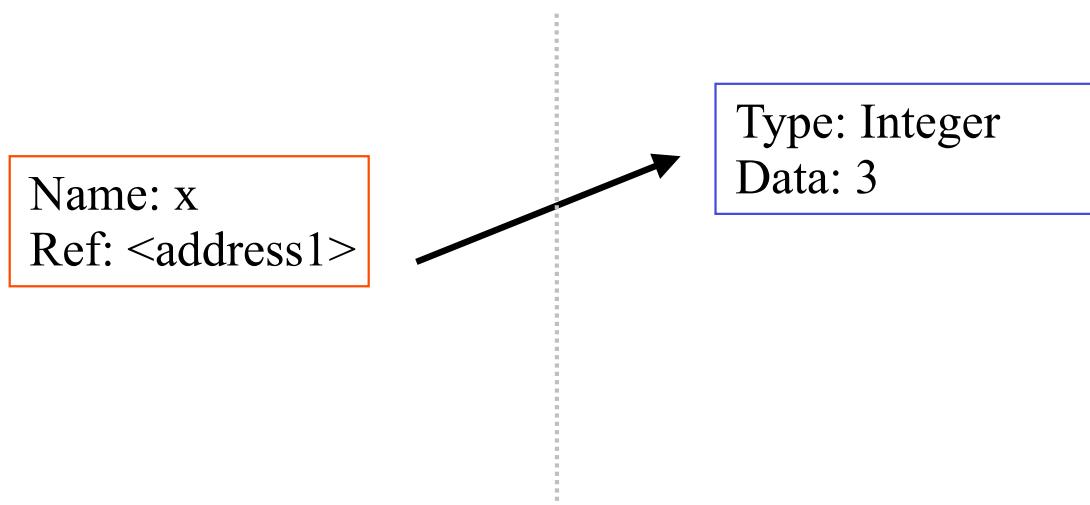
```
>>> x = 3  
>>> x = x + 1  
>>> print x  
4
```

Understanding Reference Semantics IV

- If we increment x , then what's really happening is:

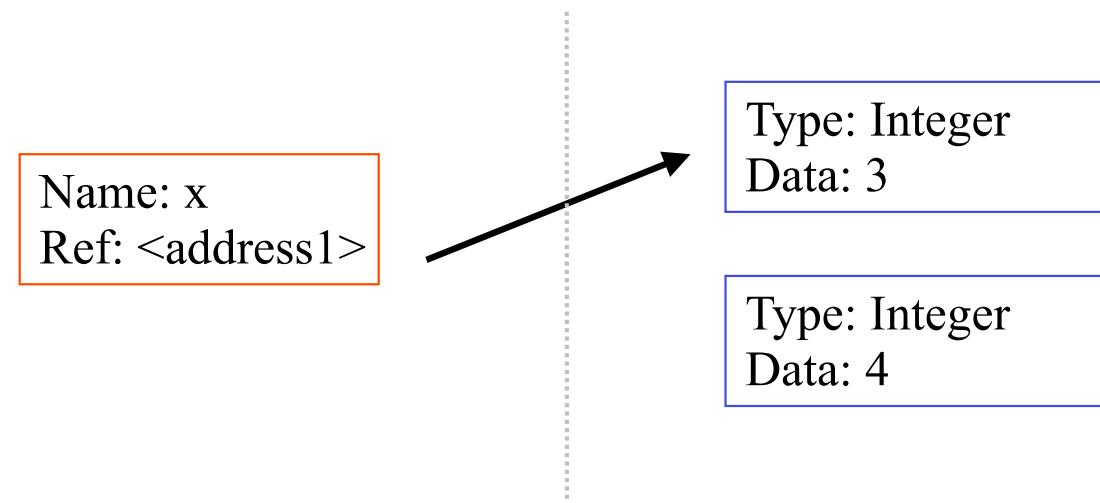
1. *The reference of name X is looked up.*
2. *The value at that reference is retrieved.*

```
>>> x = x + 1
```



Understanding Reference Semantics IV

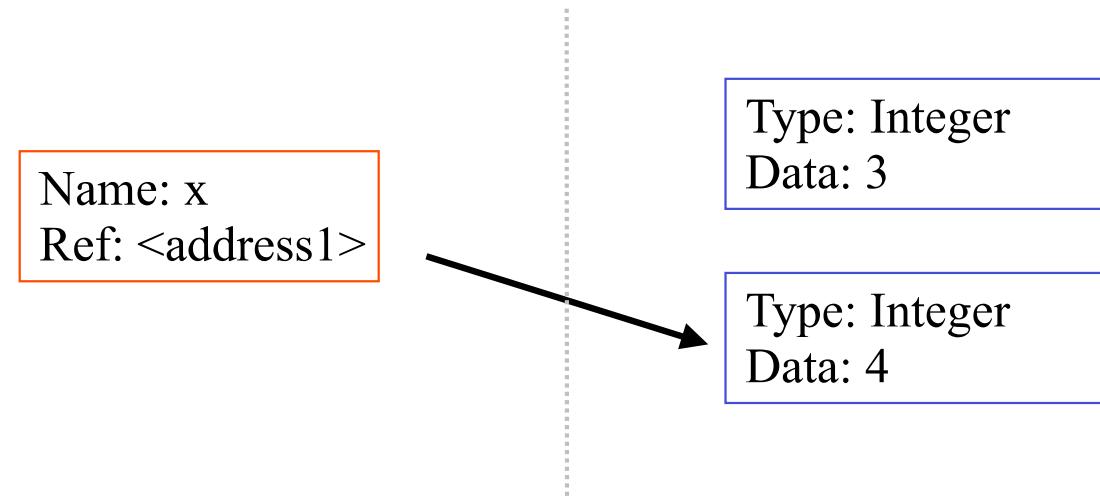
- If we increment x , then what's really happening is:
 1. The reference of name X is looked up.
 2. The value at that reference is retrieved.
 3. *The $3+1$ calculation occurs, producing a new data element 4 which is assigned to a fresh memory location with a new reference.*



Understanding Reference Semantics IV

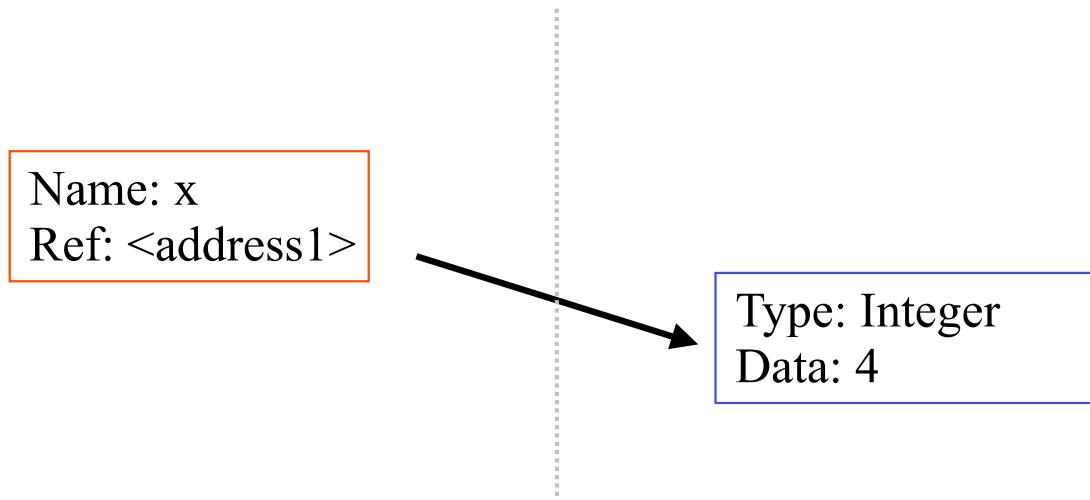
- If we increment x , then what's really happening is:

1. The reference of name X is looked up.
2. The value at that reference is retrieved.
3. The $3+1$ calculation occurs, producing a new data element 4 which is assigned to a fresh memory location with a new reference.
4. *The name X is changed to point to this new reference.*



Understanding Reference Semantics IV

- If we increment x , then what's really happening is:
 1. The reference of name X is looked up. $\ggg x = x + 1$
 2. The value at that reference is retrieved.
 3. The $3+1$ calculation occurs, producing a new data element 4 which is assigned to a fresh memory location with a new reference.
 4. The name X is changed to point to this new reference.
 5. *The old data 3 is garbage collected if no name still refers to it.*



Assignment 1

- **So, for simple built-in datatypes (integers, floats, strings), assignment behaves as you would expect:**

```
>>> x = 3      # Creates 3, name x refers to 3  
>>> y = x      # Creates name y, refers to 3.  
>>> y = 4      # Creates ref for 4. Changes y.  
>>> print x    # No effect on x, still ref 3.  
3
```

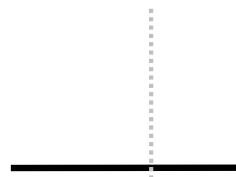


Assignment 1

- So, for simple built-in datatypes (integers, floats, strings), assignment behaves as you would expect:

→ `>>> x = 3 # Creates 3, name x refers to 3`
`>>> y = x # Creates name y, refers to 3.`
`>>> y = 4 # Creates ref for 4. Changes y.`
`>>> print x # No effect on x, still ref 3.`
3

Name: x
Ref: <address1>

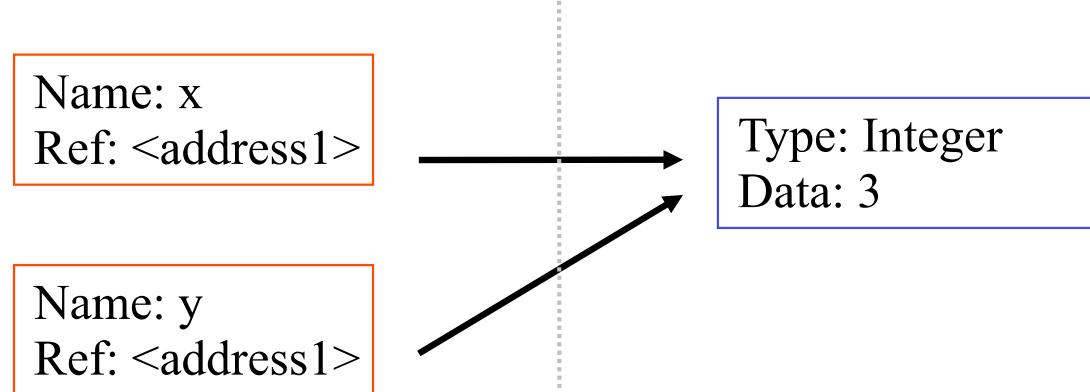


Type: Integer
Data: 3

Assignment 1

- So, for simple built-in datatypes (integers, floats, strings), assignment behaves as you would expect:

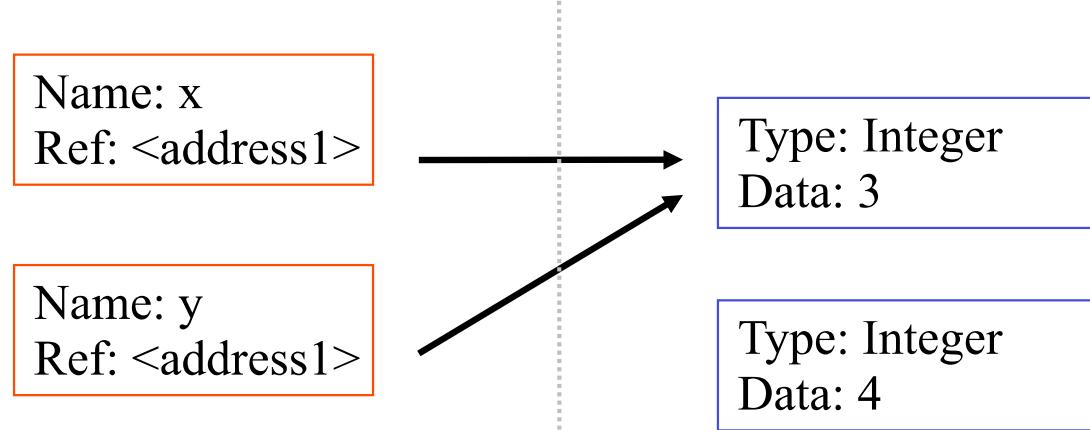
```
>>> x = 3      # Creates 3, name x refers to 3  
→ >>> y = x      # Creates name y, refers to 3.  
>>> y = 4      # Creates ref for 4. Changes y.  
>>> print x      # No effect on x, still ref 3.  
3
```



Assignment 1

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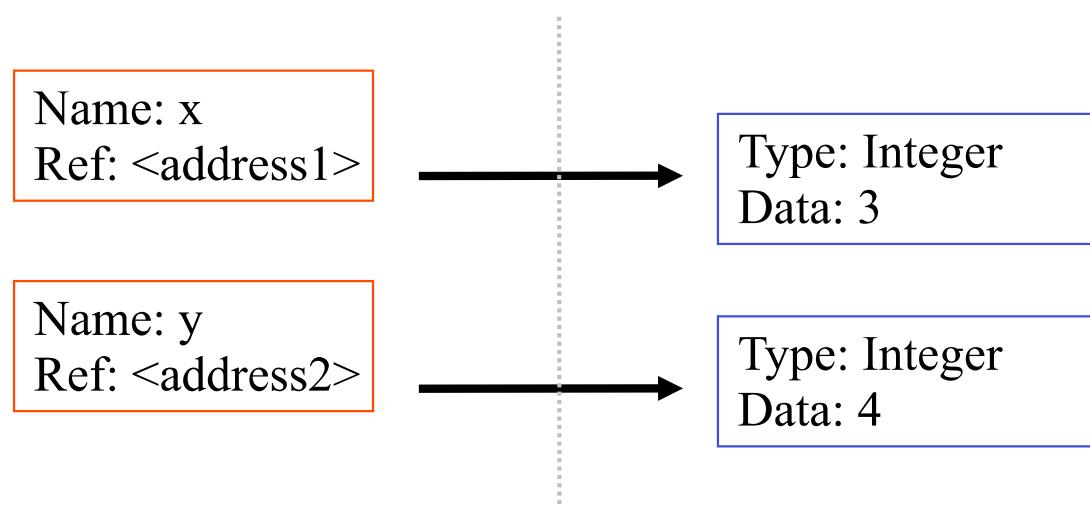
```
>>> x = 3      # Creates 3, name x refers to 3  
→ >>> y = x      # Creates name y, refers to 3.  
>>> y = 4      # Creates ref for 4. Changes y.  
>>> print x      # No effect on x, still ref 3.  
3
```



Assignment 1

- So, for simple built-in datatypes (integers, floats, strings), assignment behaves as you would expect:

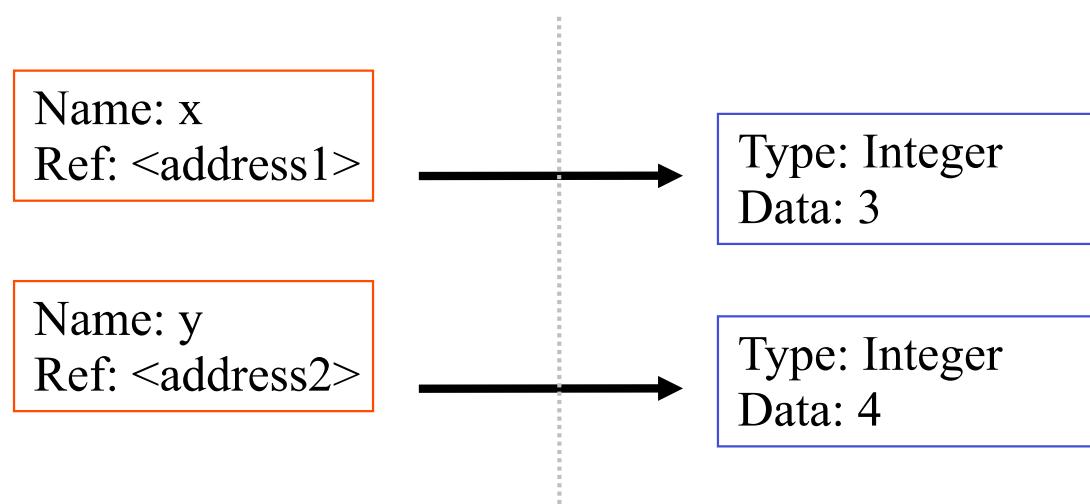
```
>>> x = 3      # Creates 3, name x refers to 3  
>>> y = x      # Creates name y, refers to 3.  
→ >>> y = 4     # Creates ref for 4. Changes y.  
>>> print x    # No effect on x, still ref 3.  
3
```



Assignment 1

- So, for simple built-in datatypes (integers, floats, strings), assignment behaves as you would expect:

```
>>> x = 3      # Creates 3, name x refers to 3  
>>> y = x      # Creates name y, refers to 3.  
>>> y = 4      # Creates ref for 4. Changes y.  
→ >>> print x  # No effect on x, still ref 3.  
3
```



Assignment 2

- For other data types (lists, dictionaries, user-defined types), assignment works differently.
 - These datatypes are “**mutable**.”
 - When we change these data, we do it *in place*.
 - We don’t copy them into a new memory address each time.
 - If we type `y=x` and then modify `y`, both `x` and `y` are changed.

immutable

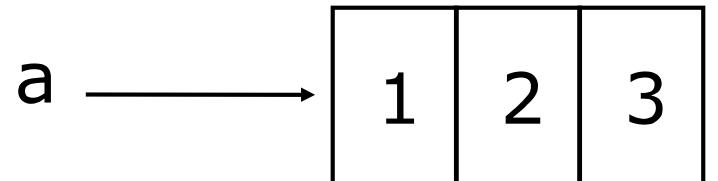
```
>>> x = 3  
>>> y = x  
>>> y = 4  
>>> print x  
3
```

mutable

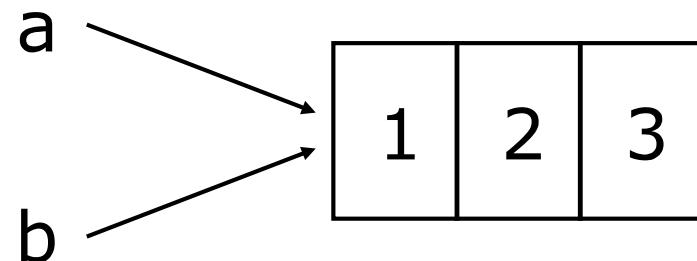
```
x = some mutable object  
y = x  
make a change to y  
look at x  
x will be changed as well
```

Why? Changing a Shared List

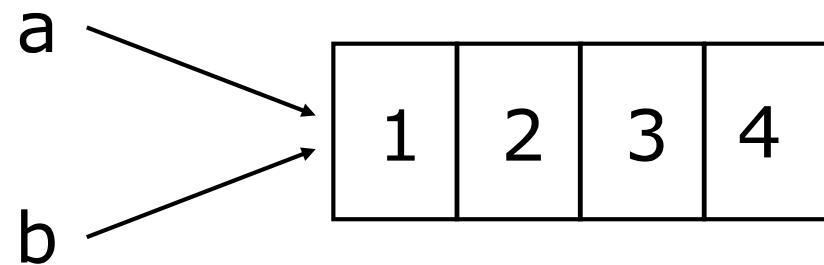
`a = [1, 2, 3]`



`b = a`



`a.append(4)`



Our surprising example surprising no more...

- So now, here's our code:

```
>>> a = [1, 2, 3]    # a now references the list [1, 2, 3]
>>> b = a            # b now references what a references
>>> a.append(4)      # this changes the list a references
>>> print b          # if we print what b references,
[1, 2, 3, 4]          # SURPRISE! It has changed...
```

Sequence types: Tuples, Lists, and Strings

Sequence Types

1. Tuple

- A simple ***immutable*** ordered sequence of items
- Items can be of mixed types, including collection types

2. Strings

- ***Immutable***
- **Conceptually very much like a tuple**

3. List

- ***Mutable*** ordered sequence of items of mixed types

Similar Syntax

- All three sequence types (tuples, strings, and lists) share much of the same syntax and functionality.
- Key difference:
 - Tuples and strings are *immutable*
 - Lists are *mutable*
- The operations shown in this section can be applied to *all* sequence types
 - most examples will just show the operation performed on one

Sequence Types 1

- **Tuples are defined using parentheses (and commas).**

```
>>> tu = (23, 'abc', 4.56, (2,3), 'def')
```

- **Lists are defined using square brackets (and commas).**

```
>>> li = ["abc", 34, 4.34, 23]
```

- **Strings are defined using quotes (" , ' , or """).**

```
>>> st = "Hello World"
```

```
>>> st = 'Hello World'
```

```
>>> st = """This is a multi-line  
string that uses triple quotes."""
```

Sequence Types 2

- We can access individual members of a tuple, list, or string using square bracket “array” notation.
- ***Note that all are 0 based...***

```
>>> tu = (23, 'abc', 4.56, (2,3), 'def')  
>>> tu[1]      # Second item in the tuple.  
'abc'
```

```
>>> li = ["abc", 34, 4.34, 23]  
>>> li[1]      # Second item in the list.  
34
```

```
>>> st = "Hello World"  
>>> st[1]    # Second character in string.  
'e'
```

Positive and negative indices

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')
```

Positive index: count from the left, starting with 0.

```
>>> t[1]  
'abc'
```

Negative lookup: count from right, starting with -1.

```
>>> t[-3]  
4.56
```

Slicing: Return Copy of a Subset 1

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')
```

Return a copy of the container with a subset of the original members. Start copying at the first index, and stop copying before the second index.

```
>>> t[1:4]
('abc', 4.56, (2,3))
```

You can also use negative indices when slicing.

```
>>> t[1:-1]
('abc', 4.56, (2,3))
```

Slicing: Return Copy of a Subset 2

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')
```

Omit the first index to make a copy starting from the beginning of the container.

```
>>> t[:2]  
(23, 'abc')
```

Omit the second index to make a copy starting at the first index and going to the end of the container.

```
>>> t[2:]  
(4.56, (2,3), 'def')
```

Copying the Whole Sequence

To make a *copy* of an entire sequence, you can use `[:]`.

```
>>> t[:]
(23, 'abc', 4.56, (2,3), 'def')
```

Note the difference between these two lines for mutable sequences:

```
>>> list2 = list1      # 2 names refer to 1 ref
                  # Changing one affects both

>>> list2 = list1[:] # Two independent copies, two refs
```

The 'in' Operator

- Boolean test whether a value is inside a container:

```
>>> t = [1, 2, 4, 5]
>>> 3 in t
False
>>> 4 in t
True
>>> 4 not in t
False
```

- For strings, tests for substrings

```
>>> a = 'abcde'
>>> 'c' in a
True
>>> 'cd' in a
True
>>> 'ac' in a
False
```

- Be careful: the *in* keyword is also used in the syntax of *for loops* and *list comprehensions*.

The + Operator

- The + operator produces a *new* tuple, list, or string whose value is the concatenation of its arguments.

```
>>> (1, 2, 3) + (4, 5, 6)
(1, 2, 3, 4, 5, 6)
```

```
>>> [1, 2, 3] + [4, 5, 6]
[1, 2, 3, 4, 5, 6]
```

```
>>> "Hello" + " " + "World"
'Hello World'
```

The * Operator

- The * operator produces a **new tuple, list, or string** that “repeats” the original content.

```
>>> (1, 2, 3) * 3  
(1, 2, 3, 1, 2, 3, 1, 2, 3)
```

```
>>> [1, 2, 3] * 3  
[1, 2, 3, 1, 2, 3, 1, 2, 3]
```

```
>>> "Hello" * 3  
'HelloHelloHello'
```

Mutability: Tuples vs. Lists

Tuples: Immutable

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')
>>> t[2] = 3.14
```

```
Traceback (most recent call last):
  File "<pyshell#75>", line 1, in -toplevel-
    tu[2] = 3.14
TypeError: object doesn't support item assignment
```

You can't change a tuple.

You can make a fresh tuple and assign its reference to a previously used name.

```
>>> t = (23, 'abc', 3.14, (2,3), 'def')
```

Lists: Mutable

```
>>> li = ['abc', 23, 4.34, 23]
>>> li[1] = 45
>>> li
['abc', 45, 4.34, 23]
```

- We can change lists *in place*.
- Name *li* still points to the same memory reference when we're done.
- The mutability of lists means that they aren't as fast as tuples.

Operations on Lists Only 1

```
>>> li = [1, 11, 3, 4, 5]

>>> li.append('a')      # Our first exposure to method syntax
>>> li
[1, 11, 3, 4, 5, 'a']

>>> li.insert(2, 'i')
>>> li
[1, 11, 'i', 3, 4, 5, 'a']
```

The *extend* method vs the + operator.

- + creates a fresh list (with a new memory reference)
- *extend* operates on list li in place.

```
>>> li.extend([9, 8, 7])
>>> li
[1, 2, 'i', 3, 4, 5, 'a', 9, 8, 7]
```

Confusing:

- Extend takes a list as an argument.
- Append takes a singleton as an argument.

```
>>> li.append([10, 11, 12])
>>> li
[1, 2, 'i', 3, 4, 5, 'a', 9, 8, 7, [10, 11, 12]]
```

Operations on Lists Only 3

```
>>> li = [ 'a', 'b', 'c', 'b' ]  
  
>>> li.index('b')      # index of first occurrence  
1  
  
>>> li.count('b')      # number of occurrences  
2  
  
>>> li.remove('b')      # remove first occurrence  
>>> li  
[ 'a', 'c', 'b' ]
```

Operations on Lists Only 4

```
>>> li = [5, 2, 6, 8]

>>> li.reverse()      # reverse the list *in place*
>>> li
[8, 6, 2, 5]

>>> li.sort()         # sort the list *in place*
>>> li
[2, 5, 6, 8]

>>> li.sort(some_function)
# sort in place using user-defined comparison
```

Tuples vs. Lists

- **Lists slower but more powerful than tuples.**
 - Lists can be modified, and they have lots of handy operations we can perform on them.
 - Tuples are immutable and have fewer features.
- **To convert between tuples and lists use the `list()` and `tuple()` functions:**

```
li = list(tu)  
tu = tuple(li)
```

Dictionaries

Dictionaries: A Mapping type

- **Dictionaries store a mapping between a set of keys and a set of values.**
 - Keys can be any immutable type.
 - Values can be any type
 - A single dictionary can store values of different types
- **You can define, modify, view, lookup, and delete the key-value pairs in the dictionary.**

Using dictionaries

```
>>> d = { 'user' : 'bozo' , 'pswd' :1234}
>>> d[ 'user']
'bozo'
>>> d[ 'pswd' ]
1234
>>> d[ 'bozo' ]

Traceback (innermost last):
  File '<interactive input>' line 1, in ?
KeyError: bozo

>>> d = { 'user' : 'bozo' , 'pswd' :1234}
>>> d[ 'user' ] = 'clown'
>>> d
{'user': 'clown', 'pswd': 1234}

>>> d[ 'id' ] = 45
>>> d
{'user': 'clown', 'id': 45, 'pswd': 1234}
```

```
>>> d = { 'user' : 'bozo' , 'p' :1234, 'i' :34}
>>> del d[ 'user' ]          # Remove one.
>>> d
{ 'p' :1234, 'i' :34}
>>> d.clear()               # Remove all.
>>> d
{ }
```



```
>>> d = { 'user' : 'bozo' , 'p' :1234, 'i' :34}
>>> d.keys()                # List of keys.
['user', 'p', 'i']
>>> d.values()               # List of values.
['bozo', 1234, 34]
>>> d.items()                # List of item tuples.
[('user', 'bozo'), ('p', 1234), ('i', 34)]
```

Functions

Functions

- ***def* creates a function and assigns it a name**
- ***return* sends a result back to the caller**
- **Arguments are passed by assignment**
- **Arguments and return types are not declared**

```
def <name>(arg1, arg2, ..., argN):  
    <statements>  
    return <value>
```

```
def times(x,y):  
    return x*y
```

Passing Arguments to Functions

- *Arguments are passed by assignment*
- *Passed arguments are assigned to local names*
- *Assignment to argument names don't affect the caller*
- *Changing a mutable argument may affect the caller*

```
def changer (x,y):  
    x = 2                      # changes local value of x only  
    y[0] = 'hi'                  # changes shared object
```

Optional Arguments

- Can define defaults for arguments that need not be passed

```
def func(a, b, c=10, d=100):  
    print a, b, c, d
```

```
>>> func(1,2)  
1 2 10 100
```

```
>>> func(1,2,3,4)  
1,2,3,4
```

Gotchas

- **All functions in Python have a return value**
 - even if no return line inside the code.
- **Functions without a return return the special value `None`.**
- **There is no function overloading in Python.**
 - Two different functions can't have the same name, even if they have different arguments.
- **Functions can be used as any other data type.**
They can be:
 - Arguments to function
 - Return values of functions
 - Assigned to variables
 - Parts of tuples, lists, etc

Control of Flow

Examples

```
if x == 3:  
    print "X equals 3."  
elif x == 2:  
    print "X equals 2."  
else:  
    print "X equals something else."  
print "This is outside the 'if'."  
  
assert(number_of_players < 5)
```

```
x = 3  
while x < 10:  
    if x > 7:  
        x += 2  
        continue  
    x = x + 1  
    print "Still in the loop."  
    if x == 8:  
        break  
print "Outside of the loop."  
  
for x in range(10):  
    if x > 7:  
        x += 2  
        continue  
    x = x + 1  
    print "Still in the loop."  
    if x == 8:  
        break  
    print "Outside of the loop."
```

Modules

Why Use Modules?

- **Code reuse**
 - Routines can be called multiple times within a program
 - Routines can be used from multiple programs
- **Namespace partitioning**
 - Group data together with functions used for that data
- **Implementing shared services or data**
 - Can provide global data structure that is accessed by multiple subprograms

Modules

- **Modules are functions and variables defined in separate files**
- **Items are imported using from or import**

```
from module import function  
function()
```

```
import module  
module.function()
```

- **Modules are namespaces**

- Can be used to organize variable names, i.e.

```
atom.position = atom.position - molecule.position
```

Classes and Objects

What is an Object?

- A software item that contains variables and methods
- Object Oriented Design focuses on
 - Encapsulation:
 - dividing the code into a public interface, and a private implementation of that interface
 - Polymorphism:
 - the ability to overload standard operators so that they have appropriate behavior based on their context
 - Inheritance:
 - the ability to create subclasses that contain specializations of their parents

Example

```
class atom(object):
    def __init__(self,atno,x,y,z):
        self.atno = atno
        self.position = (x,y,z)
    def symbol(self): # a class method
        return Atno_to_Symbol[atno]
    def __repr__(self): # overloads printing
        return '%d %10.4f %10.4f %10.4f' %
            (self.atno, self.position[0],
             self.position[1],self.position[2])

>>> at = atom(6,0.0,1.0,2.0)
>>> print at
6  0.0000  1.0000 2.0000
>>> at.symbol()
'C'
```

Atom Class

- Overloaded the default constructor
- Defined class variables (atno,position) that are persistent and local to the atom object
- Good way to manage shared memory:
 - instead of passing long lists of arguments, encapsulate some of this data into an object, and pass the object.
 - much cleaner programs result
- Overloaded the print operator
- We now want to use the atom class to build molecules...

Molecule Class

```
class molecule:
    def __init__(self, name='Generic'):
        self.name = name
        self.atomlist = []
    def addatom(self, atom):
        self.atomlist.append(atom)
    def __repr__(self):
        str = 'This is a molecule named %s\n' % self.name
        str = str + 'It has %d atoms\n' % len(self.atomlist)
        for atom in self.atomlist:
            str = str + `atom` + '\n'
        return str
```

Using Molecule Class

```
>>> mol = molecule('Water')
>>> at = atom(8,0.,0.,0.)
>>> mol.addatom(at)
>>> mol.addatom(atom(1,0.,0.,1.))
>>> mol.addatom(atom(1,0.,1.,0.))
>>> print mol
This is a molecule named Water
It has 3 atoms
8  0.000 0.000 0.000
1  0.000 0.000 1.000
1  0.000 1.000 0.000
```

- Note that the print function calls the atoms print function
 - Code reuse: only have to type the code that prints an atom once; this means that if you change the atom specification, you only have one place to update.

Inheritance

```
class qm_molecule(molecule):
    def addbasis(self):
        self.basis = []
        for atom in self.atomlist:
            self.basis = add_bf(atom, self.basis)
```

- **`__init__`, `__repr__`, and `__addatom__` are taken from the parent class (`molecule`)**
- **Added a new function `addbasis()` to add a basis set**
- **Another example of code reuse**
 - Basic functions don't have to be retyped, just inherited
 - Less to rewrite when specifications change

Overloading

```
class qm_molecule(molecule):
    def __repr__(self):
        str = 'QM Rules!\n'
        for atom in self.atomlist:
            str = str + `atom` + '\n'
        return str
```

- Now we only inherit `__init__` and `addatom` from the parent
- We define a new version of `__repr__` specially for QM

Adding to Parent Functions

- **Sometimes you want to extend, rather than replace, the parent functions.**

```
class qm_molecule(molecule):
    def __init__(self, name="Generic", basis="6-31G**"):
        self.basis = basis
        super(qm_molecule, self).__init__(name)
```

Public and Private Data

- In Python anything with two leading underscores is private
 - __a, __my_variable
- Anything with one leading underscore is semi-private, and you should feel guilty accessing this data directly.
 - _b
 - Sometimes useful as an intermediate step to making data private

The Extra Stuff...

File I/O, Strings, Exceptions...

```
>>> try:  
...     1 / 0  
... except:  
...     print('That was silly!')  
... finally:  
...     print('This gets executed no matter what')  
...  
That was silly!  
This gets executed no matter what
```

```
fileptr = open('filename')  
somestring = fileptr.read()  
for line in fileptr:  
    print line  
fileptr.close()  
  
>>> a = 1  
>>> b = 2.4  
>>> c = 'Tom'  
>>> '%s has %d coins worth a total of $%.02f' % (c, a, b)  
'Tom has 1 coins worth a total of $2.40'
```