Introduction to Python

Heavily based on presentations by

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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

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.**

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

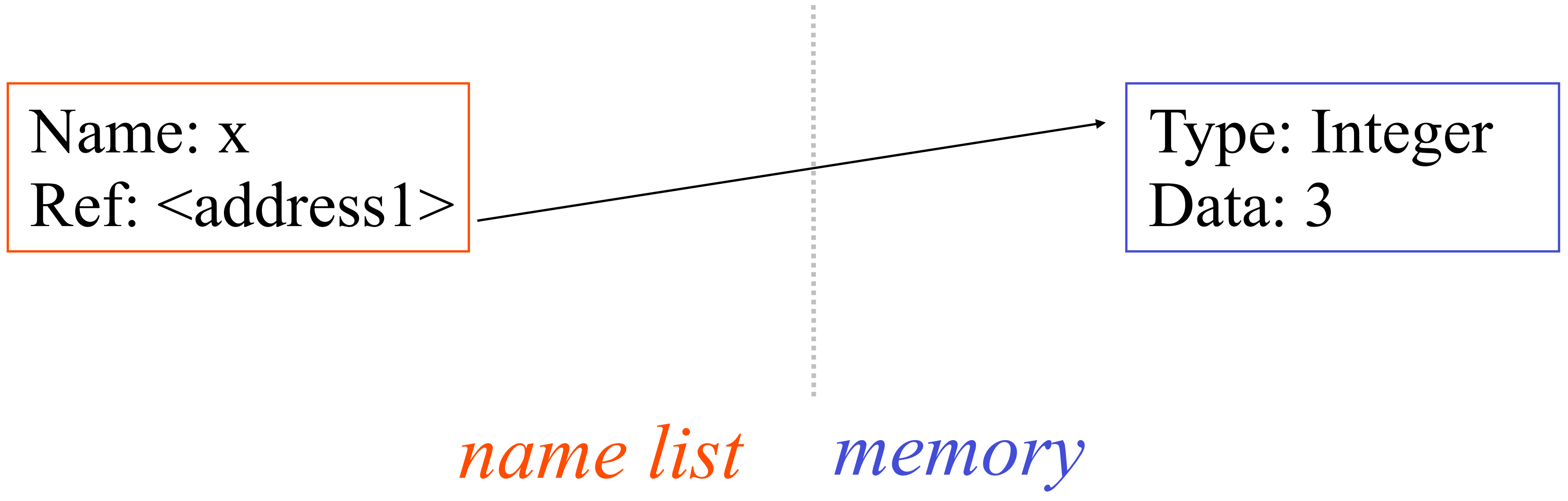
- **Assignment manipulates references**
  - x = y **does not make a copy** of the object y references
  - x = y makes x **reference** the object y references
- **Very useful; but beware!**
- **Example:**

```
>>> 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

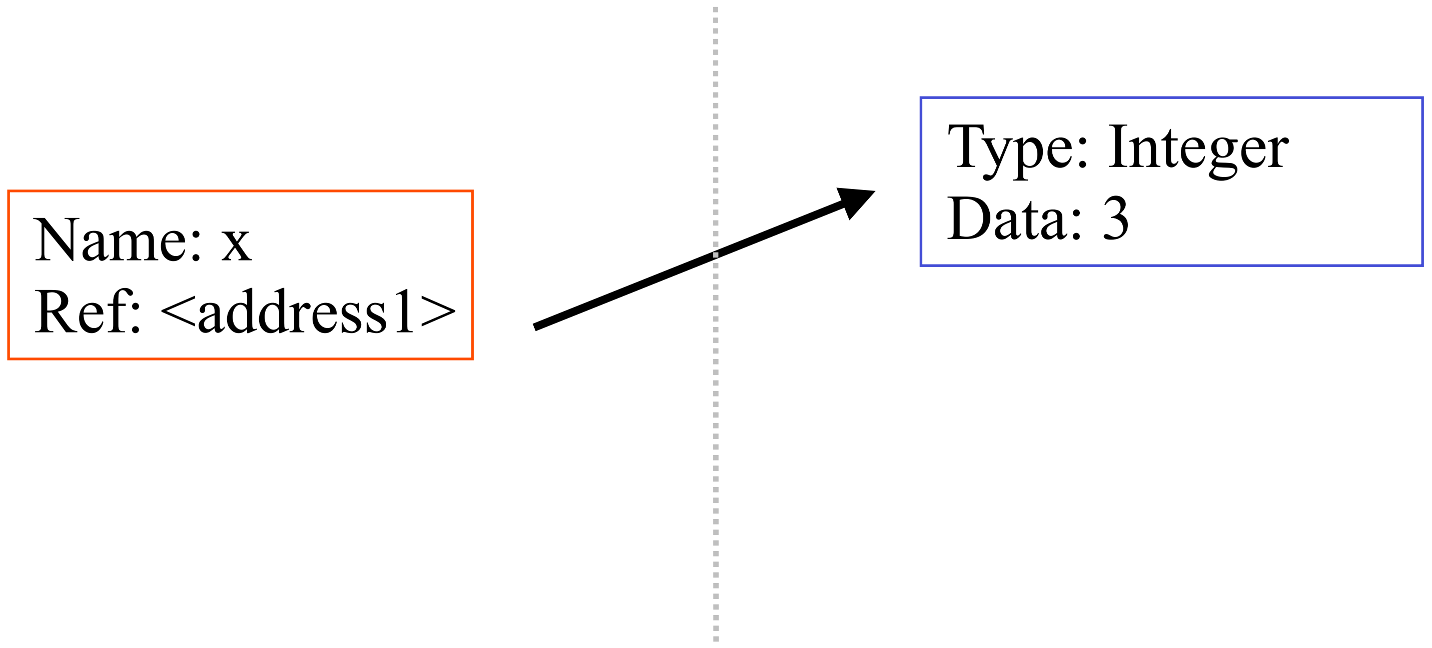
- The data 3 we created is of type integer. In Python, the datatypes integer, float, and string (and tuple) are “immutable.”
- This doesn’t mean we can’t change the value of x, i.e. *change what x refers to* …
- For example, we could increment x:

```
>>> 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.*

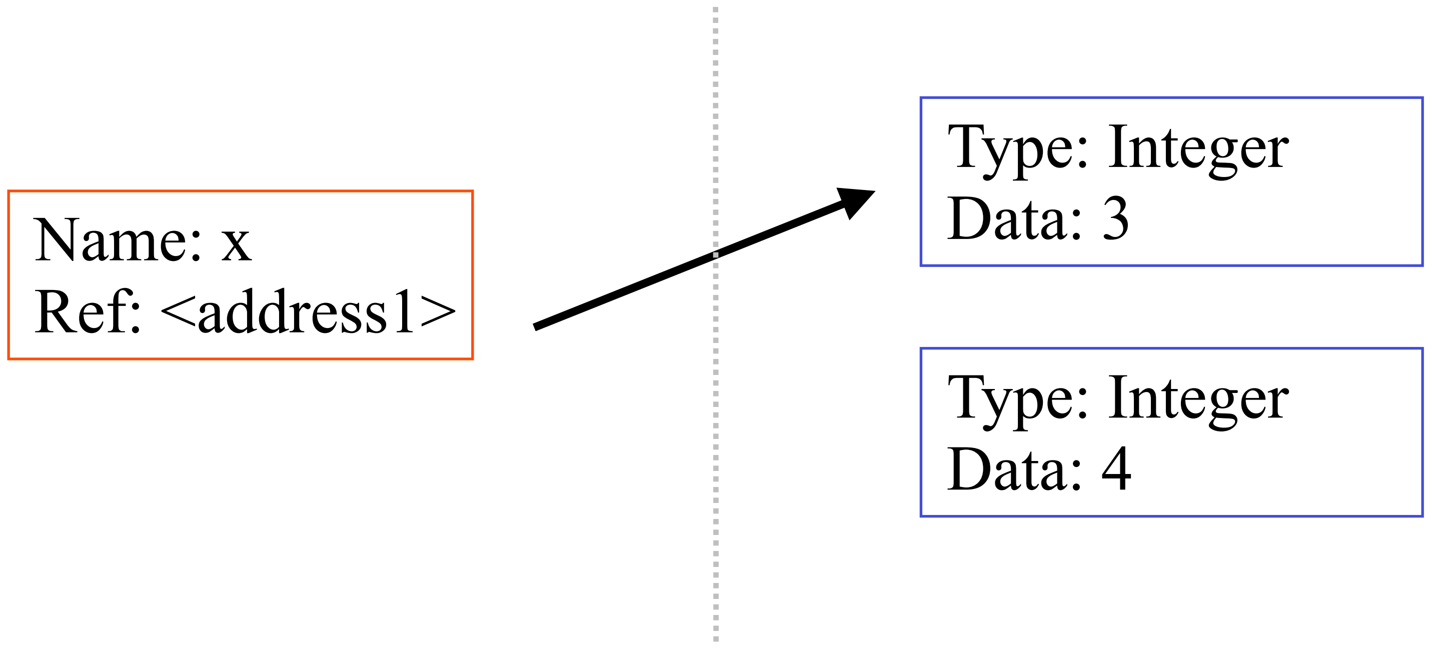
```
>>> x = x + 1
```



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.*

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



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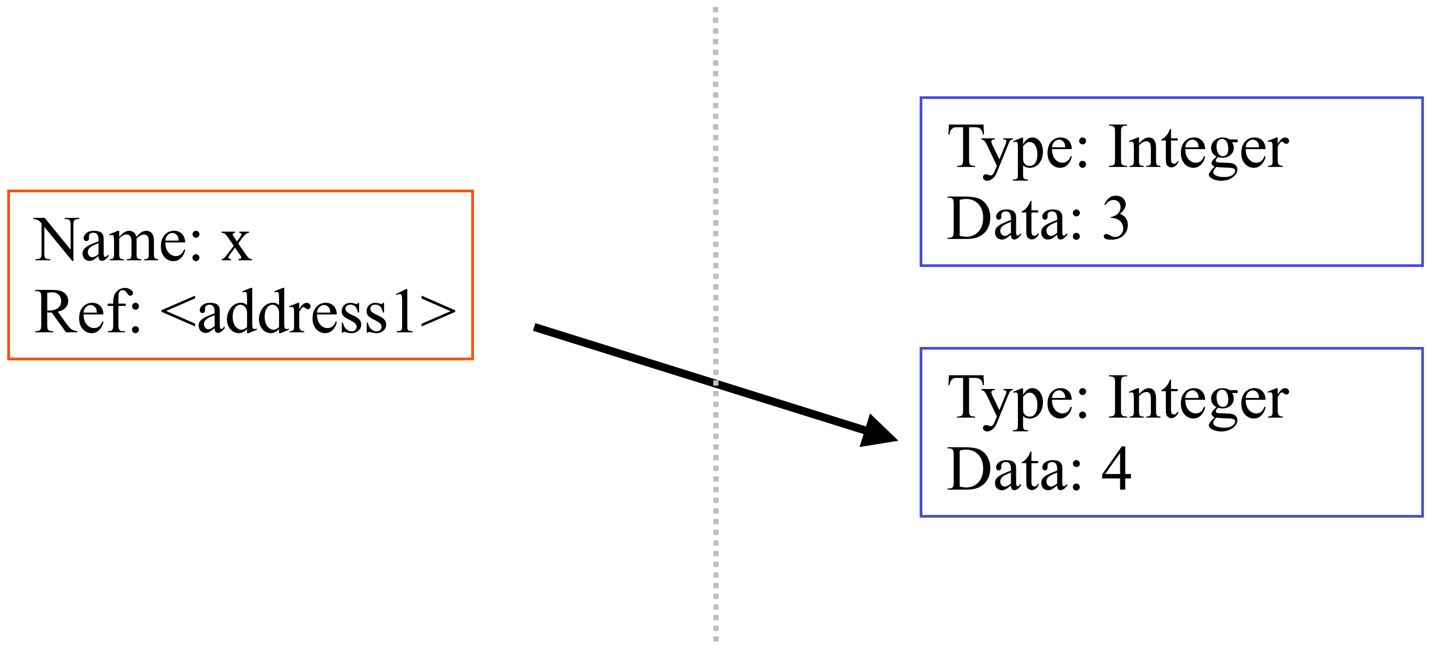
4. *The name* ***x*** *is changed to point to this new reference.*



Understanding Reference Semantics IV

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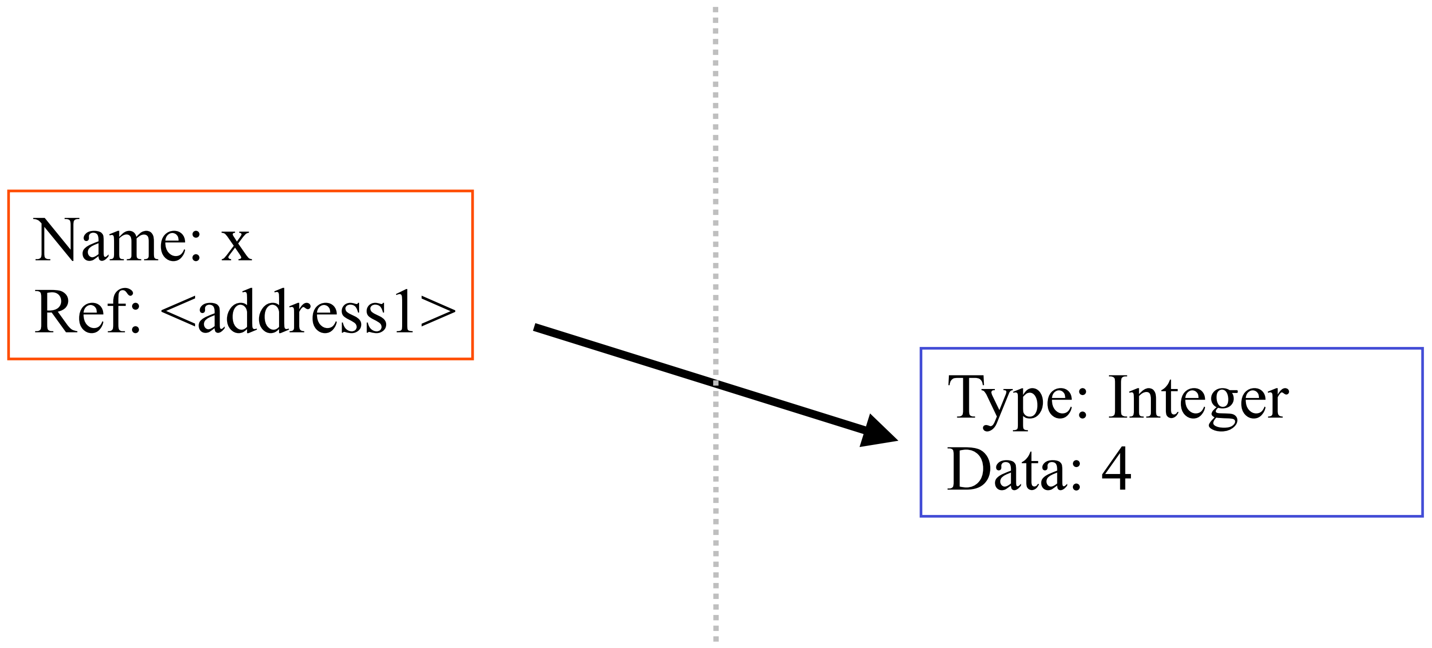
2. The value at that reference is retrieved.
3. The 3+1 calculation occurs, producing a new data element **4** which is assigned to a fresh memory location with a new reference.
4. The name **x** is changed to point to this new reference.
5. *The old data* ***3*** *is garbage collected if no name still 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
```

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→ >>> x = 3        # Creates 3, name x refers to 3
  >>> y = x        # Creates name y, refers to 3.
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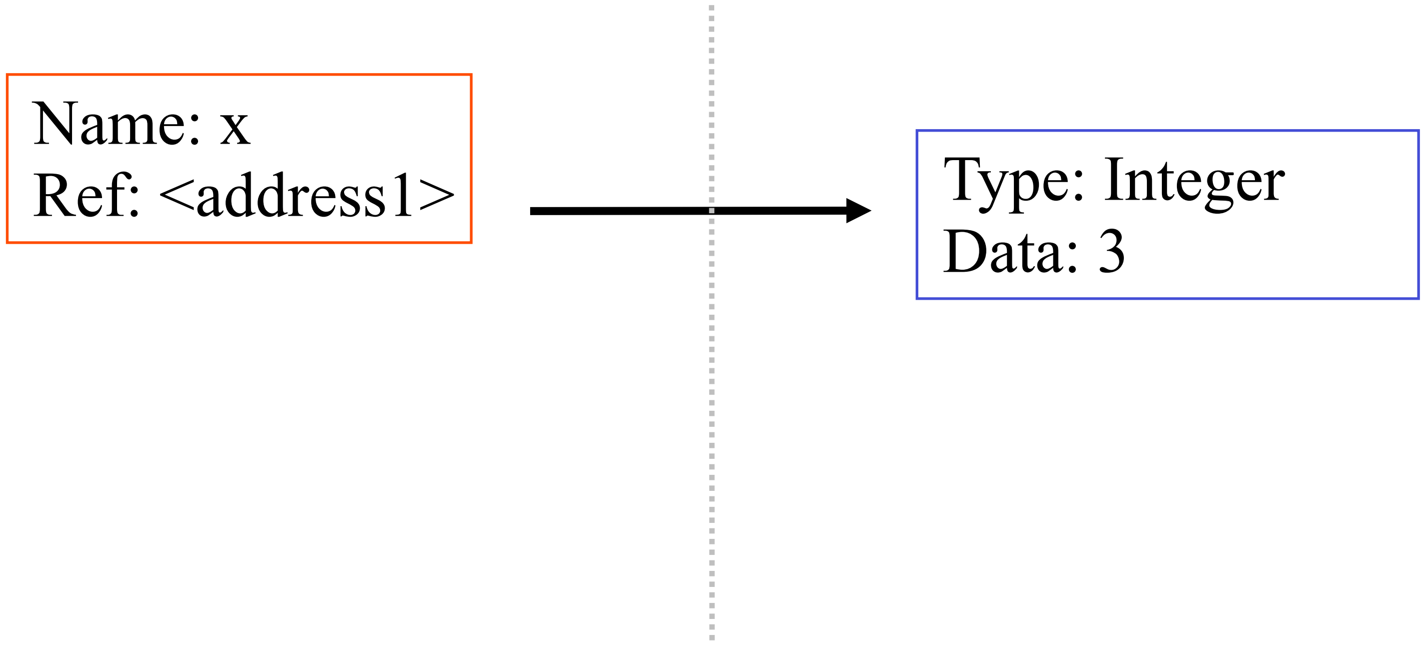
  3
```



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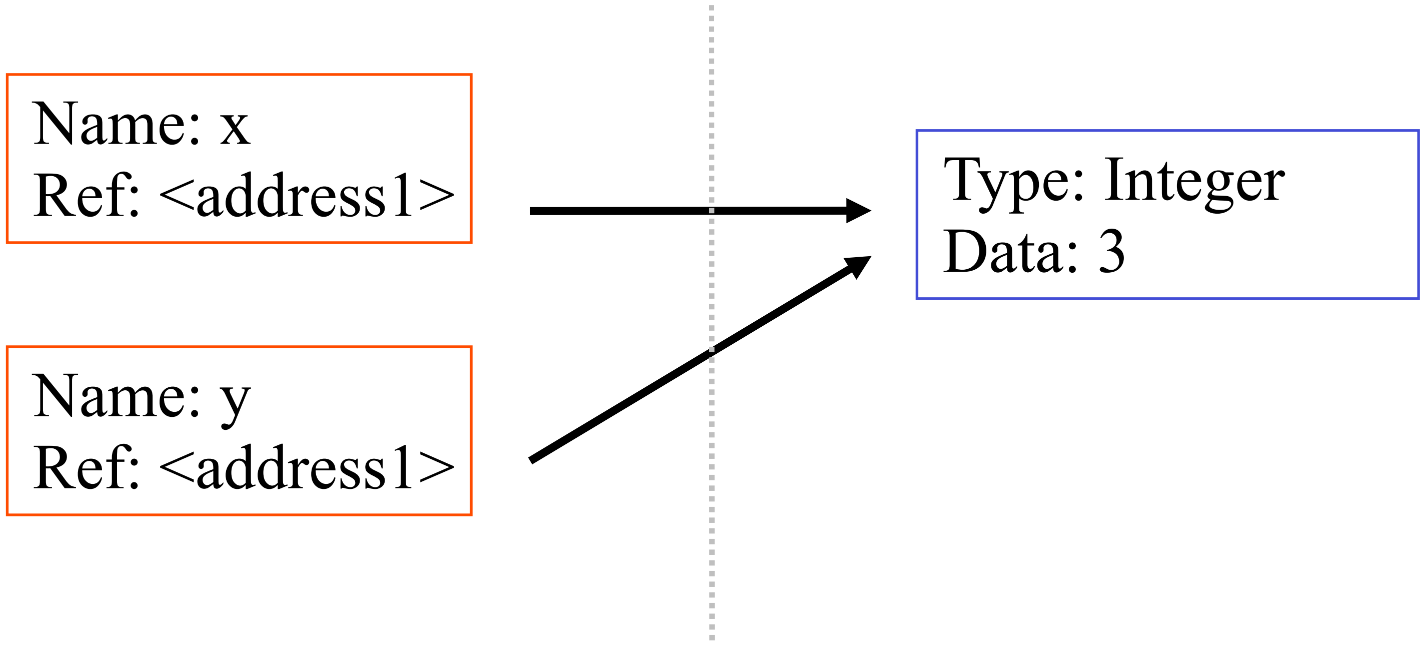

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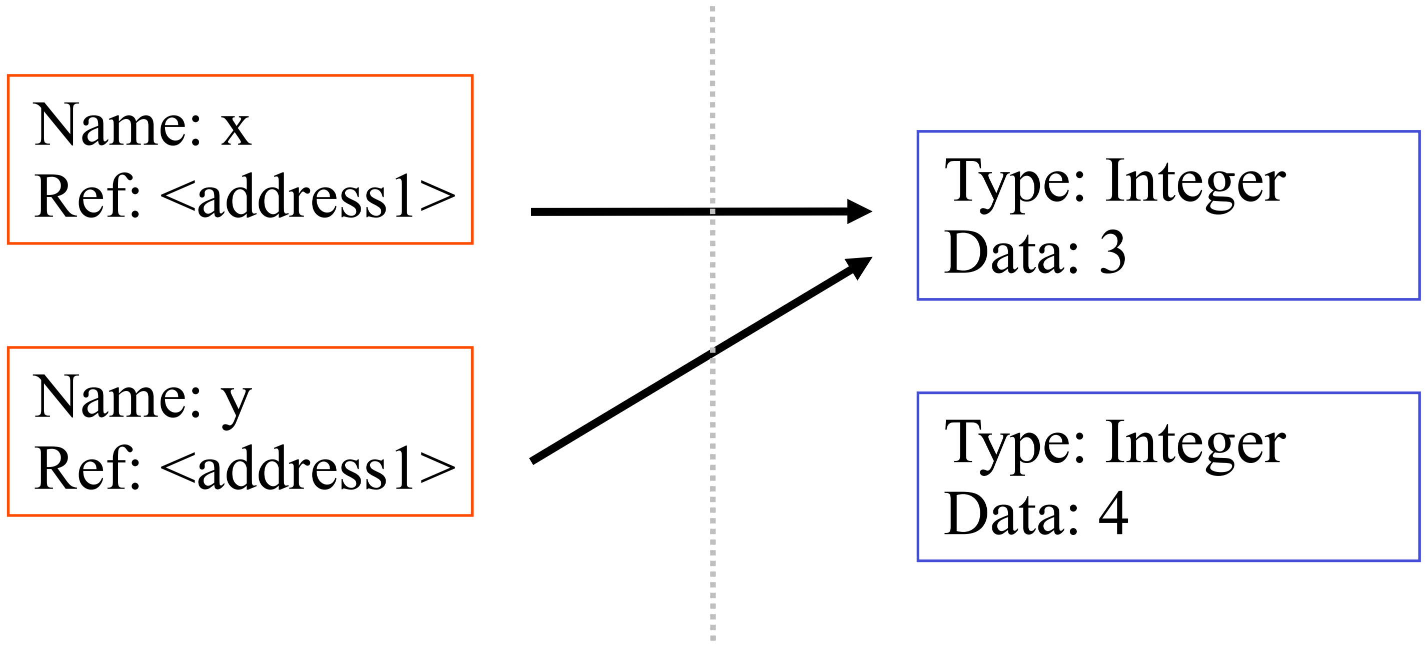

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   3
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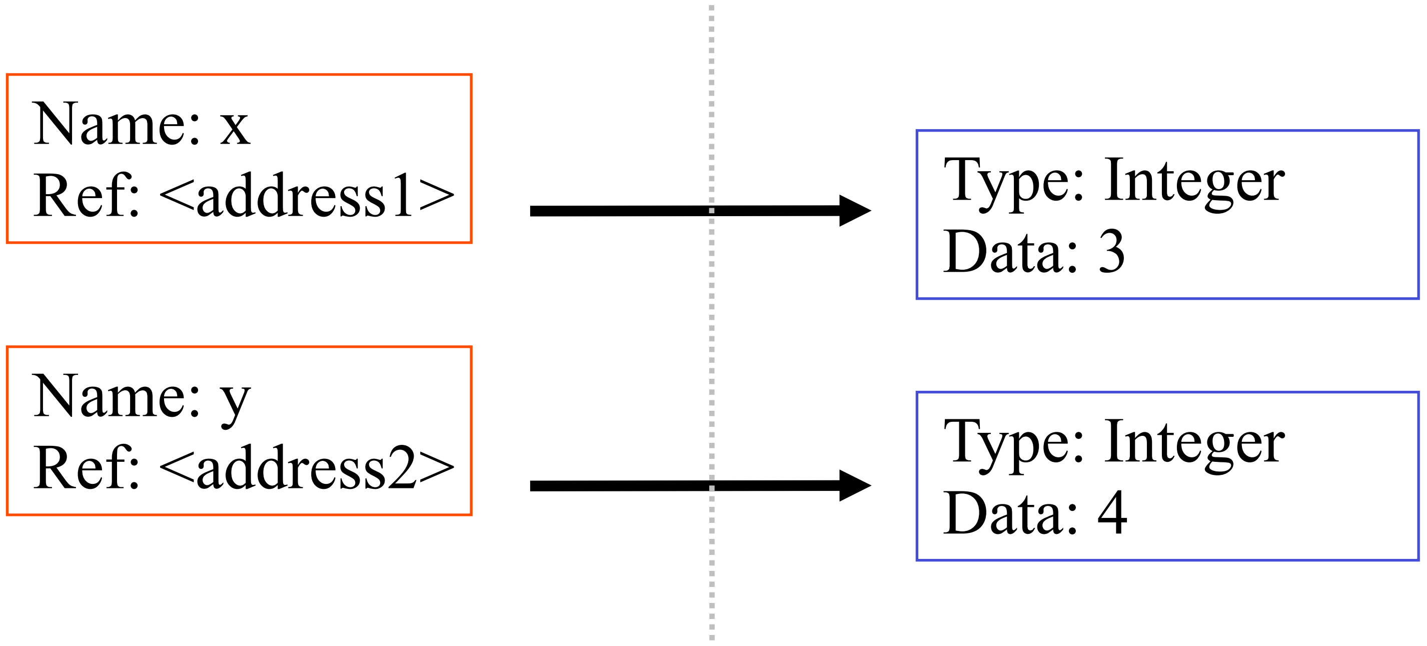

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>>> y = 4        # Creates ref for 4. Changes y.
>>> print x      # No effect on x, still ref 3.
3
```
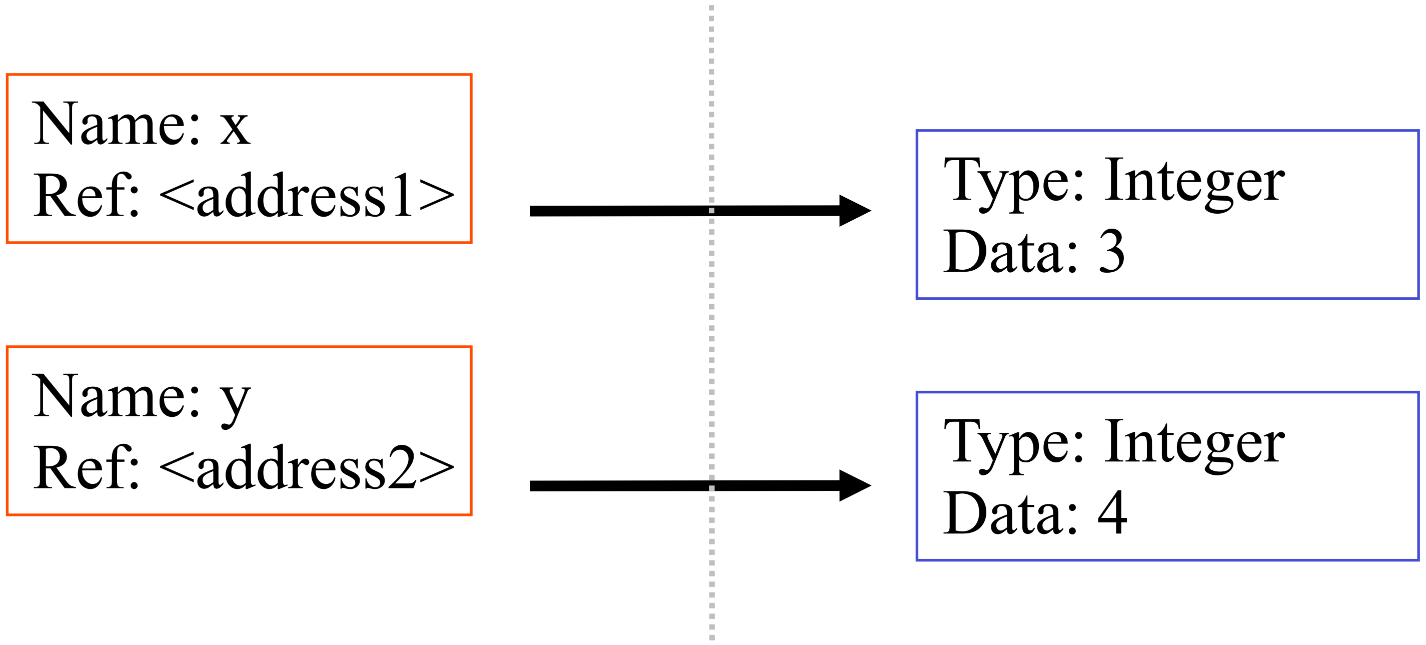



Assignment 2

- **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

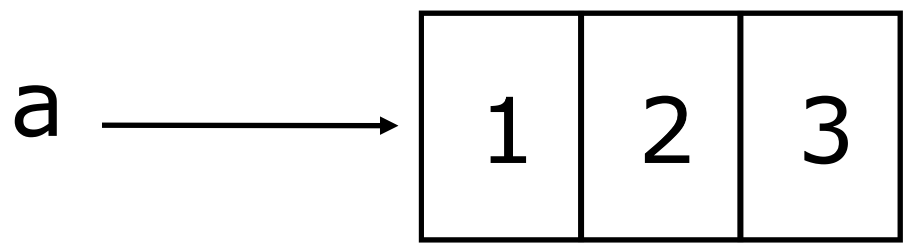
```
>>> x = 3
>>> y = x
>>> y = 4
>>> print x
3
```

mutable

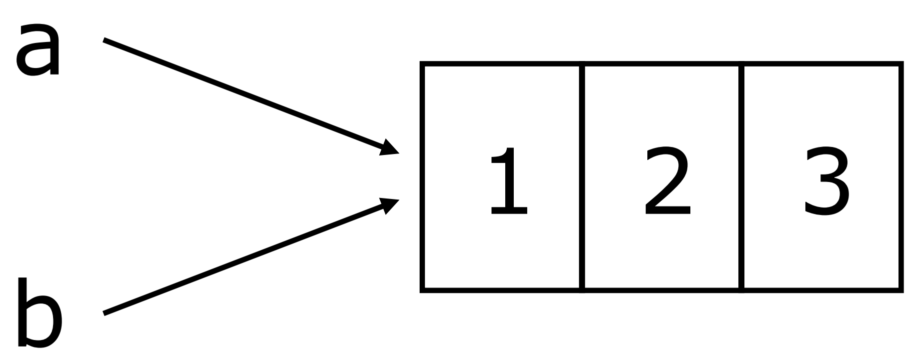
```
x = some mutable object
y = x
make a change to y
look at x
x will be changed as well
```

Why? Changing a Shared List

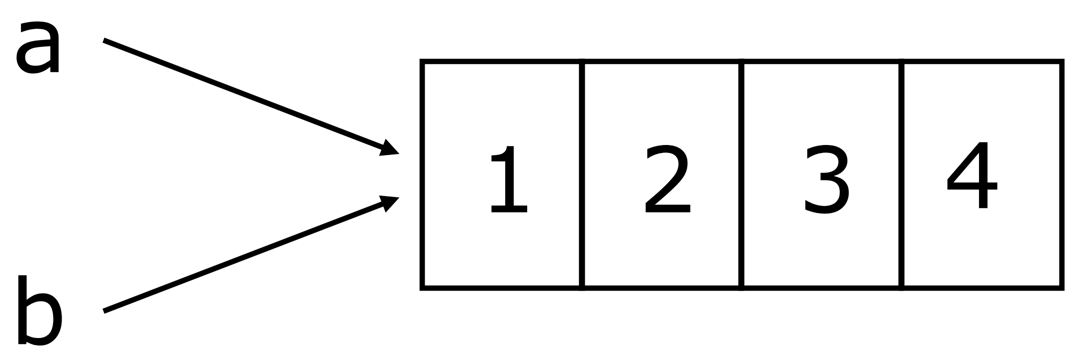
```
a = [1, 2, 3]
```



```
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.**

Creating and accessing 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
```

Updating Dictionaries

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

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

- Keys must be unique.
- Assigning to an existing key replaces its value.

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

- Dictionaries are unordered
  - New entry might appear anywhere in the output.
- (Dictionaries work by *hashing*)

Removing dictionary entries

```
>>> d = {‘user’:‘bozo’, ‘p’:1234, ‘i’:34}

>>> del d[‘user’]                 # Remove one.
>>> d
{‘p’:1234, ‘i’:34}

>>> d.clear()                     # Remove all.
>>> d
{}
```

Useful Accessor Methods

```
>>> 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)]
```

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

Defining Functions

Function definition begins with “def.”

Function name and its arguments.

```
def get_final_answer(filename):
    “Documentation String”
    line1
    line2
    return total_counter
```

Colon.

The indentation matters…
First line with less
indentation is considered to be
outside of the function definition.

The keyword ‘return’ indicates the
value to be sent back to the caller.

No header file or declaration of types of function or arguments.

Python and Types

Python determines the data types of *variable bindings* in a program automatically. ***"Dynamic Typing"***

But Python's not casual about types, it enforces the types of *objects*. ***"Strong Typing"***

So, for example, you can't just append an integer to a string. You must first convert the integer to a string itself.

```
x = "the answer is " # Decides x is bound to a string.
y = 23                 # Decides y is bound to an integer.
print x + y    # Python will complain about this.
```

Calling a Function

- **The syntax for a function call is:**

```
>>> def myfun(x, y):
        return x * y
>>> myfun(3, 4)
12
```

- **Parameters in Python are "Call by Assignment."**
  - Sometimes acts like "call by reference" and sometimes like "call by value" in C++.
    - —Mutable datatypes: Call by reference.
    - —Immutable datatypes: Call by value.

Functions without returns

- ***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*****.**
  - *None* is a special constant in the language.
  - *None* is used like *NULL*, *void*, or *nil* in other languages.
  - *None* is also logically equivalent to False.
  - The interpreter doesn’t print *None*

Function overloading? No.

- **There is no function overloading in Python.**
  - Unlike C++, a Python function is specified by its name alone
    - — The number, order, names, or types of its arguments cannot be used to distinguish between two functions with the same name.
  - Two different functions can't have the same name, even if they have different arguments.
- **But: see *operator overloading* in later slides**

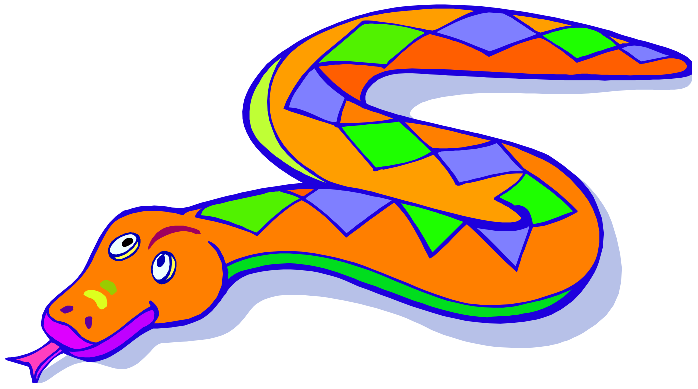
(Note: van Rossum playing with function overloading for the future)

Functions are first-class objects in Python

- 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
  - …

```
>>> def myfun(x):
        return x*3

>>> def applier(q, x):
        return q(x)

>>> applier(myfun, 7)
21
```

Logical Expressions



True and False

- ***True*** **and** ***False*** **are constants in Python.**

- **Other values equivalent to** ***True*** **and** ***False*****:**
  - *False*: zero, *None*, empty container or object
  - *True*: non-zero numbers, non-empty objects

- **Comparison operators: ==, !=, <, <=, etc.**
  - X and Y have same value: `X == Y`
  - Compare with `X is Y` :
    - —X and Y are two variables that refer to the *identical same object.*

Boolean Logic Expressions

- **You can also combine Boolean expressions.**
  - *true* if a is true and b is true: `a and b`
  - *true* if a is true or b is true: `a or b`
  - *true* if a is false: `not a`
- **Use parentheses as needed to disambiguate complex Boolean expressions.**

Special Properties of *and* and *or*

- **Actually *and* and *or* *don't* return *True* or *False*.**
- **They return the value of one of their sub-expressions (which may be a non-Boolean value).**
- `X and Y and Z`
  - If all are true, returns value of Z.
  - Otherwise, returns value of first false sub-expression.
- `X or Y or Z`
  - If all are false, returns value of Z.
  - Otherwise, returns value of first true sub-expression.
- ***And* and *or* use *lazy evaluation*, so no further expressions are evaluated**

The “and-or” Trick

- **A trick to implement a simple conditional**

```
      result = test and expr1 or expr2
```

  - When test is *True*, result is assigned expr1.
  - When test is *False*, result is assigned expr2.
  - Works almost like `(test ? expr1 : expr2)` expression of C++.

- ***But* if the value of expr1 is *ever False,* the trick doesn’t work.**
- **Avoid (hard to debug), but you may see it in the code.**
- **Made unnecessary by conditional expressions in Python 2.5 (see next slide)**

Conditional Expressions: New in Python 2.5

- `x = true_value if condition else false_value`
- Uses lazy evaluation:
  - **First, `condition` is evaluated**
  - **If *True*, `true_value` is evaluated and returned**
  - **If *False*, `false_value` is evaluated and returned**

- Suggested use:
- `x = (true_value if condition else false_value)`

Control of Flow

Control of Flow

- **There are several Python expressions that control the flow of a program. All of them make use of Boolean conditional tests.**
  - *if* Statements
  - *while* Loops
  - *assert* Statements

if Statements

```
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'."
```

Be careful! The keyword *if* is also used in the syntax of filtered *list comprehensions*.

Note:

- **Use of indentation for blocks**
- **Colon (*:*) after boolean expression**

while Loops

```
x = 3
while x < 10:
    x = x + 1
    print “Still in the loop.”
print “Outside of the loop.”
```

break and *continue*

- You can use the keyword *break* inside a loop to leave the *while* loop entirely.

- You can use the keyword *continue* inside a loop to stop processing the current iteration of the loop and to immediately go on to the next one.

assert

- **An *assert* statement will check to make sure that something is true during the course of a program.**
  - If the condition if false, the program stops.

```
assert(number_of_players < 5)
```

Examples

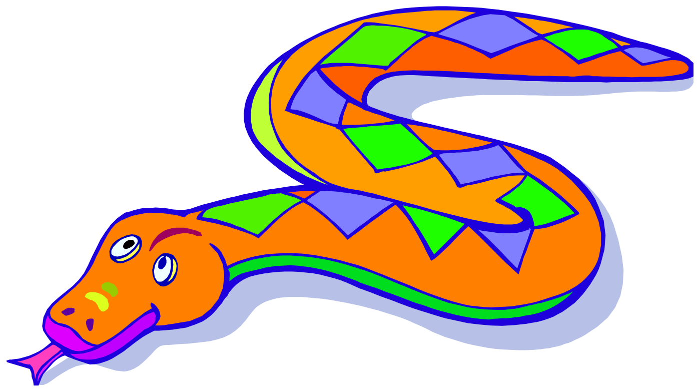
```
if x == 3:
    print “X equals 3.”
elif x == 2:
    print “X equals 2.”
else:
    print “X equals something else.”
print “This is outside the ‘if’.”
```

```
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.”
```

Generating Lists using “List Comprehensions”



List Comprehensions

- **A powerful feature of the Python language.**
  - Generate a new list by applying a function to every member of an original list.
  - Python programmers use list comprehensions extensively. You'll see many of them in real code.

- **The syntax of a *list comprehension* is somewhat tricky.**
  - Syntax suggests that of a *for*-loop, an *in* operation, or an *if* statement
    - —all three of these keywords ('*for*', '*in*', and '*if*') are also used in the syntax of forms of list comprehensions.

Using List Comprehensions 1

```
>>> li = [3, 6, 2, 7]
>>> [elem*2 for elem in li]
[6, 12, 4, 14]
```

Note: Non-standard colors on next several slides to help clarify the list comprehension syntax.

[expression for name in list]

- Where expression is some calculation or operation acting upon the variable name.

- For each member of the list, the list comprehension
  1. sets name equal to that member,
  2. calculates a new value using expression,
- It then collects these new values into a list which is the return value of the list comprehension.

Using List Comprehensions 2

`[` expression `for` name `in` list `]`

- If list contains elements of different types, then expression must operate correctly on the types of all of list members.

- If the elements of list are other containers, then the name can consist of a container of names that match the type and “shape” of the list members.

```
>>> li = [(‘a’, 1), (‘b’, 2), (‘c’, 7)]
>>> [ n * 3 for (x, n) in li]
[3, 6, 21]
```

Using List Comprehensions 3

`[` **expression** `for` **name** `in` **list** `]`

- **expression can also contain user-defined functions.**

```
>>> def subtract(a, b):
        return a - b

>>> oplist = [(6, 3), (1, 7), (5, 5)]
>>> [subtract(y, x) for (x, y) in oplist]
[-3, 6, 0]
```

Filtered List Comprehension 1

```
[expression for name in list if filter]
```

- Filter determines whether expression is performed on each member of the list.
- For each element of list, checks if it satisfies the filter condition.
- If it returns *False* for the filter condition, it is omitted from the list before the list comprehension is evaluated.

Filtered List Comprehension 2

[expression `for` name `in` list `if` filter]

```
>>> li = [3, 6, 2, 7, 1, 9]
>>> [elem * 2 for elem in li if elem > 4]
[12, 14, 18]
```

- Only 6, 7, and 9 satisfy the filter condition.
- So, only 12, 14, and 18 are produced.

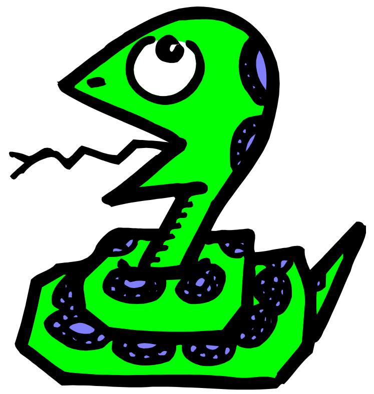
Nested List Comprehensions

- **Since list comprehensions take a list as input and produce a list as output, they are easily nested:**

```
>>> li = [3, 2, 4, 1]
>>> [elem*2 for elem in
         [item+1 for item in li] ]
[8, 6, 10, 4]
```

- **The inner comprehension produces: [4, 3, 5, 2].**
- **So, the outer one produces: [8, 6, 10, 4].**

For Loops



For Loops / List Comprehensions

- **Python's list comprehensions and split/join operations provide natural idioms that usually require a for-loop in other programming languages.**
  - As a result, Python code uses many fewer for-loops
  - Nevertheless, it's important to learn about for-loops.

- *Caveat*! **The keywords *for* and *in* are also used in the syntax of list comprehensions, but this is a totally different construction.**

For Loops 1

Note: Non-standard colors on these slides.

- **A for-loop steps through each of the items in a list, tuple, string, or any other type of object which is "iterable"**

```
 for <item> in <collection>:
   <statements>
```

- **If <collection> is a list or a tuple, then the loop steps through each element of the sequence.**

- **If <collection> is a string, then the loop steps through each character of the string.**

```
 for someChar in "Hello World":
    print someChar
```

For Loops 2

```
for <item> in <collection>:
  <statements>
```

- **<item> can be more complex than a single variable name.**
  - When the elements of <collection> are themselves sequences, then <item> can match the structure of the elements.
  - This multiple assignment can make it easier to access the individual parts of each element.

```
for (x, y) in [(a,1), (b,2), (c,3), (d,4)]:
  print x
```

For loops and the *range()* function

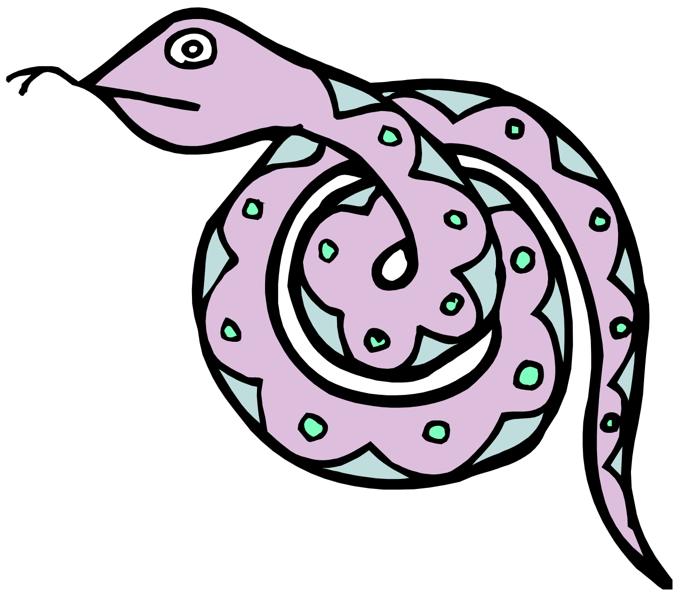
- Since a variable often ranges over some sequence of numbers, the *range()* function returns a list of numbers from 0 up to but not including the number we pass to it.

- range(5) returns [0,1,2,3,4]
- So we could say:

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

- (There are more complex forms of *range()* that provide richer functionality…)

Some Fancy Function Syntax



Lambda Notation

- Functions can be defined without giving them names.
- This is most useful when passing a short function as an argument to another function.

```
>>> applier(lambda z: z * 4, 7)
  28
```

- The first argument to applier() is an unnamed function that takes one input and returns the input multiplied by four.
- Note: only single-expression functions can be defined using this lambda notation.
- Lambda notation has a rich history in program language research, AI, and the design of the LISP language.

Default Values for Arguments

- You can provide default values for a function’s arguments
- These arguments are optional when the function is called

```
>>> def myfun(b, c=3, d=“hello”):
               return b + c
>>> myfun(5,3,”hello”)
>>> myfun(5,3)
>>> myfun(5)
```

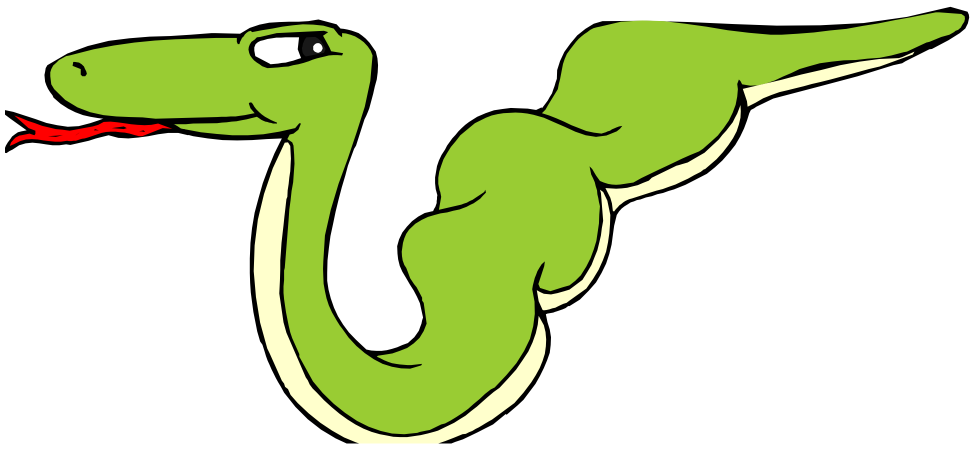
All of the above function calls return 8.

The Order of Arguments

- **You can call a function with some or all of its arguments out of order as long as you specify them (these are called keyword arguments). You can also just use keywords for a final subset of the arguments.**

```
>>> def myfun(a, b, c):
        return a-b
>>> myfun(2, 1, 43)
  1
>>> myfun(c=43, b=1, a=2)
  1
>>> myfun(2, c=43, b=1)
  1
```

Assignment and Containers



Multiple Assignment with Sequences

- We’ve seen multiple assignment before:

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

- But you can also do it with sequences.
  - The type and “shape” just has to match.

```
>>> (x, y, (w, z)) = (2, 3, (4, 5))
>>> [x, y] = [4, 5]
```

Empty Containers 1

- **Assignment creates a name, if it didn't exist already.**

  `x = 3` **Creates name x of type integer.**

- **Assignment is also what creates named references to containers.**

```
>>> d = {'a':3, 'b':4}
```

- **We can also create empty containers:**

```
>>> li = []
>>> tu = ()
>>> di = {}
```

Note: an empty container is *logically* equivalent to False. (Just like None.)

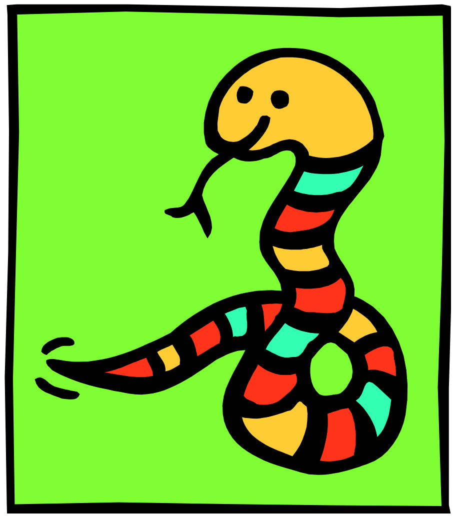
- **These three are empty, but of different *types***

Empty Containers 2

- **Why create a named reference to empty container?**
  - To initialize an empty list, for example, before using append.
  - This would cause an unknown name error a named reference to the right data type wasn't created first

```
>>> g.append(3)
Python complains here about the unknown name 'g'!
>>> g = []
>>> g.append(3)
>>> g
[3]
```

String Operations



String Operations

- A number of methods for the string class perform useful formatting operations:

```
>>> "hello".upper()
'HELLO'
```

- Check the Python documentation for many other handy string operations.

- Helpful hint: use `<string>.strip()` to strip off final newlines from lines read from files

String Formatting Operator: *%*

- **The operator *%* allows strings to be built out of many data items in a "fill in the blanks" fashion.**
  - Allows control of how the final string output will appear.
  - For example, we could force a number to display with a specific number of digits after the decimal point.

- **Very similar to the sprintf command of C.**

```
>>> x = "abc"
>>> y = 34
>>> "%s xyz %d" % (x, y)
'abc xyz 34'
```

- **The tuple following the *%* operator is used to fill in the blanks in the original string marked with *%s* or *%d*.**
  - **Check Python documentation for whether to use %s, %d, or some other formatting code inside the string.**

Printing with Python

- You can print a string to the screen using “print.”
- Using the % string operator in combination with the print command, we can format our output text.

```
>>> print  “%s xyz %d”  %  (“abc”, 34)
abc xyz 34
```

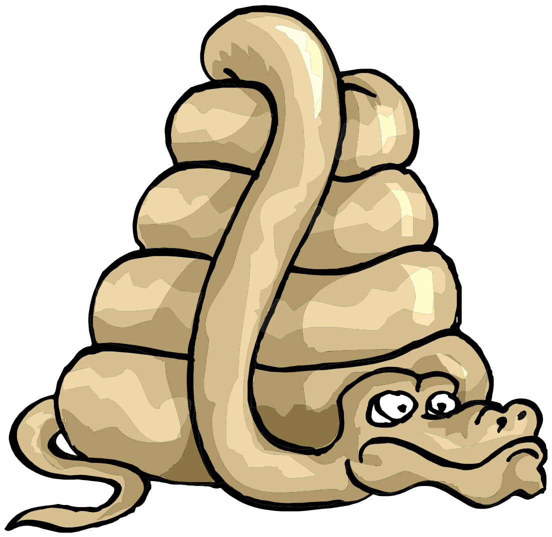
“Print” automatically adds a newline to the end of the string. If you include a list of strings, it will concatenate them with a space between them.

```
>>> print “abc”
abc
```

```
>>> print “abc”, “def”
abc def
```

- Useful trick: `>>> print “abc”,` doesn’t add newline just a single space

String Conversions



String to List to String

Note: Non-standard colors on this slide to help clarify the string syntax.

- **Join turns a list of strings into one string.**

  <separator_string>.join(<some_list>)

```
>>> ";".join( ["abc", "def", "ghi"] )
 "abc;def;ghi"
```

- **Split turns one string into a list of strings.**

  <some_string>.split(<separator_string>)

```
>>> "abc;def;ghi".split( ";" )
 ["abc", "def", "ghi"]
```

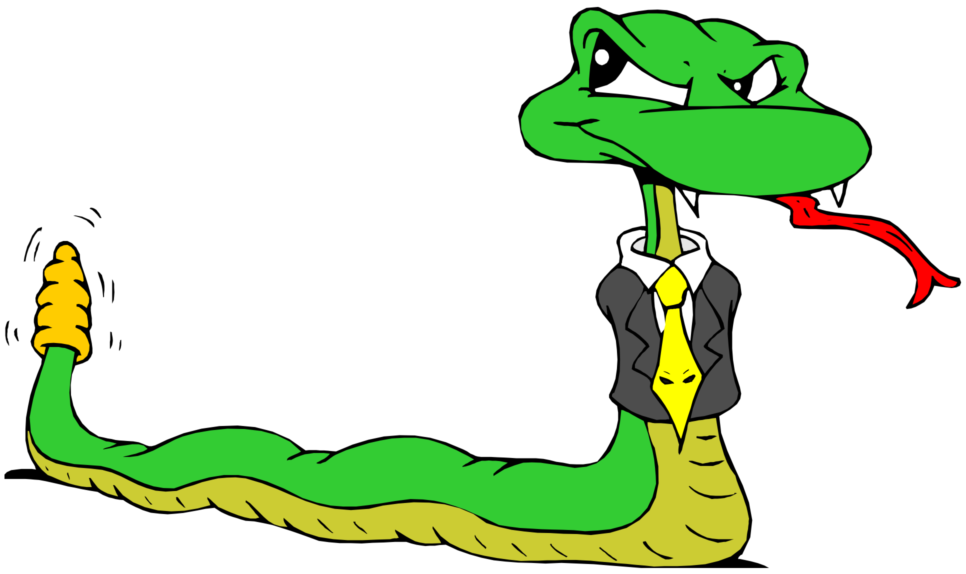
- **Note the inversion in the syntax**

Convert Anything to a String

- **The built-in str() function can convert an instance of <u>any</u> data type into a string.**
  - You can define how this function behaves for user-created data types. You can also redefine the behavior of this function for many types.

```
>>> "Hello " + str(2)
"Hello 2"
```

Importing and Modules



Importing and Modules

- Use classes & functions defined in another file.
- A Python module is a file with the same name (plus the *.py* extension)
- Like Java *import*, C++ *include*.
- Three formats of the command:

```
import somefile
from somefile import *
from somefile import className
```

What's the difference?

What gets imported from the file and what name refers to it after it has been imported.

import ...

```
import somefile
```

- *Everything* in somefile.py gets imported.
- To refer to something in the file, append the text “somefile.” to the front of its name:

```
somefile.className.method(“abc”)
somefile.myFunction(34)
```

*from … import **

```
from somefile import *
```

- *Everything* in somefile.py gets imported
- To refer to anything in the module, just use its name. Everything in the module is now in the current namespace.
- *Caveat!* Using this import command can easily overwrite the definition of an existing function or variable!

```
className.method("abc")
myFunction(34)
```

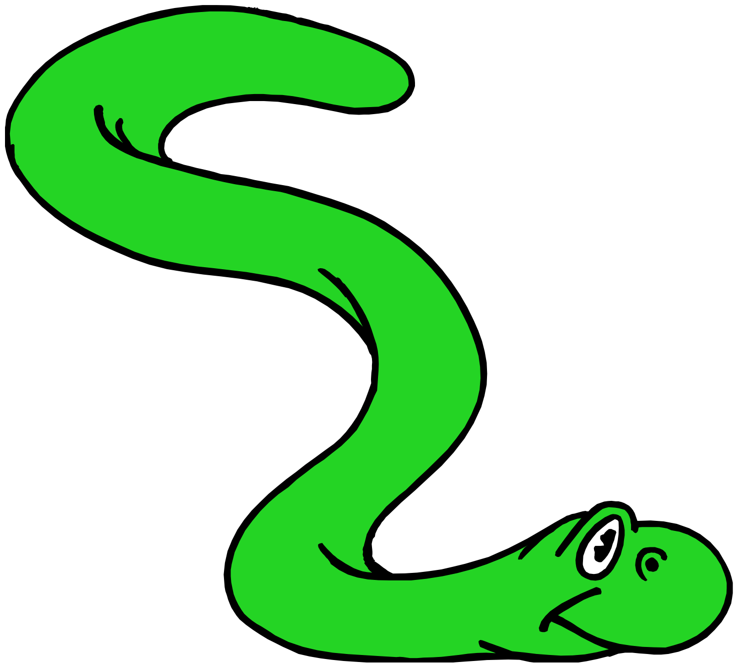
from … import …

```
from somefile import className
```

- **Only the item *className* in somefile.py gets imported.**
- **After importing *className*, you can just use it without a module prefix. It's brought into the current namespace.**
- ***Caveat*! This will overwrite the definition of this particular name if it is already defined in the current namespace!**

```
className.method("abc")        ← This got imported by this command.
myFunction(34)                 ← This one didn't.
```

Object Oriented Programming in Python: Defining Classes



It’s all objects…

- **Everything in Python is really an object.**
  - We’ve seen hints of this already…
    ```
    “hello”.upper()
    list3.append(‘a’)
    dict2.keys()
    ```
  - These look like Java or C++ method calls.
  - New object classes can easily be defined in addition to these built-in data-types.
- **In fact, programming in Python is typically done in an object oriented fashion.**

Defining a Class

- **A *class* is a special data type which defines how to build a certain kind of object.**
  - The *class* also stores some data items that are shared by all the instances of this class.
  - *Instances* are objects that are created which follow the definition given inside of the class.
- **Python doesn't use separate class interface definitions as in some languages. You just define the class and then use it.**

Methods in Classes

- **Define a *method* in a *class* by including function definitions within the scope of the class block.**
  - There must be a special first argument ***`self`*** in *all* method definitions which gets bound to the calling instance
  - There is usually a special method called ***`__init__`*** in most classes
  - We'll talk about both later…

A simple class definition: *student*

```
class student:
  """A class representing a student."""
  def __init__(self,n,a):
      self.full_name = n
      self.age = a
  def get_age(self):
      return self.age
```

Creating and Deleting Instances

Instantiating Objects

- There is no “new” keyword as in Java.
- Merely use the class name with () notation and assign the result to a variable.
- `__init__` serves as a constructor for the class. Usually does some initialization work.
- The arguments passed to the class name are given to its `__init__()` method.
  - So, the __init__ method for student is passed “Bob” and 21 here and the new class instance is bound to b:

```
b = student("Bob", 21)
```

Constructor: __init__

- **An `__init__` method can take any number of arguments.**
  - Like other functions or methods, the arguments can be defined with default values, making them optional to the caller.

- **However, the first argument `self` in the definition of __init__ is special…**

Self

- **The first argument of every method is a reference to the current instance of the class.**
  - By convention, we name this argument ***`self`***.

- **In `__init__`, *`self`* refers to the object currently being created; so, in other class methods, it refers to the instance whose method was called.**
  - Similar to the keyword *this* in Java or C++.
  - But Python uses *self* more often than Java uses *this*.

Self

- Although you must specify *`self`* explicitly when ***defining*** the method, you don't include it when ***calling*** the method.
- Python passes it for you automatically.

Defining a method:

(this code inside a class definition.)

```
def set_age(self, num):
   self.age = num
```

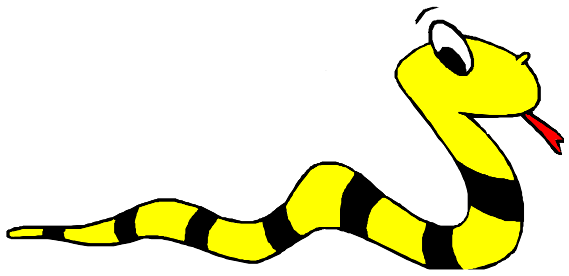
Calling a method:

```
>>> x.set_age(23)
```

Deleting instances: No Need to “free”

- **When you are done with an object, you don’t have to delete or free it explicitly.**
  - Python has automatic garbage collection.
  - Python will automatically detect when all of the references to a piece of memory have gone out of scope. Automatically frees that memory.
  - Generally works well, few memory leaks.
  - There’s also no “destructor” method for classes.

Access to Attributes and Methods



Definition of student

```
class student:
  “““A class representing a student.”””
  def __init__(self,n,a):
      self.full_name = n
      self.age = a
  def get_age(self):
      return self.age
```

Traditional Syntax for Access

```
>>> f = student (“Bob Smith”, 23)

>>> f.full_name     # Access an attribute.
“Bob Smith”

>>> f.get_age()      # Access a method.
23
```

Accessing unknown members

- **Problem: Occasionally the name of an attribute or method of a class is only given at run time…**

- **Solution: `getattr(object_instance, string)`**
  - **`string`** is a string which contains the name of an attribute or method of a class
  - **`getattr(object_instance, string)`** returns a reference to that attribute or method

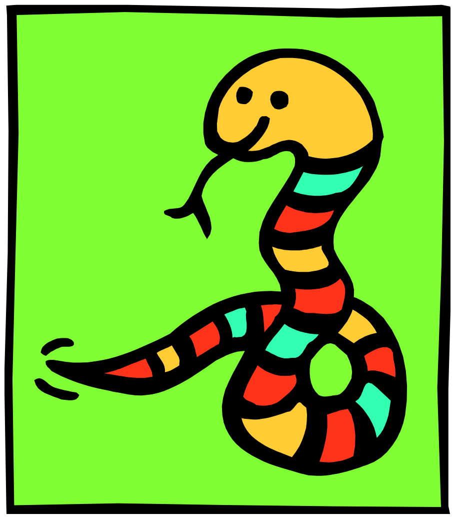
getattr(object_instance, string)

```
>>> f = student(“Bob Smith”, 23)

>>> getattr(f, “full_name”)
“Bob Smith”

>>> getattr(f, “get_age”)
 <method get_age of class studentClass at 010B3C2>

>>> getattr(f, “get_age”)()    # We can call this.
23

>>> getattr(f, “get_birthday”)
      # Raises AttributeError – No method exists.
```

hasattr(object_instance,string)

```
>>> f = student(“Bob Smith”, 23)

>>> hasattr(f, “full_name”)
True

>>> hasattr(f, “get_age”)
True

>>> hasattr(f, “get_birthday”)
False
```

Attributes



Two Kinds of Attributes

- **The non-method data stored by objects are called attributes.**

- *Data* attributes
  - Variable owned by a *particular instance* of a class.
  - Each instance has its own value for it.
  - These are the most common kind of attribute.

- *Class* attributes
  - Owned by the *class as a whole*.
  - *All instances of the class share the same value for it.*
  - Called “static” variables in some languages.
  - Good for
    - —class-wide constants
    - —building counter of how many instances of the class have been made

Data Attributes

- **Data attributes are created and initialized by an `__init__()` method.**
    - Simply assigning to a name creates the attribute.
    - Inside the class, refer to data attributes using `self`
        - —for example, `self.full_name`

```
class teacher:
   "A class representing teachers."
   def __init__(self,n):
        self.full_name = n
   def print_name(self):
        print self.full_name
```

Class Attributes

- **Because all instances of a class share one copy of a class attribute:**
  - when *any* instance changes it, the value is changed for *all* instances.
- **Class attributes are defined**
  - *within* a class definition
  - *outside* of any method
- **Since there is one of these attributes *per class* and not one *per instance*, they are accessed using a different notation:**
  - Access class attributes using `self.__class__.name` notation.

```
class sample:
    x = 23
   def increment(self):
      self.__class__.x += 1
```

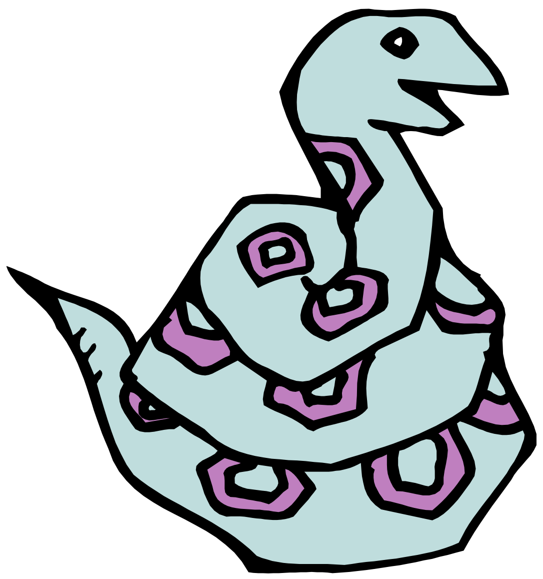
```
>>> a = sample()
>>> a.increment()
>>> a.__class__.x
24
```

Data vs. Class Attributes

```
class counter:
   overall_total = 0
        # class attribute
   def __init__(self):
       self.my_total = 0
         # data attribute
   def increment(self):
      counter.overall_total = \
      counter.overall_total + 1
      self.my_total = \
      self.my_total + 1
```

```
>>> a = counter()
>>> b = counter()
>>> a.increment()
>>> b.increment()
>>> b.increment()
>>> a.my_total
1
>>> a.__class__.overall_total
3
>>> b.my_total
2
>>> b.__class__.overall_total
3
```

Inheritance



Subclasses

- **A class can *extend* the definition of another class**
  - Allows use (or extension) of methods and attributes already defined in the previous one.
  - New class: *subclass*. Original: *parent*, *ancestor* or *superclass*
- **To define a subclass, put the name of the superclass in parentheses after the subclass's name on the first line of the definition.**

```
class ai_student(student):
```

  - Python has no 'extends' keyword like Java.
  - Multiple inheritance is supported.

Redefining Methods

- **To *redefine a method* of the parent class, include a new definition using the same name in the subclass.**
  - The old code won't get executed.

- **To execute the method in the parent class *in addition to* new code for some method, explicitly call the parent's version of the method.**

```
parentClass.methodName(self, a, b, c)
```

  - **The only time you ever explicitly pass 'self' as an argument is when calling a method of an ancestor.**

Definition of a class extending student

```
class student:
  "A class representing a student."

  def __init__(self,n,a):
      self.full_name = n
      self.age = a

  def get_age(self):
      return self.age
----------------------------------------------------------
class ai_student (student):
  "A class extending student."

  def __init__(self,n,a,s):
      student.__init__(self,n,a) #Call __init__ for student
      self.section_num = s

  def get_age():    #Redefines get_age method entirely
      print "Age: " + str(self.age)
```

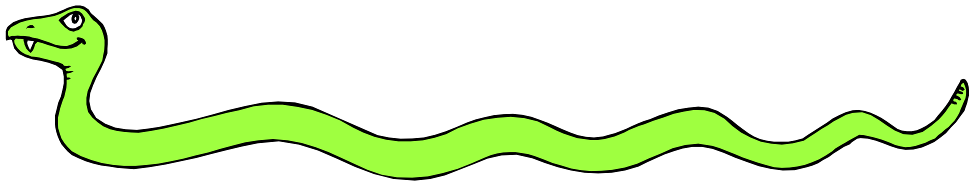
Extending __init__

- **Same as for redefining any other method…**
  - Commonly, the ancestor's `__init__` method is executed in addition to new commands.
  - You'll often see something like this in the `__init__` method of subclasses:

```
parentClass.__init__(self, x, y)
```

where parentClass is the name of the parent's class.

Special Built-In Methods and Attributes



Built-In Members of Classes

- **Classes contain many methods and attributes that are included by Python even if you don't define them explicitly.**
  - Most of these methods define automatic functionality triggered by special operators or usage of that class.
  - The built-in attributes define information that must be stored for all classes.
- **All built-in members have double underscores around their names: `__init__` `__doc__`**

Special Methods

- **For example, the method `__repr__` exists for all classes, and you can always redefine it.**
- **The definition of this method specifies how to turn an instance of the class into a string.**
  - `print f` sometimes calls `f.__repr__()` to produce a string for object f.

  - If you type `f` at the prompt and hit ENTER, then you are also calling `__repr__` to determine what to display to the user as output.

Special Methods – Example

```
class student:
    ...
     def __repr__(self):
        return “I’m named ” + self.full_name
    ...

>>> f = student(“Bob Smith”, 23)
>>> print f
I’m named Bob Smith
>>> f
“I’m named Bob Smith”
```

Special Methods

- **You can redefine these as well:**

`__init__`	: The constructor for the class.
`__cmp__`	: Define how `==` works for class.
`__len__`	: Define how `len(` obj `)` works.
`__copy__`	: Define how to copy a class.

- **Other built-in methods allow you to give a class the ability to use [ ] notation like an array or ( ) notation like a function call.**

Special Data Items

- **These attributes exist for all classes.**

  `__doc__` : Variable storing the documentation string for that class.

  `__class__` : Variable which gives you a reference to the class from any instance of it.

  `__module__` : Variable which gives you a reference to the module in which the particular class is defined.

- **Useful:**
  - **`dir(x)` returns a list of all methods and attributes defined for object x**

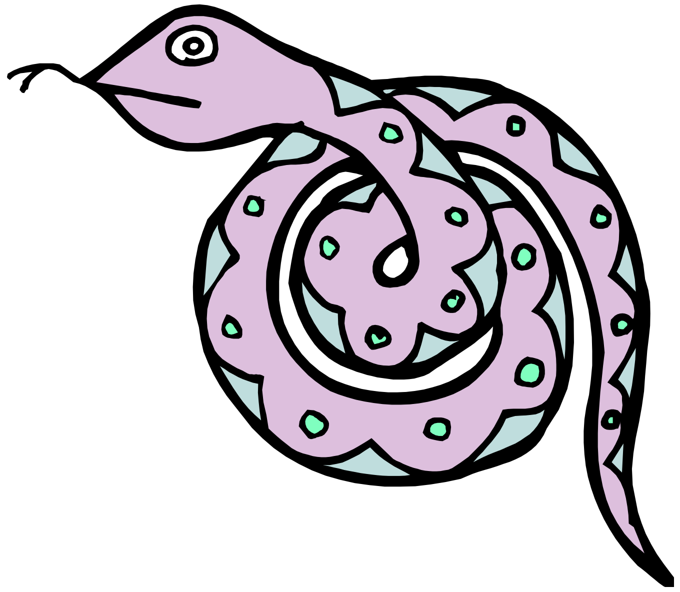
Special Data Items – Example

```
>>> f = student("Bob Smith", 23)

>>> print f.__doc__
A class representing a student.

>>> f.__class__
< class studentClass at 010B4C6 >

>>> g = f.__class__("Tom Jones", 34)
```

Private Data and Methods

- **Any attribute or method with two leading underscores in its name (but none at the end) is private. It cannot be accessed outside of that class.**
    - Note:
      Names with two underscores at the beginning ***and the end*** are for built-in methods or attributes for the class.
    - Note:
      There is no ‘protected’ status in Python; so, subclasses would be unable to access these private data either.

File Processing and Error Handling: Learning on your own…



File Processing with Python

This is a good way to play with the error handing capabilities of Python. Try accessing files without permissions or with non-existent names, etc.

You'll get plenty of errors to look at and play with!

```
fileptr = open('filename')

somestring = fileptr.read()

for line in fileptr:
   print line

fileptr.close()
```

Exception Handling

- **Errors are a kind of object in Python.**
  - More specific kinds of errors are subclasses of the general Error class.

- **You use the following commands to interact with them:**
  - Try
  - Except
  - Finally
  - Catch

My favorite statement in Python

- **`yield(a,b,c)`**
  - Turns a loop into a *generator function* that can be used for
    - —Lazy evaluation
    - —Creating potentially infinite lists in a usable way…
- **See Section 6.8 of the Python reference manual (click here)**

Finally…

- `pass`
  - It does absolutely nothing.

- **Just holds the place of where something should go syntactically. Programmers like to use it to waste time in some code, or to hold the place where they would like put some real code at a later time.**

```
for i in range(1000):
    pass
```

Like a "no-op" in assembly code, or a set of empty braces {} in C++ or Java.

Regular Expressions and Match Objects

- **Python provides a very rich set of tools for pattern matching against strings in module *re* (for regular expression)**

- **For a gentle introduction to regular expressions in Python see**

  http://www.diveintopython.org/regular_expressions/index.html

  Or

  http://www.amk.ca/python/howto/regex/regex.html

Simple RE Matching in Python NLTK

Set up:

```
>>> import re
>>> from nltk_lite.utilities import re_show
>>> sent = "colourless green ideas sleep furiously“
```

Matching using re_show *from NLTK*:

```
>>> re_show(’l’, sent)
co{l}our{l}ess green ideas s{l}eep furious{l}y
>>> re_show(’green’, sent)
colourless {green} ideas sleep furiously
```

Substitutions

- E.g. replace all instances of l with s.
- Creates an output string (doesn’t modify input)

```
>>> re.sub(’l’, ’s’, sent)
’cosoursess green ideas sseep furioussy’
```

- Work on substrings (NB not words)

```
>>> re.sub(’green’, ’red’, sent)
’colourless red ideas sleep furiously’
```

More Complex Patterns

- Disjunction:

```
>>> re_show(’(green|sleep)’, sent)
colourless {green} ideas {sleep} furiously
>>> re.findall(’(green|sleep)’, sent)
[’green’, ’sleep’]
```

- Character classes, e.g. non-vowels followed by vowels:

```
>>> re_show(’[^aeiou][aeiou]’, sent)
{co}{lo}ur{le}ss g{re}en{ i}{de}as s{le}ep {fu}{
>>> re.findall(’[^aeiou][aeiou]’, sent)
[’co’, ’lo’, ’le’, ’re’, ’ i’, ’de’, ’le’, ’fu’,
```

Structured Results

- Select a sub-part to be returned
- e.g. non-vowel characters which appear before a vowel:

```
>>> re.findall('([^aeiou])[aeiou]', sent)
['c', 'l', 'l', 'r', ' ', 'd', 'l', 'f', 'r']
```

- generate tuples, for later tabulation

```
>>> re.findall('([^aeiou])([aeiou])', sent)
[('c', 'o'), ('l', 'o'), ('l', 'e'), ('r', 'e'),
```