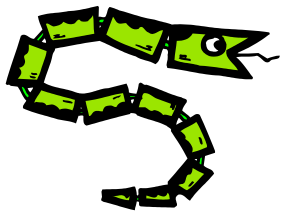
Python I



Some material adapted from Upenn cmpe391 slides and other sources

Overview

- Names & Assignment
- Data types
- Sequences types: Lists, Tuples, and Strings
- Mutability
- Understanding Reference Semantics in Python

A Code Sample (in IDLE)

```
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

- **Indentation matters to meaning the code**
  - Block structure indicated by indentation
- **The first assignment to a variable creates it**
  - Dynamic typing: No declarations, names don’t have types, objects do
- **Assignment uses = and comparison uses ==**
- **For numbers + - * / % are as expected.**
  - Use of + for string concatenation.
  - Use of % for string formatting (like printf in C)
- **Logical operators are words (`and,or,not`) *not* symbols**
- **The basic printing command is `print`**

Basic Datatypes

- **Integers (default for numbers)**

  `z = 5 / 2  # Answer 2, integer division`
- **Floats**

  `x = 3.456`
- **Strings**
  - Can use "…" or '…' to specify, "foo" == 'foo'
  - Unmatched can occur within the string
    `"John's"` or `'John said "foo!".'`
  - 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, use *consistent* indentation instead
  - First line with *less* indentation is outside of the block
  - First line with *more* indentation starts a nested block
- Colons start of a new block in many constructs, e.g. function definitions, then clauses

Comments

- Start comments with #, rest of line is ignored
- Can include a "documentation string" as the first line of a new function or class you define
- Development environments, debugger, and other tools use it: it's good style to include one

```
def fact(n):
  """fact(n) assumes n is a positive
  integer and returns facorial of n."""
  assert(n>0)
  return 1 if n==1 else n*fact(n-1)
```

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 don't have an intrinsic type, *objects* have types

  Python determines type of the reference automatically based on what data is 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
- Python uses *reference semantics* (more later)

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
```

Naming conventions

The Python community has these recommended naming conventions

- **joined_lower** for functions, methods and, attributes
- **joined_lower** or **ALL_CAPS** for constants
- **StudlyCaps** for classes
- **camelCase** only to conform to pre-existing conventions
- Attributes: interface, _internal, __private

Python PEPs

- Where do such conventions come from?
  - The community of users
  - Codified in PEPs
- Python's development is done via the Python Enhancement Proposal (PEP) process
- PEP: a standardized design document, e.g. proposals, descriptions, design rationales, and explanations for language features
  - Similar to IETF RFCs
  - See the PEP index
- PEP 8: Style Guide for Python Code

Assignment

- You can assign to multiple names at the same time

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

- This makes it easy to swap values

```
>>> x, y = y, x
```

- Assignments can be chained

```
>>> a = b = x = 2
```

Accessing Non-Existent Name

Accessing a name before it's been properly created (by placing it on the left side of an assignment), raises an error

```
>>> y

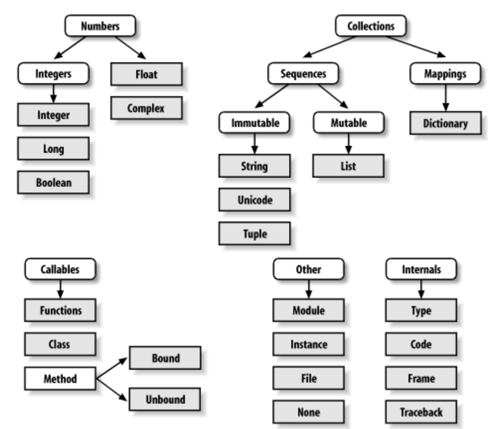
Traceback (most recent call last):
  File "<pyshell#16>", line 1, in -toplevel-
    y
NameError: name 'y' is not defined
>>> y = 3
>>> y
3
```

Python's data types

Everything is an object

- Python data is represented by objects or by relations between objects
- Every object has an identity, a type and a value
- **Identity** never changes once created Location or address in memory
- **Type** (e.g., integer, list) is unchangeable and determines the possible values it could have and operations that can be applied
- **Value** of some objects is fixed (e.g., an integer) and can change for others (e.g., list)

Python's built-in type hierarchy



Sequence types: Tuples, Lists, and Strings

Sequence Types

- Sequences are *containers* that hold objects
- Finite, ordered, indexed by integers
- Tuple
  - An *immutable* ordered sequence of items
  - Items can be of mixed types, including collection types
- Strings
  - An *immutable* ordered sequence of chars
  - Conceptually very much like a tuple
- List
  - A *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

- Define tuples using parentheses and commas

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

- Define lists are using square brackets and commas

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

- Define strings using quotes (", ', or """).

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

Sequence Types 2

- 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 index: count from right, starting with –1

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

Slicing: Return Copy of a Subset

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

- Returns 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

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

Slicing: Return Copy of a Subset

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

- Omit 1st index to make a copy starting from the beginning of container

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

- Omit 2nd index to make a copy starting at 1st index and going to end of the container

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

Copying the Whole Sequence

- [:] makes a *copy* of an entire sequence

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

- Note the difference between these two lines for mutable sequences

```
>>> l2 = l1 # Both refer to same ref,
            # changing one affects both
>>> l2 = l1[:] # Independent copies, two
refs
```

Copying a Sequence

```
>>> l1 = l2 = ['a','b','c']
>>> l1
['a', 'b', 'c']
>>> l2
['a', 'b', 'c']
>>> l1[1] = 'x'
>>> l1
['a', 'x', 'c']
>>> l2
['a', 'x', 'c']
>>>
```

```
>>> l1 = ['a','b','c']
>>> l2 = l1[:]
>>> l1
['a', 'b', 'c']
>>> l2
['a', 'b', 'c']
>>> l1[1] = 'x'
>>> l1
['a', 'x', 'c']
>>> l2
['a', 'b', 'c']
>>>
```

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

Lists are 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.

Tuples are 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’)
```

- *The immutability of tuples means they’re faster than lists*

Operations on Lists Only

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

>>> li.append('a')  # Note the 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 +

- + creates a fresh list with a new memory ref
- *extend* operates on list `li` in place.

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

- *Potentially 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

- Lists have many methods, including index, count, remove, reverse, sort

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

Operations on Lists Only

```
>>> 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
```

Tuple details

- The **comma** is the tuple creation operator, not parens

```
>>> 1,
(1,)
```

- Python shows parens for clarity (best practice)

```
>>> (1,)
(1,)
```

- Don't forget the comma!

```
>>> (1)
1
```

- Trailing comma only required for singletons others
- Empty tuples have a special syntactic form

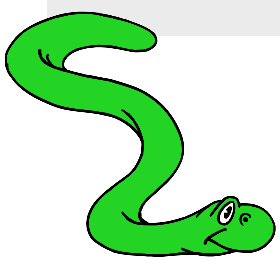
```
>>> ()
()
>>> tuple()
()
```

Summary: Tuples vs. Lists

- Lists slower but more powerful than tuples
  - Lists can be modified, and they have lots of handy operations and mehtods
  - 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)
```

Understanding Reference Semantics in Python



Understanding Reference Semantics

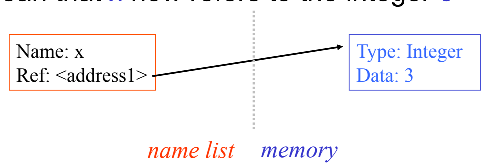
- Assignment manipulates references
  —x = y does not make a copy of the object y references
  —x = y makes x reference the object y references
- Very useful; but beware!, e.g.

```
>>> 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 Semantic

- There's a lot going on with `x = 3`
- 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

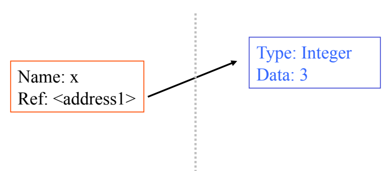
- The data 3 we created is of type integer – objects are typed, variables are not
- In Python, the datatypes integer, float, and string (and tuple) are "immutable"
- This doesn't mean we can't change the value of x, i.e. *change what x refers to …*
- For example, we could increment x:

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

Understanding Reference Semantics

When we increment x, then what happens is:

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




```
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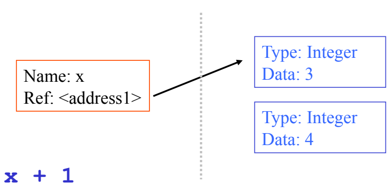
```

Understanding Reference Semantics

When we increment x, then what 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*




```
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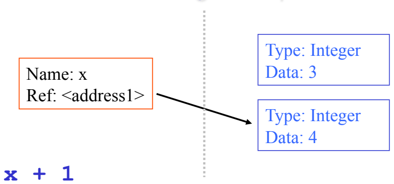
```

Understanding Reference Semantics

When we increment x, then what 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 new ref*




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

Assignment

So, for simple built-in datatypes (integers, floats, strings) assignment behaves as expected

```
>>> 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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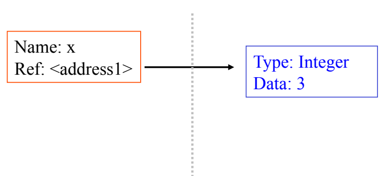

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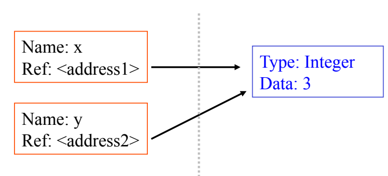

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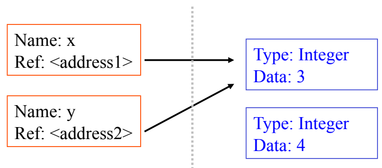

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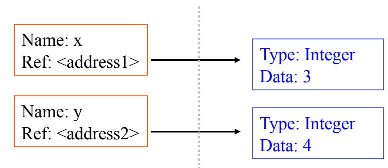
```



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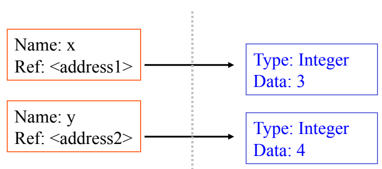
3
```



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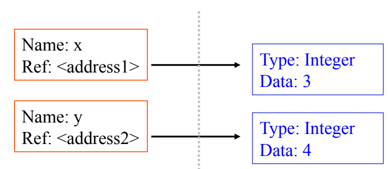
3
```



Assignment & mutable objects

For other data types (lists, dictionaries, user-defined types), assignment work the same, but some methods change the objects

- These datatypes are “mutable”
- Change occur *in place*
- We don’t copy them to a new memory address each time
- If we type y=x, then modify y, both x and y are changed

immutable

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

mutable

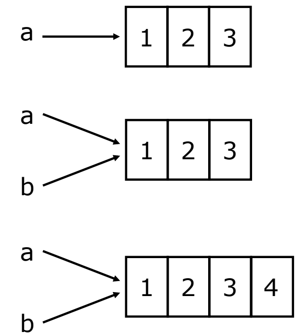
```
x = some mutable object
y = x
make a change to y
look at x
x will be changed as well
```

Why? Changing a Shared List

a = [1, 2, 3]

b = a

a.append(4)



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…
```

Conclusion

- Python uses a simple reference semantics much like Scheme or Java