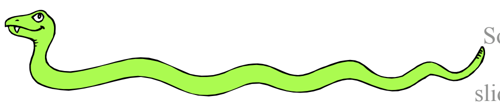
Python 2



Some material adapted from Upenn cis391 slides and other sources

Overview

- Dictionaries
- Functions
- Logical expressions
- Flow of control
- Comprehensions
- For loops
- More on functions
- Assignment and containers
- Strings

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 or delete the key-value pairs in the dictionary
- Python's dictionaries are also known as *hash tables* and *associative arrays*

Creating & accessing dictionaries

```
>>> d = {'user':'bozo', 'pswd':1234}
>>> d['user']
'bozo'
>>> d['pswd']
123
>>> 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 entries can appear anywhere in 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
{}
>>> a=[1,2]
>>> del a[1]        # del works on lists, too
>>> a
[1]
```

Useful Accessor Methods

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

>>> d.keys()  # List of keys, VERY useful
['user', 'p', 'i']

>>> d.values() # List of values
['bozo', 1234, 34]

>>> d.items()  # List of item tuples
[('user','bozo'), ('p',1234), ('i',34)]
```

A Dictionary Example

Problem: count the frequency of each word in text read from the standard input, print results

- Six versions of increasing complexity
- **wf1.py** is a simple start
- **wf2.py** uses a common idiom for default values
- **wf3.py** sorts the output alphabetically
- **wf4.py** downcase and strip punctuation from words and ignore stop words
- **wf5.py** sort output by frequency
- **wf6.py** add command line options: -n, -t, -h

Dictionary example: wf1.py

```
#!/usr/bin/python
import sys
freq = {}   # frequency of words in text
for line in sys.stdin:
    for word in line.split():
        if word in freq:
            freq[word] = 1 + freq[word]
        else:
            freq[word] = 1
print freq
```

Dictionary example wf1.py

```
#!/usr/bin/python
import sys
freq = {}   # frequency of words in text
for line in sys.stdin:
    for word in line.split():
        if word in freq:
            freq[word] = 1 + freq[word]
        else:
            freq[word] = 1
print freq
```

This is a common pattern

Dictionary example wf2.py

```
#!/usr/bin/python
import sys
freq = {}   # frequency of words in text
for line in sys.stdin:
    for word in line.split():
        freq[word] = 1 + freq.get(word,0)
print freq
```

key

Default value if not found

Dictionary example wf3.py

```
#!/usr/bin/python
import sys
freq = {}   # frequency of words in text

for line in sys.stdin:
    for word in line.split():
        freq[word] = freq.get(word,0)

for w in sorted(freq.keys()):
    print w, freq[w]
```

Dictionary example wf4.py

```
#!/usr/bin/python
import sys
from operator import itemgetter
punctuation = """'!"#$%&\'()*+,-./:;<=>?
  @[\\]^_`{|}~'"""

freq = {}     # frequency of words in text
stop_words = {}
for line in open("stop_words.txt"):
    stop_words[line.strip()] = True
```

Dictionary example wf5.py

```
for line in sys.stdin:
  for word in line.split():
    word = word.strip(punctuation).lower()
      if not word in stop_words:
        freq[word] = freq.get(word,0) + 1
words = sorted(freq.iteritems(),
  key=itemgetter(1), reverse=True)
for w,f in words:
    print w, f
```

Dictionary example wf6.py

```
from optparse import OptionParser
# read command line arguments and process
parser = OptionParser()
parser.add_option('-n', '--number', type="int",
  default=-1, help='number of words to report')
parser.add_option("-t", "--threshold", type="int",
  default=0, help="print if frequency > threshold")
(options, args) = parser.parse_args()
...
# print the top option.number words but only those
# with freq>option.threshold
for (word, freq) in words[:options.number]:
    if freq > options.threshold:
        print freq, word
```

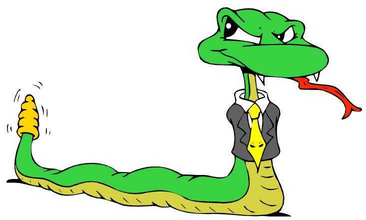
Why must keys be immutable?

- The keys used in a dictionary must be immutable objects?

```
>>> name1, name2 = 'john', ['bob', 'marley']
>>> fav = name2
>>> d = {name1: 'alive', name2: 'dead'}
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: list objects are unhashable
```

- Why is this?
- Suppose we could index a value for name2
- and then did `fav[0] = "Bobby"`
- Could we find d[name2] or d[fav] or …?

Functions in Python



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 <u>types</u> of function or arguments

Python and Types

- **Dynamic typing***:* Python determines the data types of *variable bindings* in a program automatically
- **Strong typing:** But Python’s not casual about types, it enforces the types of *objects*
- For example, you can’t just append an integer to a string, but must first convert it to a string

```
x = “the answer is ”   # x bound to a string
y = 23       # y bound to an integer.
print x + y    # Python will complain!
```

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*
  - Old values for the variables that are parameter names are hidden, and these variables are simply made to *refer to* the new values
  - All assignment in Python, including binding function parameters, uses *reference semantics.*

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)

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

Keyword Arguments

- You can call a function with some or all of its arguments out of order as long as you specify their names
- 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
```

Functions are first-class objects

Functions can be used as any other datatype, eg:

- Arguments to function
- Return values of functions
- Assigned to variables
- Parts of tuples, lists, etc

```
>>> def square(x):
        return x*x

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

>>> applier(square, 7)
49
```

Lambda Notation

- Python uses a lambda notation to create anonymous functions

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

- Python supports functional programming idioms, including closures and continuations

Lambda Notation

Be careful with the syntax

```
>>> f = lambda x,y : 2 * x + y
>>> f
<function <lambda> at 0x87d30>
>>> f(3, 4)
10
>>> v = lambda x: x*x(100)
>>> v
<function <lambda> at 0x87df0>
>>> v = (lambda x: x*x)(100)
>>> v
10000
```

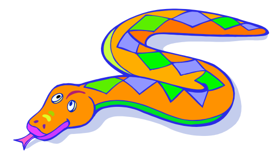
Example: composition

```
>>> def square(x):
        return x*x
>>> def twice(f):
        return lambda x: f(f(x))
>>> twice
<function twice at 0x87db0>
>>> quad = twice(square)
>>> quad
<function <lambda> at 0x87d30>
>>> quad(5)
625
```

Example: closure

```
>>> def counter(start=0, step=1):
        x = [start]
        def _inc():
            x[0] += step
            return x[0]
        return _inc
>>> c1 = counter()
>>> c2 = counter(100, -10)
>>> c1()
1
>>> c2()
90
```

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* & *or*

- Actually *and* and *or don't* return *True* or *False* but 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

- An old *deprecated* 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 C++'s `(test ? expr1 : expr2)`
- *But* if the value of expr1 is *ever False,* the trick doesn't work
- *Don't use it; m*ade unnecessary by conditional expressions in Python 2.5 (see next slide)

Conditional Expressions 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
- Standard use:

```
x = (true_value if condition else
  false_value)
```

Control of Flow

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 < 5:
     print x, "still in the loop"
     x = x + 1
3 still in the loop
4 still in the loop
>>> x = 6
>>> while x < 5:
     print x, "still in the loop"

>>>
```

break and *continue*

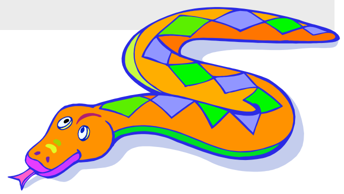
- You can use the keyword *break* inside a loop to leave the *while* loop entirely.
- You can use the keyword *continue* inside a loop to stop processing the current iteration of the loop and to immediately go on to the next one.

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
    - (more accurately: the program throws an exception)

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

List Comprehensions



Python's higher-order functions

- Python supports higher-order functions that operate on lists similar to Scheme's

```
>>> def square(x):
        return x*x
>>> def even(x):
        return 0 == x % 2
>>> map(square, range(10,20))
[100, 121, 144, 169, 196, 225, 256, 289, 324, 361]
>>> filter(even, range(10,20))
[10, 12, 14, 16, 18]
>>> map(square, filter(even, range(10,20)))
[100, 144, 196, 256, 324]
```

- But many Python programmers prefer to use list comprehensions, instead

List Comprehensions

- A *list comprehension* is a programming language construct for creating a list based on existing lists
  - Haskell, Erlang, Scala and Python have them
- Why "comprehension"? The term is borrowed from math's *set comprehension* notation for defining sets in terms of other sets
- A powerful and popular feature in Python
  - Generate a new list by applying a function to every member of an original list
- Python's notation:
  [expression for name in list]

List Comprehensions

- The syntax of a *list comprehension* is somewhat tricky

```
[x-10 for x in grades if x>0]
```

- 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

[expression for name in list]

List Comprehensions

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

Note: Non-standard colors on next few slides 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.

[expression for name in list]

List Comprehensions

- 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]
```

[expression for name in list]

List Comprehensions

- 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]
```

[expression for name in list]

Syntactic sugar

List comprehensions can be viewed as syntactic sugar for a typical higher-order functions

`[ expression for name in list ]`

map(lambda name: expression, list)

`[ 2*x+1 for x in [10, 20, 30] ]`

map(lambda x: 2*x+1, [10, 20, 30])

Filtered List Comprehension

- 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 the filter condition returns *False*, that element is omitted from the list before the list comprehension is evaluated.

[expression for name in list if filter]

Filtered List Comprehension

```
>>> 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 produce.

[expression for name in list if filter]

More syntactic sugar

Including an if clause begins to show the benefits of the sweetened form

[expression for name in list if filt]
map(lambda name . expression, filter(filt, list))

[2*x+1 for x in [10, 20, 30] if x > 0]
map(lambda x: 2*x+1,
filter(lambda x: x > 0 , [10, 20, 30])

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]

[expression for name in list]

Syntactic sugar

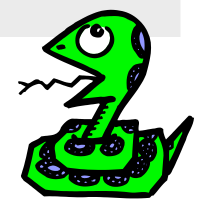
[e1 for n1 in [e1 for n1 list]]

map(lambda n1: e1,
    map(lambda n2: e2, list))

[2*x+1 for x in [y*y for y in [10, 20, 30]]]

map(lambda x: 2*x+1,
    map(lambda y: y*y, [10, 20, 30]))

For Loops



For Loops / List Comprehensions

- Python's list comprehensions provide a natural idiom that usually requires 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.
- *Take care*! The keywords *for* and *in* are also used in the syntax of list comprehensions, but this is a totally different construction.

For Loops 1

- A for-loop steps through each of the items in a collection type, 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 than a single variable name
- When the <collection> elements 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 & 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:

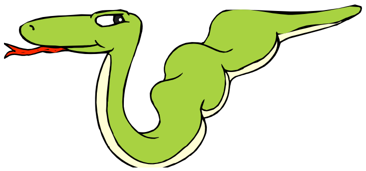
```
for x in range(5):
    print x
```

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

For Loops and Dictionaries

```
>>> ages = { "Sam" : 4, "Mary" : 3, "Bill" : 2 }
>>> ages
{'Bill': 2, 'Mary': 3, 'Sam': 4}
>>> for name in ages.keys():
   print name, ages[name]
Bill 2
Mary 3
Sam 4
>>>
```

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?

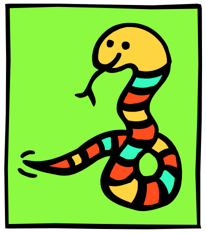
- To initialize an empty list, e.g., before using append
- This would cause an unknown name error if a named reference to the right data type wasn't created first

```
>>> 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 a la "fill in the blanks"
  - Allows control of how the final output appears
  - 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 used to fill in blanks in original string marked with *%s* or *%d*.
- Check Python documentation for codes

Printing with Python

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

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

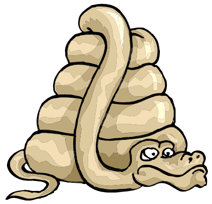
- *Print* adds a newline to the end of the string. If you include a list of strings, it will concatenate them with a space between them

```
>>> print "abc"
abc
```

```
>>> print "abc", "def"
abc def
```

- Useful trick: `>>> print "abc",` doesn't add newline just a single space

String Conversions



Join and Split

- 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

Split & Join with List Comprehensions

- Split and join can be used in a list compre-hension in the following Python idiom:

```
>>> " ".join( [s.capitalize() for s in "this is a test ".split( )] )
'This Is A Test'
>>> # For clarification:
>>> "this is a test" .split( )
['this', 'is', 'a', 'test']
>>> [s.capitalize() for s in "this is a test" .split()]
['This', 'Is', 'A', 'Test']
```

Convert Anything to a String

- The builtin **str()** function can convert an instance of <u>any</u> data type into a string.
- You 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"
```