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Python Tutorial

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based on a course I taught at Penn (but updated to Python 2.6)

www.cis.upenn.edu/~lhuang3/cse399-python

“Hello, World”

- C

```
#include <stdio.h>

int main(int argc, char ** argv)
{
   printf(“Hello, World!\n”);
}
```

- Java

```
public class Hello
{
   public static void main(String argv[])
   {
      System.out.println(“Hello, World!”);
   }
}
```

- now in Python

```
print “Hello, World!”
```

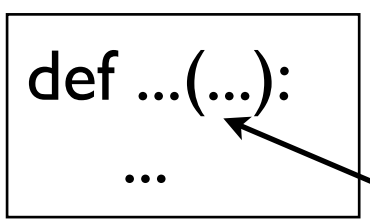
Reversing an Array

```
static int[] reverse_array(int a[])
{
   int [] temp = new int[ a.length ];
   for (int i = 0; i < len; i++)
   {
      temp [i] = a [a.length - i - 1];
   }
   return temp;
}
```

Java

```
def rev(a):
   if a == []:
      return []
   else:
      return rev(a[1:]) + [a[0]]
```

Python



no need to specify argument and return types! python will figure it out. (dynamically typed)

`a` without `a[0]`

singleton list

or even simpler:

`a.reverse()` ⟵ built-in list-processing function

Quick-sort

```java
public void sort(int low, int high)
{
    if (low >= high) return;
    int p = partition(low, high);
    sort(low, p);
    sort(p + 1, high);
}

void swap(int i, int j)
{
    int temp = a[i];
    a[i] = a[j];
    a[j] = temp;
}
```

```java
int partition(int low, int high)
{
    int pivot = a[low];
    int i = low - 1;
    int j = high + 1;
    while (i < j)
    {
        i++; while (a[i] < pivot) i++;
        j--; while (a[j] > pivot) j--;
        if (i < j) swap(i, j);
    }
    return j;
}
```

Java

Python

```python
def sort(a):
    if a == []:
        return []
    else:
        pivot = a[0]
        left  = [x for x in a if x < pivot ]
        right = [x for x in a[1:] if x >= pivot]
        return sort(left) + [pivot] + sort(right)
```

$$\{x \mid x \in a,\ x < pivot\}$$

smaller semantic-gap!

Python is...

- a scripting language (strong in text-processing)
  - interpreted, like Perl, but much more elegant
- a very high-level language (closer to human semantics)
  - almost like pseudo-code!
- procedural (like C, Pascal, Basic, and many more)
- but also object-oriented (like C++ and Java)
- and even functional! (like ML/OCaml, LISP/Scheme, Haskell, etc.)
- from today, you should use Python for everything
  - not just for scripting, but for serious coding!

Basic Python Syntax

Numbers and Strings

- like Java, Python has built-in (atomic) types
  - numbers (`int`, `float`), `bool`, `string`, `list`, etc.
  - numeric operators: `+ - * / ** %`

```
>>> a = 5
>>> b = 3
>>> type (5)
<type 'int'>
>>> a += 4
>>> a
9
```

no `i++` or `++i`

```
>>> c = 1.5
>>> 5/2
2
>>> 5/2.
2.5
>>> 5 ** 2
25
```

```
>>> s = “hey”
>>> s + “ guys”
'hey guys'
>>> len(s)
3
>>> s[0]
'h'
>>> s[-1]
'y'
```

```
>>> from __future__ import division
>>> 5/2
2.5
```

recommended!

Assignments and Comparisons

```
>>> a = b = 0
>>> a
0
>>> b
0

>>> a, b = 3, 5
>>> a + b
8
>>> (a, b) = (3, 5)
>>> a + b
>>> 8
>>> a, b = b, a
(swap)
```

```
>>> a = b = 0
>>> a == b
True
>>> type (3 == 5)
<type 'bool'>
>>> "my" == 'my'
True

>>> (1, 2) == (1, 2)
True

>>> 1, 2 == 1, 2
???
(1, False, 2)
```

`for` loops and `range()`

- `for` always iterates through a list or sequence

```
>>> sum = 0
>>> for i in range(10):
...     sum += i
...
>>> print sum
45

>>> for word in ["welcome", "to", "python"]:
...     print word,
...
welcome to python

>>> range(5), range(4,6), range(1,7,2)
([0, 1, 2, 3, 4], [4, 5], [1, 3, 5])
```

Java 1.5

```
foreach (String word : words)
    System.out.println(word)
```

`while` loops

- very similar to `while` in Java and C
  - but be careful
    - `in` behaves differently in `for` and `while`
  - `break` statement, same as in Java/C

```
>>> a, b = 0, 1
>>> while b <= 5:
...         print b
...         a, b = b, a+b
...
1
1
2
3
5
```

simultaneous assignment

fibonacci series

Conditionals

```
>>> if x < 10 and x >= 0:
...     print x, "is a digit"
...
>>> False and False or True
True
>>> not True
False
```

```
>>> if 4 > 5:
...     print "foo"
... else:
...     print "bar"
...
bar
```

```
>>> print "foo" if 4 > 5 else "bar"
...
>>> bar
```

conditional expr since Python 2.5

C/Java `printf( (4>5)? "foo" : "bar");`

if … elif … else

```
>>> a = "foo"
>>> if a in ["blue", "yellow", "red"]:
...     print a + " is a color"
... else:
...     if a in ["US", "China"]:
...         print a + " is a country"
...     else:
...         print "I don't know what", a, "is!"
...
I don't know what foo is!
```

```
>>> if a in …:
...     print …
... elif a in …:
...     print …
... else:
...     print …
```

C/Java

```
switch (a) {
    case "blue":
    case "yellow":
    case "red":
        print ...; break;
    case "US":
    case "China":
        print ...; break;
    else:
        print ...;
}
```

`break`, `continue` and `else`

- `break` and `continue` borrowed from C/Java
- special `else` in loops
  - when loop terminated *normally* (i.e., not by `break`)
  - very handy in testing a set of properties

```
>>> for n in range(2, 10):
...     for x in range(2, n):
...         if n % x == 0:
...             break
...     else:
...         print n,
...
```

prime numbers

C/Java

```
for (n=2; n<10; n++) {
   good = true;
   for (x=2; x<n; x++)
      if (n % x == 0) {
         good = false;
         break;
      }
   if (good)
      printf("%d ", n);
}
```

|| func(n)

if (x==n)

Defining a Function `def`

- no type declarations needed! wow!
  - Python will figure it out at run-time
    - you get a run-time error for type violation
      - well, Python does not have a compile-error at all

```
>>> def fact(n):
...     if n == 0:
...         return 1
...     else:
...         return n * fact(n-1)
...
>>> fact(4)
24
```

Fibonacci Revisited

```
>>> a, b = 0, 1
>>> while b <= 5:
...         print b
...         a, b = b, a+b
...
1
1
2
3
5
```

```
def fib(n):
   if n <= 1:
      return n
   else:
      return fib (n-1) + fib (n-2)
```

conceptually cleaner, but much slower!

```
>>> fib(5)
5
>>> fib(6)
8
```

Default Values

```
>>> def add(a, L=[]):
...     return L + [a]
...
>>> add(1)
[1]

>>> add(1,1)
error!

>>> add(add(1))
[[1]]

>>> add(add(1), add(1))
???
[1, [1]]
```

lists are heterogenous!

Approaches to Typing

- ✓ strongly typed: types are strictly enforced. no implicit type conversion
- – weakly typed: not strictly enforced
- – statically typed: type-checking done at compile-time
- ✓ dynamically typed: types are inferred at runtime

	weak	strong
static	C, C++	Java, Pascal
dynamic	Perl, VB	Python, OCaml, Scheme

Lists

heterogeneous variable-sized array

```
a = [1,'python', [2,'4']]
```

Basic List Operations

- length, subscript, and slicing

```
>>> a = [1,'python', [2,'4']]
>>> len(a)
3
>>> a[2][1]
'4'
>>> a[3]
IndexError!
>>> a[-2]
'python'
>>> a[1:2]
['python']
```

```
>>> a[0:3:2]
[1, [2, '4']]

>>> a[:-1]
[1, 'python']

>>> a[0:3:]
[1, 'python', [2, '4']]

>>> a[0::2]
[1, [2, '4']]

>>> a[::]
[1, 'python', [2, '4']]

>>> a[:]
[1, 'python', [2, '4']]
```

+, extend, +=, append

- extend (+=) and append mutates the list!

```
>>> a = [1,'python', [2,'4']]
>>> a + [2]
[1, 'python', [2, '4'], 2]
>>> a.extend([2, 3])
>>> a
[1, 'python', [2, '4'], 2, 3]
```

same as `a += [2, 3]`

```
>>> a.append('5')
>>> a
[1, 'python', [2, '4'], 2, 3, '5']
>>> a[2].append('xtra')
>>> a
[1, 'python', [2, '4', 'xtra'], 2, 3, '5']
```

Comparison and Reference

- as in Java, comparing built-in types is by value
  - by contrast, comparing objects is by reference

```
>>> [1, '2'] == [1, '2']
True
>>> a = b = [1, '2']
>>> a == b
True
>>> a is b
True
>>> b [1] = 5
>>> a
[1, 5]
>>> a = 4
>>> b
[1, 5]
>>> a is b
>>> False
```

```
>>> c = b [:]
>>> c
[1, 5]
>>> c == b
True
>>> c is b
False
```

slicing gets a shallow copy

what about `a += [1]`?

```
>>> b[:0] = [2]
>>> b
[2, 1, 3, 4]
>>> b[1:3]=[]
>>> b
[2, 4]
```

insertion

deletion

List Comprehension

```
>>> a = [1, 5, 2, 3, 4 , 6]
>>> [x*2 for x in a]
[2, 10, 4, 6, 8, 12]

>>> [x for x in a if \
... len( [y for y in a if y < x] ) == 3 ]
[4]

>>> a = range(2,10)
>>> [x*x for x in a if \
... [y for y in a if y < x and (x % y == 0)] == [] ]
???
[4, 9, 25, 49]
```

4th smallest element

square of prime numbers

List Comprehensions

```
>>> vec = [2, 4, 6]
>>> [[x,x**2] for x in vec]
[[2, 4], [4, 16], [6, 36]]

>>> [x, x**2 for x in vec]
SyntaxError: invalid syntax

>>> [(x, x**2) for x in vec]
[(2, 4), (4, 16), (6, 36)]

>>> vec1 = [2, 4, 6]
>>> vec2 = [4, 3, -9]
>>> [x*y for x in vec1 for y in vec2]
[8, 6, -18, 16, 12, -36, 24, 18, -54]
```

(cross product)

```
>>> [x+y for x in vec1 for y in vec2]
[6, 5, -7, 8, 7, -5, 10, 9, -3]

>>> [vec1[i]*vec2[i] for i in range(len(vec1))]
[8, 12, -54]
```

(dot product)

Strings

sequence of characters

Basic String Operations

- join, split, strip
- upper(), lower()

```
>>> s = " this is  a  python course. \n"
>>> words = s.split()
>>> words
['this', 'is', 'a', 'python', 'course.']
>>> s.strip()
'this is  a  python course.'
>>> " ".join(words)
'this is a python course.'
>>> "; ".join(words).split("; ")
['this', 'is', 'a', 'python', 'course.']
>>> s.upper()
' THIS IS  A  PYTHON COURSE. \n'
```

http://docs.python.org/lib/string-methods.html

Basic Search/Replace in String

```
>>> "this is a course".find("is")
2
>>> "this is a course".find("is a")
5
>>> "this is a course".find("is at")
-1

>>> "this is a course".replace("is", "was")
'thwas was a course'
>>> "this is a course".replace(" is", " was")
'this was a course'
>>> "this is a course".replace("was", "were")
'this is a course'
```

these operations are much faster than regexps!

String Formatting

```
>>> print “%.2f%%” % 97.2363
97.24

>>> s = '%s has %03d quote types.' % ("Python", 2)
>>> print s
Python has 002 quote types.
```

Tuples

immutable lists

Tuples and Equality

- caveat: singleton tuple

```
a += (1,2)  # new copy
```

- `==`, `is`, `is not`

```
>>> (1, 'a')
(1, 'a')
>>> (1)
1
>>> [1]
[1]
>>> (1,)
(1,)
>>> [1,]
[1]
>>> (5) + (6)
11
>>> (5,)+ (6,)
(5, 6)
```

```
>>> 1, 2 == 1, 2
(1, False, 2)
>>> (1, 2) == (1, 2)
True
>>> (1, 2) is (1, 2)
False
>>> "ab" is "ab"
True
>>> [1] is [1]
False
>>> 1 is 1
True
>>> True is True
True
```

Comparison

- between the same type: "lexicographical"
- between different types: arbitrary
- `cmp()`: three-way <, >, ==
  - C: `strcmp(s, t)`, Java: `a.compareTo(b)`

```
>>> (1, 'ab') < (1, 'ac')
True
>>> (1, ) < (1, 'ac')
True
>>> [1] < [1, 'ac']
True
>>> 1 < True
False
>>> True < 1
False
```

```
>>> [1] < [1, 2] < [1, 3]
True
>>> [1] == [1,] == [1.0]
True
>>> cmp ( (1, ), (1, 2) )
-1
>>> cmp ( (1, ), (1, ) )
0
>>> cmp ( (1, 2), (1, ) )
1
```

enumerate

```
>>> words = ['this', 'is', 'python']
>>> i = 0
>>> for word in words:
...     i += 1
...     print i, word
...
1 this
2 is
3 python

>>> for i, word in enumerate(words):
...     print i+1, word
...
```

- how to enumerate two lists/tuples simultaneously?

zip and _

```
>>> a = [1, 2]
>>> b = ['a', 'b']

>>> zip (a,b)
[(1, 'a'), (2, 'b')]

>>> zip(a,b,a)
[(1, 'a', 1), (2, 'b', 2)]

>>> zip ([1], b)
[(1, 'a')]


>>> a = ['p', 'q']; b = [[2, 3], [5, 6]]
>>> for i, (x, [_, y]) in enumerate(zip(a, b)):
...       print i, x, y
...
0 p 3
1 q 6
```

zip and list comprehensions

```
>>> vec1 = [2, 4, 6]
>>> vec2 = [4, 3, -9]
>>> [(x, y) for x in vec1 for y in vec2]
[(2, 4), (2, 3), (2, -9), (4, 4), (4, 3), (4, -9), (6,
4), (6, 3), (6, -9)]

>>> [(vec1[i], vec2[i]) for i in range(len(vec1))]
[(2, 4), (4, 3), (6, -9)]

>>> sum([vec1[i]*vec2[i] for i in range(len(vec1))]
-34

>>> sum([x*y for (x,y) in zip(vec1, vec2)])
-34

>>> sum([v[0]*v[1] for v in zip(vec1, vec2)])
-34
```

how to implement zip?

binary zip: easy

```
>>> def myzip(a,b):
...     if a == [] or b == []:
...             return []
...     return [(a[0], b[0])] + myzip(a[1:], b[1:])
...

>>> myzip([1,2], ['a','b'])
[(1, 'a'), (2, 'b')]
>>> myzip([1,2], ['b'])
[(1, 'b')]
```

how to deal with arbitrarily many arguments?

Basic `import` and I/O

import and I/O

- similar to import in Java
- File I/O much easier than Java

```
import sys
for line in sys.stdin:
   print line.split()
```

or

```
from sys import *
for line in stdin:
   print line.split()
```

```
import System;
```

Java

```
import System.*;
```

```
>>> f = open("my.in", "rt")
>>> g = open("my.out", "wt")
>>> for line in f:
...     print >> g, line,
... g.close()
```

file copy

to read a line:

```
line = f.readline()
```

to read all the lines:

```
lines = f.readlines()
```

note this comma!

import and __main__

- multiple source files (modules)
  - C: #include "my.h"
  - Java: import My
- demo
- handy for debugging

foo.py

```
def pp(a):
   print " ".join(a)

if __name__ == "__main__":
   from sys import *
   a = stdin.readline()
   pp (a.split())
```

```
>>> import foo
>>> pp([1,2,3])
1 2 3
```

interactive

Quiz

- Palindromes

`abcba`

  - read in a string from standard input, and print `True` if it is a palindrome, print `False` if otherwise

```
def palindrome(s):
    if  len(s) <= 1 :
        return True
    return s[0] == s[-1] and palindrome( s[1:-1] )

if __name__ == '__main__':

    import sys
    s = sys.stdin.readline().strip()
    print palindrome(s)
```

Functional Programming

map and filter

- intuition: function as data
- we have already seen functional programming a lot!
  - list comprehension, custom comparison function

```
map(f, a)

filter(p, a)
```

```
[ f(x) for x in a ]

[ x for x in a if p(x) ]
```

```
map(f, filter(p, a))
```

```
[ f(x) for x in a if p(x) ]
```

```
>>> map(int, ['1','2'])
[1, 2]
>>> " ".join(map(str, [1,2]))
1 2
```

```
>>> def is_even(x):
...     return x % 2 == 0
...
>>> filter(is_even, [-1, 0])
[0]
```

lambda

- map/filter in one line for custom functions?
  - “anonymous inline function”
- borrowed from LISP, Scheme, ML, OCaml

```
>>> f = lambda x: x*2
>>> f(1)
2
>>> map (lambda x: x**2, [1, 2])
[1, 4]
>>> filter (lambda x: x > 0, [-1, 1])
[1]
>>> g = lambda x,y : x+y
>>> g(5,6)
11
>>> map (lambda (x,y): x+y, [(1,2), (3,4)])
[3, 7]
```

more on lambda

```
>>> f = lambda : "good!"
>>> f
<function <lambda> at 0x381730>
>>> f()
'good!'
```

lazy evaluation

```
>>> a = [5, 1, 2, 6, 4]
>>> a.sort(lambda x,y : y - x)
>>> a
[6, 5, 4, 2, 1]
```

custom comparison

Dictionaries

(heterogeneous) hash maps

Constructing Dicts

- key : value pairs

```
>>> d = {'a': 1, 'b': 2, 'c': 1}
>>> d['b']
2
>>> d['b'] = 3
>>> d['b']
3
>>> d['e']
KeyError!
>>> d.has_key('a')
True
>>> 'a' in d
True
>>> d.keys()
['a', 'c', 'b']
>>> d.values()
[1, 1, 3]
```

Other Constructions

- zipping, list comprehension, keyword argument
- dump to a list of tuples

```
>>> d = {'a': 1, 'b': 2, 'c': 1}
>>> keys = ['b', 'c', 'a']
>>> values = [2,  1,   1 ]
>>> e = dict (zip (keys, values))
>>> d == e
True
>>> d.items()
[('a', 1), ('c', 1), ('b', 2)]

>>> f = dict( [(x, x**2) for x in values] )
>>> f
{1: 1, 2: 4}

>>> g = dict(a=1, b=2, c=1)
>>> g == d
True
```

Mapping Type

Operation	Result
`len(a)`	the number of items in *a*
`a[k]`	the item of *a* with key *k*
`a[k] = v`	set `a[k]` to *v*
`del a[k]`	remove `a[k]` from *a*
`a.clear()`	remove all items from `a`
`a.copy()`	a (shallow) copy of `a`
`a.has_key(k)`	`True` if *a* has a key *k*, else `False`
`k in a`	Equivalent to *a*.has_key(*k*)
`k not in a`	Equivalent to `not` *a*.has_key(*k*)
`a.items()`	a copy of *a*'s list of (*key*, *value*) pairs
`a.values()`	a copy of *a*'s list of values
`a.get(k[, x])`	`a[k]` if *k* `in` *a*, else *x*
`a.setdefault(k[, x])`	`a[k]` if *k* `in` *a*, else *x* (also setting it)
`a.pop(k[, x])`	`a[k]` if *k* `in` *a*, else *x* (and remove k)

http://docs.python.org/lib/typesmapping.html

Sets

identity maps, unordered collection

Sets

- sets do not have a special syntactic form
  - unlike [] for lists, () for tuples and {} for dicts
- construction from lists, tuples, dicts (keys), and strs
- in, not in, add, remove

```
>>> a = set((1,2))
>>> a
set([1, 2])
>>> b = set([1,2])
>>> a == b
True
>>> c = set({1:'a', 2:'b'})
>>> c
set([1, 2])
```

```
>>> a = set([])
>>> 1 in a
False
>>> a.add(1)
>>> a.add('b')
>>> a
set([1, 'b'])
>>> a.remove(1)
>>> a
set(['b'])
```

set and frozenset type

Operation	Equivalent	Result
`len(s)`		cardinality of set *s*
`x in s`		test *x* for membership in *s*
`x not in s`		test *x* for non-membership in *s*
`s.issubset(t)`	`s <= t`	test whether every element in *s* is in *t*
`s.issuperset(t)`	`s >= t`	test whether every element in *t* is in *s*
`s.union(t)`	`s | t`	new set with elements from both *s* and *t*
`s.intersection(t)`	`s & t`	new set with elements common to *s* and *t*
`s.difference(t)`	`s - t`	new set with elements in *s* but not in *t*
`s.symmetric_difference(t)`	`s ^ t`	new set with elements in either *s* or *t* but not both
`s.copy()`		new set with a shallow copy of *s*
`s.update(t)`	`s |= t`	return set *s* with elements added from *t*
`s.intersection_update(t)`	`s &= t`	return set *s* keeping only elements also found in *t*
`s.difference_update(t)`	`s -= t`	return set *s* after removing elements found in *t*
`s.symmetric_difference_update(t)`	`s ^= t`	return set *s* with elements from *s* or *t* but not both
`s.add(x)`		add element *x* to set *s*
`s.remove(x)`		remove *x* from set *s*; raises KeyError if not present
`s.discard(x)`		removes *x* from set *s* if present
`s.pop()`		remove and return an arbitrary element from *s*; rais
`s.clear()`		remove all elements from set *s*

Basic Sorting

```
>>> a = [5, 2, 3, 1, 4]
>>> a.sort()
>>> print a
[1, 2, 3, 4, 5]

>>> a = [5, 2, 3, 1, 4]
>>> a.sort(reverse=True)
>>> a
[5, 4, 3, 2, 1]

>>> a = [5, 2, 3, 1, 4]
>>> a.sort()
>>> a.reverse()
>>> a
[5, 4, 3, 2, 1]
```

Built-in and Custom cmp

```
>>> a = [5, 2, 3, 1, 4]
>>> a.sort(cmp)
>>> print a
[1, 2, 3, 4, 5]

>>> a = [5, 2, 3, 1, 4]
>>> def reverse_numeric(x, y):
>>>     return y-x
>>>
>>> a.sort(reverse_numeric)
>>> a
[5, 4, 3, 2, 1]
```

Sorting by Keys

```
>>> a = "This is a test string from Andrew".split()
>>> a.sort(key=str.lower)
>>> a
['a', 'Andrew', 'from', 'is', 'string', 'test', 'This']

>>> import operator
>>> L = [('c', 2), ('d', 1), ('a', 4), ('b', 3), ('b', 1)]

>>> L.sort(key=operator.itemgetter(1))
>>> L
[('d', 1), ('b', 1), ('c', 2), ('b', 3), ('a', 4)]

>>> sorted(L, key=operator.itemgetter(1, 0))
[('b', 1), ('d', 1), ('c', 2), ('b', 3), ('a', 4)]
```

sort by two keys

Decorate-Sort-Undecorate

```
>>> words = "This is a test string from Andrew.".split()

>>> deco = [ (word.lower(), i, word) for i, word in \
... enumerate(words) ]

>>> deco.sort()

>>> new_words = [ word for _, _, word in deco ]

>>> print new_words
['a', 'Andrew.', 'from', 'is', 'string', 'test', 'This']
```

- Most General
- Faster than custom cmp
- stable sort (by supplying index)

default values

- counting frequencies

```
>>> def incr(d, key):
...     if key not in d:
...             d[key] = 1
...     else:
...             d[key] += 1
...

>>> def incr(d, key):
...      d[key] = d.get(key, 0) + 1
...

>>> incr(d, 'z')
>>> d
{'a': 1, 'c': 1, 'b': 2, 'z': 1}
>>> incr(d, 'b')
>>> d
{'a': 1, 'c': 1, 'b': 3, 'z': 1}
```

defaultdict

- best feature introduced in Python 2.5

```
>>> from collections import defaultdict
>>> d = defaultdict(int)
>>> d['a']
0
>>> d['b'] += 1
>>> d
{'a': 0, 'b': 1}

>>> d = defaultdict(list)
>>> d['b'] += [1]
>>> d
{'b': [1]}

>>> d = defaultdict(lambda : <expr>)
```

Example: Word Freqs

- Counting Word Frequencies
  - read in a text file, count the frequencies of each word, and print in descending order of frequency

```
import sys

if __name__ == '__main__':
    wordlist = {}
    for i, line in enumerate(sys.stdin):
        for word in line.split():
            if word in wordlist:
                wordlist[word][0] += 1
                wordlist[word][1].add(i+1)
            else:
                wordlist[word] = [1, set([i+1])]

    sortedlst = [(-freq, word, lines) \
                 for (word, (freq, lines)) in wordlist.items()]
    sortedlst.sort()
    for freq, word, lines in sortedlist:
        print -freq, word, " ".join(map(str, lines))
```

input

Python is a cool language but OCaml

is even cooler since it is purely functional

output

3 is 1 2
1 a 1
1 but 1
1 cool 1
1 cooler 2
1 even 2
1 functional 2
1 it 2
1 language 1
1 ocaml 1
1 purely 2
1 python 1
1 since 2

using defaultdict

- Counting Word Frequencies
  - read in a text file, count the frequencies of each word, and print in descending order of frequency

```
import sys
from collections import defaultdict

if __name__ == '__main__':
    wordlist = defaultdict(set)
    for i, line in enumerate(sys.stdin):
        for word in line.split():
            wordlist[word].add(i)

    sortedlist = sorted([(-len(lines), word, lines) \
                 for (word, lines) in wordlist.items()])

    for freq, word, lines in sortedlist:
        print -freq, word, " ".join(map(str, lines))
```

input

```
Python is a cool language but OCaml
is even cooler since it is purely functional
```

output

```
3 is 1 2
1 a 1
1 but 1
1 cool 1
1 cooler 2
1 even 2
1 functional 2
1 it 2
1 language 1
1 ocaml 1
1 purely 2
1 python 1
1 since 2
```

Implementation

- lists, tuples, and dicts are all implemented by hashing
- strings are implemented as arrays
- lists, tuples, and strings
  - random access: O(1)
  - insertion/deletion/in: O(n)
- dict
  - in/random access: O(1)
  - insertion/deletion: O(1)
  - no linear ordering!

Pythonic Styles

- do not write ... when you can write ...

`for key in d.keys():`	`for key in d:`
`if d.has_key(key):`	`if key in d:`

`i = 0`
`for x in a:`
`    ...`
`    i += 1`
	`for i, x in enumerate(a):`

`a[0:len(a) - i]`	`a[:-i]`
`for line in \` `    sys.stdin.readlines():`	`for line in sys.stdin:`

`for x in a:`
`    print x,`
`print`
	`print " ".join(map(str, a))`

`s = ""`
`for i in range(lev):`
`    s += " "`
`print s`
	`print " " * lev`

Object-Oriented Programming

Overview of Python OOP

- Motivations of OOP
  - complicated data structures
  - modularity
- Perl does not have built-in OOP
  - Perl + OOP ==> Ruby (pure OO, like Java)
- Python has OOP from the very beginning
  - hybrid approach (like C++)
  - nearly everything inside a class is public
  - explicit argument `self`

Classes

```
class Point(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def norm(self):
        return self.x ** 2 + self.y ** 2

    def __str__(self):
        return "(" + str(self.x) + ", " + str(self.y) + ")"
```

- constructor `__init__(self, ...)`

```
>>> p = Point (3, 4)
>>> p.x
3
>>> p.norm()
25
```

```
>>> p.__str__()
'(3, 4)'
>>> str(p)
'(3, 4)'
>>> print p
(3, 4)
```

Classes

```
class Point(object):
    "A 2D point"
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def __str__(self):
        " like toString() in Java "
        return "(" + str(self.x) + ", " + str(self.y) + ")"
```

- doc-strings (`__doc__`), like javadoc (with pydoc)
- no polymorphic functions (earlier defs will be shadowed)
  - ==> only one constructor (and no destructor)
  - each function can have only one signature
- semantics: `Point.__str__(p)` equivalent to `p.__str__()`

Implementation: dicts

```
class Point(object):
    "A 2D point"
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def __str__(self):
        " like toString() in Java "
        return "(" + str(self.x) + ", " + str(self.y) + ")"
```

```
>>> p = Point (5, 6)
>>> p.z = 7
>>> print p
(5, 6)
>>> print p.w
AttributeError - no attribute 'w'
>>> p["x"] = 1
AttributeError - no attribute 'setitem'
```

repr and cmp

```
class Point:
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def __str__(self):
        return "(" + str(self.x) + ", " + str(self.y) + ")"
```

```
>>> p = Point(3,4)
>>> p
<__main__.Point instance at 0x38be18>
>>> Point (3,4) == Point (3,4)
False
```

repr and cmp

```
class Point:
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def __str__(self):
        return "(" + str(self.x) + ", " + str(self.y) + ")"

    def __repr__(self):
        return self.__str__()

    def __cmp__(self, other):
        if self.x == other.x:
            return self.y - other.y
        return self.x - other.x
```

```
>>> p = Point(3,4)
>>> p
<__main__.Point instance at 0x38be18>
>>> Point (3,4) == Point (3,4)
False
```

with `__repr__` and `__cmp__`

```
>>> p
(3, 4)
>>> cmp(Point(3,4), Point(4,3))
-1
>>> Point (3,4) == Point (3,4)
True
```

Inheritance

```
class Point (object):
    ...
    def __str__(self):
        return "(" + self.__repr__() + ")"

    def __repr__(self):
        return str(self.x) + ", " + str(self.y)
    ...

class Point3D (Point):
    "A 3D point"
    def __init__(self, x, y, z):
        Point.__init__(self, x, y)
        self.z = z

    def __str__(self):
        return Point.__str__(self) + ", " + str(self.z)

    def __cmp__(self, other):
        tmp = Point.__cmp__(self, other)
        if tmp != 0:
            return tmp
        return self.z - other.z
```

super-class, like C++
(multiple inheritance allowed)

Overloading

- like operator overloading in C++
- special functions like `__add__()`, `__mul__()`

```
class Point:
  # previously defined methods here...

  def __add__(self, other):
    return Point(self.x + other.x, self.y + other.y)

  def __mul__(self, other):
    return self.x * other.x + self.y * other.y
```

dot-product

```
>>> p = Point (3, 4)
>>> q = Point (5, 6)
>>> print (p + q)
(8, 10)
>>> print (p * q)
35
```

mul vs. rmul

```
class Point:

    def __mul__(self, other):
        return self.x * other.x + self.y * other.y

    def __rmul__(self, other):
        return Point(other * self.x,  other * self.y)
```

scalar-multiplication

```
>>> p1 = Point(3, 4)
>>> p2 = Point(5, 7)
>>> print p1 * p2
43
>>> print 2 * p2
(10, 14)

>>> print p2 * 2
AttributeError: 'int' object has no attribute 'x'
```

iadd (+=) and neg (-)

```
class Point(object):

    def __add__(self, other):
        return Point(self.x + other.x, self.y + other.y)

    def __iadd__(self, other):
        self.x += other.x
        self.y += other.y
        return self

    def __neg__(self):
        return Point(-self.x, -self.y)
```

must return `self` here!

```
add, sub, mul, div,
radd, rsub, rmul, rdiv,
iadd, isub, imul, idiv,
neg, inv, pow,
len, str, repr,
cmp, eq, ne, lt, le, gt, ge
```

Trees

```
class Tree:
  def __init__(self, node, children=[]):
    self.node = node
    self.children = children


def total(self):
  if self == None: return 0
  return self.node + sum([x.total() for x in self.children])

def pp(self, dep=0):
  print " |" * dep, self.node
   for child in self.children:
           child.pp(dep+1)


def __str__(self):
  return "(%s)" % " ".join(map(str, \
          [self.node] + self.children))
```

```
left = Tree(2)
right = Tree(3)

>>> t = Tree(1, [Tree(2), Tree(3)])
>>> total(t)
5

>>> t.pp()
 1
 | 2
 | 3
>>> print t
(1 (2) (3))
```