Why Python?

- Because it's easy and great fun!
  - only 15 years old, yet very popular now
    - a wide-range of applications, esp. in AI and Web
  - extremely easy to learn
    - many schools have shifted their intro-courses to Python
  - fast to write
    - much shorter code compared to C, C++, and Java
  - easy to read and maintain
    - more English-like syntax and a smaller semantic-gap

On to 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!”
```

Printing an Array

```
void print_array(char* a[], int len)
{
    int i;
    for (i = 0; i < len; i++)
    {
        printf("%s\n", a[i]);
    }
}
```

has to specify `len`,
and only for one type (`char*`)

C

Python

```
for element in list:
    print element
```

only indentations
no { ... } blocks!

```
for ... in ... :
    ...
```

no C-style for-loops!

~~`for (i = 0; i < 10; i++)`~~

or even simpler:

```
print list
```

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

Python

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

```
def ...(...):
    ...
```

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

`a[1:]` — a without a[0]

`[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!

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

|| func(n)

```
>>> 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);
}
```

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
```

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!

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

```
>>> b[:0] = [2]
>>> b
[2, 1, 5]
```

insertion

```
>>> b[1:3]=[]
>>> b
[2]
```

deletion

```
>>> a = b
>>> b += [1]
>>> a is b
True
```

`a += b` means `a.extend(b)` NOT `a = a + b` !!

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

Strings

sequence of characters

String Literals

- single quotes and double quotes; escape chars
- strings are immutable!

```
>>> 'spam eggs'
'spam eggs'
>>> 'doesn't'
SyntaxError!
>>> 'doesn\'t'
"doesn't"
>>> "doesn't"
"doesn't"
>>> "doesn"t"
SyntaxError!
>>> s = "aa"
>>> s[0] ='b'
TypeError!
```

```
>>> s = "a\nb"
>>> s
'a\nb'
>>> print s
a
b
>>> "\"Yes,\" he said."
'"Yes," he said.'
>>> s = '"Isn\'t," she said.'
>>> s
'"Isn\'t," she said.'
>>> print s
"Isn't," she said.
```

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.
```

Pythonic Styles

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

<table>
<tr><th>do not write ...</th><th>when you can write ...</th></tr>
<tr><td><pre>for key in d.keys():</pre></td><td><pre>for key in d:</pre></td></tr>
<tr><td><pre>if d.has_key(key):</pre></td><td><pre>if key in d:</pre></td></tr>
<tr><td><pre>i = 0
for x in a:
    ...
    i += 1</pre></td><td><pre>for i, x in enumerate(a):</pre></td></tr>
<tr><td><pre>a[0:len(a) - i]</pre></td><td><pre>a[:-i]</pre></td></tr>
<tr><td><pre>for line in \
    sys.stdin.readlines():</pre></td><td><pre>for line in sys.stdin:</pre></td></tr>
<tr><td><pre>for x in a:
    print x,
print</pre></td><td><pre>print " ".join(map(str, a))</pre></td></tr>
<tr><td><pre>s = ""
for i in range(lev):
    s += " "
print s</pre></td><td><pre>print " " * lev</pre></td></tr>
</table>

Tuples

immutable lists

Tuples and Equality

- caveat: singleton tuple
- `==`, `is`, `is not`

```
a += (1,2)   # new copy
a += [1,2]   # in-place
```

```
>>> (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
```

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
```

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]
```

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>)
```

Basic `import` and I/O

`import` and I/O

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

demo

```
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

demo

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

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

interactive

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

Functional Programming

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]
```

demo

Object-Oriented Programming

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
```

- “self” is like “this” pointer in C++/Java/C#/PHP
- constructor `__init__(self, ...)`
- every (new-style) class is a subclass of Object like Java
    - we will only use new-style classes in this course

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

Member variables

- each instance has its own hashmap for variables!
- you can add new fields on the fly (weird... but handy...)

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

    def __str__(self):
        return "(%s, %s)" % (self.x, self.y)
```

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

More efficient: __slots__

- like C++/Java: fixed list of member variables
- class-global hash: all instances of this class share this hash
  - can't add new variables to an instance on the fly

```
class Point(object):
    __slots__ = "x", "y"

    def __init__(self, x, y):
        self.x = x
        self.y = y

    def __str__(self):
        " like toString() in Java "
        return "(%s, %s)" % (self.x, self.y)

>>> p = Point(5, 6)
>>> p.z = 7
AttributeError!
```

Special function `__str__`

```
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 "(%s, %s)" % (self.x, self.y)
```

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

```
print p
=> str(p)
=> p.__str__()
=> Point.__str__(p)
```

Special functions: str vs repr

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

   def __str__(self):
      return "(%s, %s)" % (self.x, self.y)
```

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

Special functions: str vs repr

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

    def __str__(self):
        return "(%s, %s)" % (self.x, self.y)

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

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

```
>>> p
(3, 4)
>>> repr(p)
(3, 4)
```

Special functions: str vs repr

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

when __str__ is not defined, __repr__ is used
if __repr__ is not defined, Object.__repr__ is used

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

Special functions: cmp

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

    def __str__(self):
        return "(%s, %s)" % (self.x, self.y)
```

by default,
Python class object comparison
is by pointer! define __cmp__!

```
>>> p = Point(3,4)
>>> Point (3,4) == Point (3,4)
False
```

Special functions: cmp

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

    def __str__(self):
        return "(%s, %s)" % (self.x, self.y)

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

if __eq__ is not defined, __cmp__ is used;

if __cmp__ is not defined, Object.__cmp__ is used (by reference)

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

```
>>> cmp(Point(3,4), Point(4,3))
-1

=> Point(3,4).__cmp__(Point(4,3))
=> Point.__cmp__(Point(3,4), Point(4,3))

>>> Point (3,4) == Point (3,4)
True
```

unique signature for each method

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

    def __init__(self, x, y, z):
        self.x, self.y, self.z = x, y, z

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

- no polymorphic functions (earlier defs will be shadowed)
  - ==> only one constructor (and no destructor)
  - each function can have only one signature
    - because Python is dynamically typed

Inheritance

```
class Point (object):
    ...
    def __str__(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)
        return tmp if tmp != 0 else self.z - other.z
```

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

__slots__ in inheritance

- like C++/Java: fixed list of member variables
- class-global hash: can't add new field on the fly

```
class Point(object):
    __slots__ = "x", "y"

    def __init__(self, x, y):
        self.x, self.y = x, y

class Point3D(Point):
    __slots__ = "z"

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

>>> p = Point3D(5, 6, 7)
>>> p.z = 7
```

n-ary Trees

```
class Tree (object):
  __slots__ = "node", "children"
  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)
6

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

numpy

- numeric/scientific computations

```
>>> from numpy  import *
>>> a = arange(15).reshape(3, 5)
>>> a
array([[ 0,  1,  2,  3,  4],
       [ 5,  6,  7,  8,  9],
       [10, 11, 12, 13, 14]])
>>> a.shape
(3, 5)
>>> a.ndim
2
>>> a.dtype.name
'int32'
>>> a.itemsize
4
>>> a.size
15
>>> type(a)
numpy.ndarray
>>> b = array([6, 7, 8])
>>> b
array([6, 7, 8])
>>> type(b)
numpy.ndarray
```

```
>>> from numpy  import *
>>> a = array( [2,3,4] )
>>> a
array([2, 3, 4])
>>> a.dtype
dtype('int32')
>>> b = array([1.2, 3.5, 5.1])
>>> b.dtype
dtype('float64')
```

```
>>> b = array( [ (1.5,2,3),
(4,5,6) ] )
>>> b
array([[ 1.5,  2. ,  3. ],
       [ 4. ,  5. ,  6. ]])
```

```
>>> arange( 10, 30, 5 )
array([10, 15, 20, 25])
>>> arange( 0, 2, 0.3 )    # accepts floats
array([ 0. ,  0.3,  0.6,  0.9,
        1.2,  1.5,  1.8])
```

numpy array

```
>>> a = arange(6)                          # 1d array
>>> print a
[0 1 2 3 4 5]
>>>
>>> b = arange(12).reshape(4,3)            # 2d array
>>> print b
[[ 0  1  2]
 [ 3  4  5]
 [ 6  7  8]
 [ 9 10 11]]
>>>
>>> c = arange(24).reshape(2,3,4)          # 3d array
>>> print c
[[[ 0  1  2  3]
  [ 4  5  6  7]
  [ 8  9 10 11]]

 [[12 13 14 15]
  [16 17 18 19]
  [20 21 22 23]]]
```

```
>>> print arange(10000)
[   0    1    2 ..., 9997 9998 9999]
>>>
>>> print
arange(10000).reshape(100,100)
[[   0    1    2 ...,   97   98   99]
 [ 100  101  102 ...,  197  198  199]
 [ 200  201  202 ...,  297  298  299]
 ...,
 [9700 9701 9702 ..., 9797 9798 9799]
 [9800 9801 9802 ..., 9897 9898 9899]
 [9900 9901 9902 ..., 9997 9998 9999]]
```

array operations

```
>>> A = array( [[1,1],
...              [0,1]] )
>>> B = array( [[2,0],
...              [3,4]] )
>>> A*B                              # elementwise product
array([[2, 0],
       [0, 4]])
>>> C = dot(A,B)                     # matrix product
>>> C
array([[5, 4],
       [3, 4]])

>>> C.transpose()                 # transpose an array or a matrix
array([[5, 3],
       [4, 4]])

>>> C.T
array([[5, 3],
       [4, 4]])
```

array operations

```
>>> a = array( [20,30,40,50] )
>>> b = arange( 4 )
>>> b
array([0, 1, 2, 3])
>>> c = arange(0, 2, 0.5)   # arange supports float step size
>>> c
array([0, 0.5, 1, 1.5])
>>> c = a-b
>>> c
array([20, 29, 38, 47])
>>> b**2
array([0, 1, 4, 9])
>>> 10*sin(a)
array([ 9.12945251, -9.88031624,  7.4511316 , -2.62374854])
>>> a<35
array([True, True, False, False], dtype=bool)
```

in-place operations

```
>>> a = ones((2,3), dtype=int)
>>> b = random.random((2,3))
>>> a *= 3
>>> a
array([[3, 3, 3],
       [3, 3, 3]])
>>> b += a
>>> b
array([[ 3.69092703,  3.8324276 ,  3.0114541 ],
       [ 3.18679111,  3.3039349 ,  3.37600289]])
>>> a += b                                  # b is converted to integer type
>>> a
array([[6, 6, 6],
       [6, 6, 6]])
```

indexing and slicing

```
>>> a = arange(10)**3
>>> a
array([  0,   1,   8,  27,  64, 125, 216, 343, 512, 729])
>>> a[2]
8
>>> a[2:5]
array([ 8, 27, 64])
>>> a[:6:2] = -1000    # equivalent to a[0:6:2] = -1000;
>>> a
array([-1000,     1, -1000,    27, -1000,   125,   216,   343,   512,   729])
>>> a[ : :-1]                                 # reversed a
array([  729,   512,   343,   216,   125, -1000,    27, -1000,     1, -1000])
>>> for i in a:
...         print i**(1/3.),
...
nan 1.0 nan 3.0 nan 5.0 6.0 7.0 8.0 9.0
```

```
>>> a = array( [20,30,40,50] )
>>> a<35
array([True, True, False, False], dtype=bool)
>>> a[a<35] = 35               # indexing with boolean array
>>> a
array( [35,35,40,50] )
```

multidimensional indexing/slicing

```
>>> def f(x,y):
...         return 10*x+y
...
>>> b = fromfunction(f,(5,4),dtype=int)
>>> b
array([[ 0,  1,  2,  3],
       [10, 11, 12, 13],
       [20, 21, 22, 23],
       [30, 31, 32, 33],
       [40, 41, 42, 43]])
>>> b[2,3]
23
>>> b[0:5, 1]                       # each row in the second column of b
array([ 1, 11, 21, 31, 41])
>>> b[ : ,1]                        # equivalent to the previous example
array([ 1, 11, 21, 31, 41])
>>> b[1:3, : ]                      # each column in the second and third row of b
array([[10, 11, 12, 13],
       [20, 21, 22, 23]])
```