The Python Programming Language

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(Part I - Introducing Python)

Course Overview

- An overview of Python in two acts
  - Part I : Writing scripts and manipulating data
  - Part II : Getting organized (functions, modules, objects)
- It's not a comprehensive reference, but there will be a lot of examples and topics to give you a taste of what Python programming is all about

Prerequisites

- I'm going to assume that...
  - you have written programs
  - you know about basic data structures
  - you know what a function is
  - you know about basic system concepts (files, I/O, processes, threads, network, etc.)
- I do not assume that you know Python

My Background

- C/assembler programming
- Started using Python in 1996 as a control language for physics software running on supercomputers at Los Alamos.
- Author: "Python Essential Reference"
- Developer of several open-source packages
- Currently working on parsing/compiler writing tools for Python.

What is Python?

- An interpreted, dynamically typed programming language.
- In other words: A language that's similar to Perl, Ruby, Tcl, and other so-called "scripting languages."
- Created by Guido van Rossum around 1990.
- Named in honor of Monty Python

Why was Python Created?

"My original motivation for creating Python was the perceived need for a higher level language in the Amoeba [Operating Systems] project. I realized that the development of system administration utilities in C was taking too long. Moreover, doing these things in the Bourne shell wouldn't work for a variety of reasons. ... So, there was a need for a language that would bridge the gap between C and the shell."

- Guido van Rossum

Important Influences

- C (syntax, operators, etc.)
- ABC (syntax, core data types, simplicity)
- Unix ("Do one thing well")
- Shell programming (but not the syntax)
- Lisp, Haskell, and Smalltalk (later features)

Some Uses of Python

- Text processing/data processing
- Application scripting
- Systems administration/programming
- Internet programming
- Graphical user interfaces
- Testing
- Writing quick "throw-away" code

More than "Scripting"

- Although Python is often used for "scripting", it is a general purpose programming language
- Major applications are written in Python
- Large companies you have heard of are using hundreds of thousands of lines of Python.

Part 1

Getting Started

Where to get Python?

http://www.python.org

- Site for downloads, community links, etc.
- Current production version: Python-2.6.2
- Supported on virtually all platforms

Support Files

- Program files, examples, and datafiles for this tutorial are available here:

http://www.dabeaz.com/usenix2009/pythonprog/

- Please go there and follow along

Running Python (Unix)

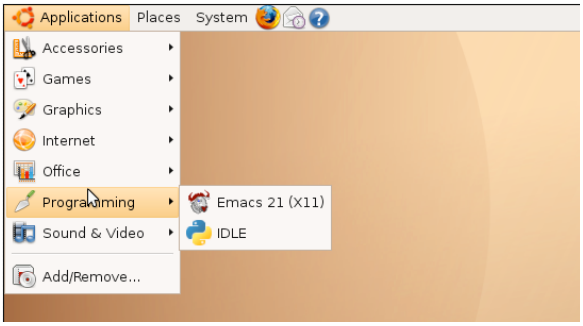
- From the shell

```
shell % python
Python 2.5.1 (r251:54869, Apr 18 2007, 22:08:04)
[GCC 4.0.1 (Apple Computer, Inc. build 5367)] on darwin
Type "help", "copyright", "credits" or "license"
>>>
```

- Integrated Development Environment (IDLE)

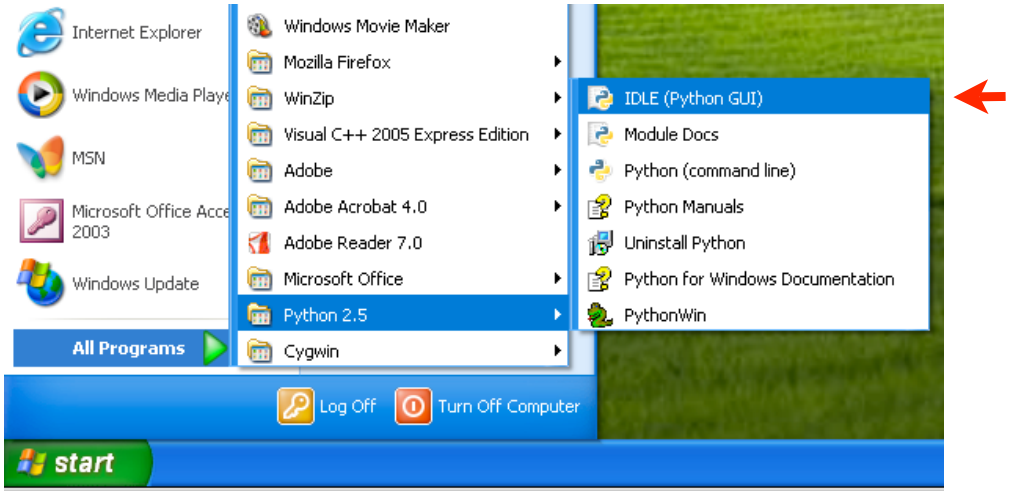
```
shell % idle
```

or



Running Python (win)

- Start Menu (IDLE or PythonWin)



Python Interpreter

- All programs execute in an interpreter
- If you give it a filename, it interprets the statements in that file in order
- Otherwise, you get an "interactive" mode where you can experiment
- There is no compilation

Interactive Mode

- Read-eval loop

```
>>> print "hello world"
hello world
>>> 37*42
1554
>>> for i in range(5):
...     print i
...
0
1
2
3
4
>>>
```

- Executes simple statements typed in directly
- This is one of the most useful features

Creating Programs

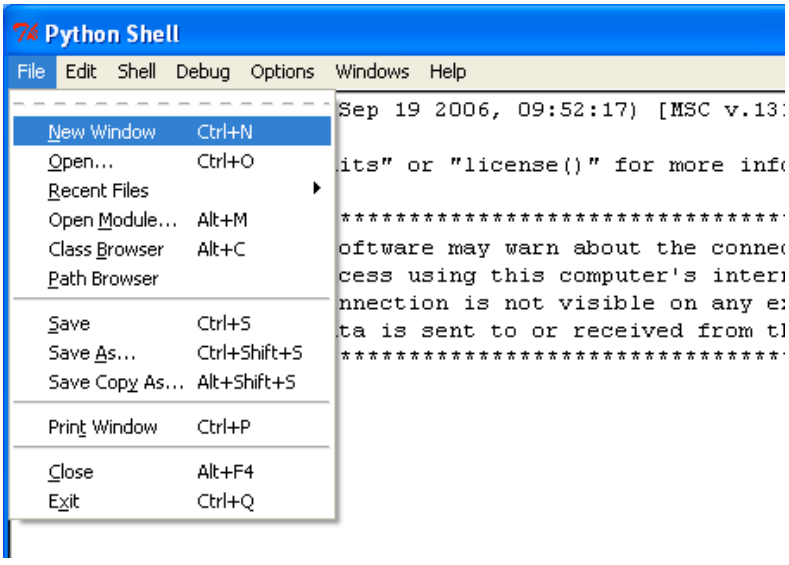
- Programs are put in .py files

```
# helloworld.py
print "hello world"
```

- Source files are simple text files
- Create with your favorite editor (e.g., emacs)
- Note: There may be special editing modes
- There are many IDEs (too many to list)

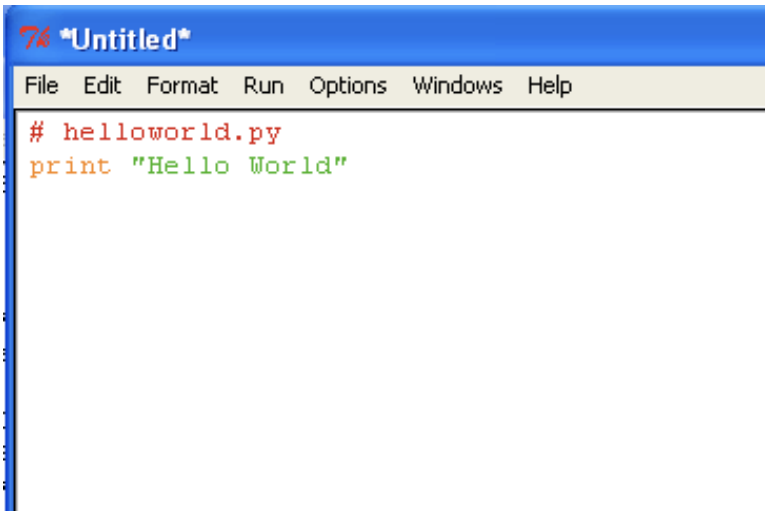
Creating Programs

- Creating a new program in IDLE



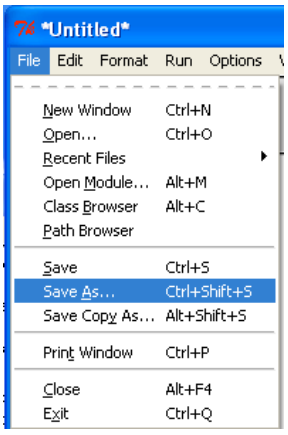
Creating Programs

- Editing a new program in IDLE



Creating Programs

- Saving a new Program in IDLE



Running Programs

- In production environments, Python may be run from command line or a script
- Command line (Unix)

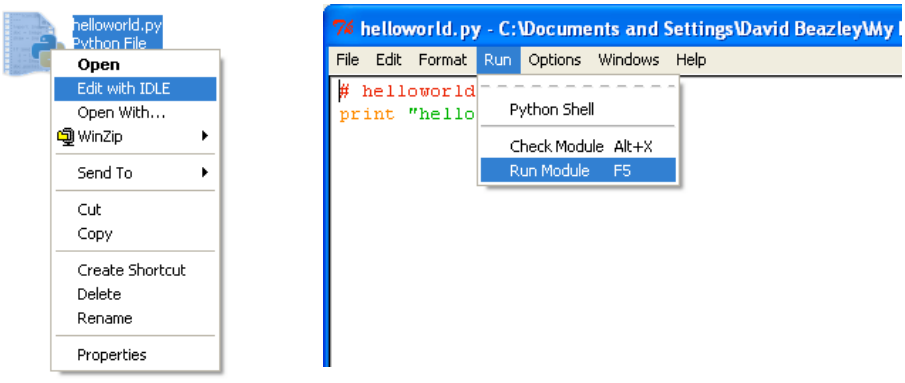
```
shell % python helloworld.py
hello world
shell %
```

- Command shell (Windows)

```
C:\Somewhere>c:\python26\python helloworld.py
hello world
C:\Somewhere>
```


Running Programs (IDLE)

- Select "Run Module" (F5)



- Will see output in IDLE shell window

Part 2

Python 101 - A First Program

A Sample Program

- Dave's Mortgage

  Dave has taken out a $500,000 mortgage from Guido's Mortgage, Stock, and Viagra trading corporation. He got an unbelievable rate of 4% and a monthly payment of only $499. However, Guido, being kind of soft-spoken, didn't tell Dave that after 2 years, the rate changes to 9% and the monthly payment becomes $3999.

- Question: How much does Dave pay and how many months does it take?

mortgage.py

```
# mortgage.py

principle  = 500000        # Initial principle
payment    = 499           # Monthly payment
rate       = 0.04          # The interest rate
total_paid = 0             # Total amount paid
months     = 0             # Number of months

while principle > 0:
      principle = principle*(1+rate/12) - payment
      total_paid += payment
      months     += 1
      if months == 24:
          rate    = 0.09
          payment = 3999

print "Total paid", total_paid
print "Months", months
```


Python 101: Statements

```
# mortgage.py

principle  = 500000
payment    = 499
rate       = 0.04
total_paid = 0
months     = 0             # Number of months

while principle > 0:
      principle = principle*(1+rate/12) - payment
      total_paid += payment
      months     += 1
      if months == 24:
          rate    = 0.09
          payment = 3999

print "Total paid", total_paid
print "Months", months
```

Each statement appears on its own line

No semicolons

Python 101: Comments

```
# mortgage.py

principle  = 500000
payment    = 499
rate       = 0.04
total_paid = 0
months     = 0

# Initial principle
# Monthly payment
# The interest rate
# Total amount paid
# Number of months

while principle > 0:
      principle = principle * (1+rate/12) - payment
      total_paid += payment
      months     += 1
      if months == 24:
          rate    = 0.09
          payment = 3999

print "Total paid", total_paid
print "Months", months
```

starts a comment which extends to the end of the line

Python 101: Variables

```
# mortgage.py

principle  = 500000
payment    = 499
rate       = 0.04
total_paid = 0
months     = 0

while principle > 0:
      principle = princ
      total_paid += pay
      months     += 1
      if months == 24:
          rate    = 0.0
          payment = 399

print "Total paid", tot
print "Months", months
```

Variables are declared by assigning a name to a value.

- Same name rules as C ([a-zA-Z_][a-zA-Z0-9_]*)
- You do not declare types like int, float, string, etc.
- Type depends on value

Python 101: Keywords

```
# mortgage.py

principle
payment
rate
total_paid
months

while principle > 0
      principle = p
      total_paid +=
      months     +=
      if months ==
          rate    =
          payment =

print "Total paid",
print "Months", mon
```

Python has a small set of keywords and statements

Keywords are C-like

and	**else**	import	raise
assert	except	in	**return**
break	exec	is	try
class	finally	lambda	**while**
continue	**for**	not	yield
def	from	or	
del	global	pass	
elif	**if**	print	

Python 101: Looping

while executes a loop as long as a condition is True

```
while expression:
    statements
    ...
```

```
principle
payment
erest rate
mount paid
of months
```

```
while principle > 0:
      principle = principle*(1+rate/12) - payment
      total_paid += payment
      months     += 1
      if months == 24:
          rate    = 0.09
          payment = 3999

print "T
print "M
```

loop body denoted by indentation

Python 101: Conditionals

if-elif-else checks a condition

```
if expression:
   statements
   ...
elif expression:
   statements
   ...
else:
   statements
   ...
```

```
                                  al principle
                                  nly payment
                                  nterest rate
                                  l amount paid
                                  er of months

                                  te/12) - payment
        months     += 1
        if months == 24:
            rate    = 0.09
            payment = 3999

print "Total
print "Months
```

body of conditional denoted by indentation

Python 101: Indentation

```
# mortgage.py

principle  = 500000        # Initial principle
payment    = 499
rate       = 0.04
total_paid = 0
months     = 0

while principle > 0:
      principle = principle*(1+rate/12) - payment
      total_paid += payment
      months     += 1
      if months == 24:
          rate    = 0.09
          payment = 3999

print "Total paid", total_paid
print "Months", months
```

: indicates that an indented block will follow

Python 101: Indentation

```
# mortgage.py

principle  = 500000        # Initial principle
payment    = 499           # Monthly payment
rate       = 0.04          # The interest rate
total_paid = 0             # Total amount paid
months     = 0             # Number of months

while principle > 0:
      principle = principle*(1+rate/12) - payment
      total_paid += payment
      months     += 1
      if months == 24:
          rate    = 0.09
          payment = 3999
```

Python only cares about consistent indentation in the same block

Python 101: Primitive Types

```
# mortgage.py

principle  = 500000
payment    = 499
rate       = 0.04
total_paid = 0
months     = 0

while principle > 0:
      principle = principle*(1+rate/12) - payment
      total_paid += payment
      months     += 1
      if months == 24:
          rate    = 0.09
          payment = 3999

print "Total paid", total_paid
print "Months", months
```

Numbers:
- Integer
- Floating point

Strings

Python 101: Expressions

```
# mortgage.py
```

Python uses conventional syntax for operators and expressions

```
ial principle
hly payment
interest rate
l amount paid
er of months

while principle > 0:
      principle = principle*(1+rate/12) - payment
      total_paid += payment
      months     += 1
      if months == 24:
          rate    = 0.09
          payment = 3999

print "Total paid", total_p
print "Months", months
```

Basic Operators

```
+ - * / // % ** << >> | & ^
< > <= >= == != and or not
```


More on Relations

- Boolean expressions: and, or, not

```
if b >= a and b <= c:
    print "b is between a and c"

if not (b < a or b > c):
    print "b is still between a and c"
```

- Don't use &&, ||, and ! as in C

```
&&  ⟶  and
||  ⟶  or
!   ⟶  not
```

- Relations do not require surrounding ( )

Python 101: Output

```
# mortgage.py

principle  = 500000        # Initial principle
payment    = 499           # Monthly payment
rate       = 0.04          # The interest rate
total_paid = 0             # Total amount paid
months     = 0             # Number of months
```

print writes to standard output
- Items are separated by spaces
- Includes a terminating newline
- Works with any Python object

```
print "Total paid", total_paid
print "Months", months
```


Running the Program

- Command line

```
shell % python mortgage.py
Total paid 2623323
Months 677
shell %
```

- Keeping the interpreter alive (-i option or IDLE)

```
shell % python -i mortgage.py
Total paid 2623323
Months 677
>>> months/12
56
>>>
```

- In this latter mode, you can inspect variables and continue to type statements.

Interlude

- If you know another language, you already know a lot of Python
- Python uses standard conventions for statement names, variable names, numbers, strings, operators, etc.
- There is a standard set of primitive types such as integers, floats, and strings that look the same as in other languages.
- Indentation is most obvious "new" feature

Getting Help

- Online help is often available
- help() command (interactive mode)

```
IDLE 1.2
>>> help("range")
Help on built-in function range in module __builtin__:

range(...)
    range([start,] stop[, step]) -> list of integers

    Return a list containing an arithmetic progression of integers.
    range(i, j) returns [i, i+1, i+2, ..., j-1]; start (!) defaults to 0.
    When step is given, it specifies the increment (or decrement).
    For example, range(4) returns [0, 1, 2, 3].  The end point is omitted!
    These are exactly the valid indices for a list of 4 elements.

>>>
```

- Documentation at http://www.python.org

dir() function

- dir() returns list of symbols

```
>>> import sys
>>> dir(sys)
['__displayhook__', '__doc__', '__excepthook__',
'__name__', '__stderr__', '__stdin__', '__stdout__',
'_current_frames', '_getframe', 'api_version', 'argv',
'builtin_module_names', 'byteorder', 'call_tracing',
'callstats', 'copyright', 'displayhook', 'exc_clear',
'exc_info', 'exc_type', 'excepthook', 'exec_prefix',
'executable', 'exit', 'getcheckinterval',
 ...
'version_info', 'warnoptions']
```

- Useful for exploring, inspecting objects, etc.

Part 3

Basic Datatypes and File I/O

More on Numbers

- Numeric Datatypes

```
a = True          # A boolean (True or False)
b = 42            # An integer (32-bit signed)
c = 81237742123L  # A long integer (arbitrary precision)
d = 3.14159       # Floating point (double precision)
```

- Integer operations that overflow become longs

```
>>> 3 ** 73
675851986348175232355204436243179 23L
>>> a = 72883988882883812
>>> a
72883988882883812L
>>>
```

- Integer division truncates (for now)

```
>>> 5/4
1
>>>
```


More on Strings

- String literals use several quoting styles

```
a = "Yeah but no but yeah but..."

b = 'computer says no'

c = '''
Look into my eyes, look into my eyes,
the eyes, the eyes, the eyes,
not around the eyes,
don't look around the eyes,
look into my eyes, you're under.
'''
```

- Standard escape sequences work (e.g., '\n')
- Triple quotes capture all literal text enclosed

Basic String Manipulation

- Length of a string

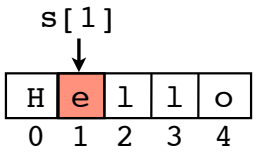
```
n = len(s)        # Number of characters in s
```

- String concatenation

```
s = "Hello"
t = "World"
a = s + t         # a = "HelloWorld"
```

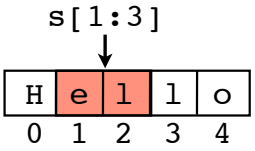
- Strings as arrays : s[*n*]

```
s = "Hello"
s[1]  ⟶ 'e'
s[-1] ⟶ 'o'
```



- Slices : s[*start:end*]

```
s[1:3] ⟶ "el"
s[:4]  ⟶ "Hell"
s[-4:] ⟶ "ello"
```



Type Conversion

- Converting between data types

```
a = int(x)        # Convert x to an integer
b = long(x)       # Convert x to a long
c = float(x)      # Convert x to a float
d = str(x)        # Convert x to a string
```

- Examples:

```
>>> int(3.14)
3
>>> str(3.14)
'3.14'
>>> int("0xff")
255
>>>
```

Programming Problem

- Dave's stock scheme

  After watching 87 straight hours of "Guido's Insane Money" on his Tivo, Dave hatched a get rich scheme and purchased a bunch of stocks.

  He can no longer remember the evil scheme, but he still has the list of stocks in a file "portfolio.dat".

- Write a program that reads this file, prints a report, and computes how much Dave spent during his late night stock "binge."

The Input File

- Input file: portfolio.dat

```
IBM      50      91.10
MSFT    200      51.23
GOOG    100     490.10
AAPL     50     118.22
YHOO     75      28.34
SCOX    500       2.14
RHT      60      23.45
```

- The data: Name, Shares, Price per Share

portfolio.py

```
# portfolio.py

total = 0.0
f     = open("portfolio.dat","r")

for line in f:
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float(fields[2])
    total += shares*price
    print  "%-10s %8d %10.2f" % (name,shares,price)

f.close()
print "Total", total
```


Python File I/O

```
# portfolio.py

total = 0.0
f     = open("portfolio.dat","r")

for line in
    fields =
    name   =
    shares =
    price  =
    total +=
    print  "

f.close()
print "Total", total
```

```
"r"  - Read
"w"  - Write
"a"  - Append
```

Files are modeled after C stdio.

- f = open() - opens a file
- f.close() - closes the file

Data is just a sequence of bytes

Reading from a File

```
# portfolio.py

total = 0.0
f     = open("p

for line in f:
    fields = line.split()
    name   = fields[0]
    shares = in
    price  = fl
    total += sh
    print  "%-1

f.close()
print "Total",
```

Loops over all lines in the file.
Each line is returned as a string.

Alternative reading methods:

- f.read([nbytes])
- f.readline()
- f.readlines()

String Processing

```
# portfolio.

total = 0.0
f     = open

for line in f:
    fields = line.split()
    name   = fields[0]
    shares = int(
    price  = floa
    total += shar
    print  "%-10s

f.close()
print "Total", to
```

Strings have various "methods."
split() splits a string into a list of strings

```
line = 'IBM      50      91.10\n'

          fields = line.split()

fields = ['IBM', '50', '91.10']
```

Lists

```
# portfolio.py

total = 0.0
f     = open("por

for line in f:
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float(fields[2])
    total += shares*price
    print  "%-10s %8d

f.close()
print "Total", total
```

A 'list' is an ordered sequence of objects. It's like an array.

```
fields = ['IBM', '50', '91.10']
```


Types and Operators

```
# portfolio.py

total = 0.0
f     = open("portfo

for line in f:
    fields = line.sp
    name   = fields[
    shares = int(fields[1])
    price  = float(fields[2])
    total += shares*price
    print  "%-10s %8d %10.2f" % (name,shares,price)

f.close()
print "Total",
```

To work with data, it must be converted to an appropriate type (e.g., number, string, etc.)

Operators only work if objects have "compatible" types

String Formatting

```
# portfolio.py

total = 0.0
f     = ope

for line i
    fields
    name
    shares = int(fields[1])
    price  = float(fields[2])
    total += shares*price
    print  "%-10s %8d %10.2f" % (name,shares,price)

f.close()
print "Total
```

% operator when applied to a string, formats it. Similar to the C printf() function.

format string

values

Sample Output

```
shell % python portfolio.py
IBM             50      91.10
MSFT           200      51.23
GOOG           100     490.10
AAPL            50     118.22
YHOO            75      28.34
SCOX           500       2.14
RHT             60      23.45
Total 74324.5
shell %
```

More on Files

- Opening a file

```
f = open("filename","r")     # Reading
g = open("filename","w")     # Writing
h = open("filename","a")     # Appending
```

- Reading

```
f.read([nbytes])        # Read bytes
f.readline()            # Read a line
f.readlines()           # Read all lines into a list
```

- Writing

```
g.write("Hello World\n")   # Write text
print >>g, "Hello World"   # print redirection
```

- Closing

```
f.close()
```


More String Methods

```
s.endswith(suffix)   # Check if string ends with suffix
s.find(t)            # First occurrence of t in s
s.index(t)           # First occurrence of t in s
s.isalpha()          # Check if characters are alphabetic
s.isdigit()          # Check if characters are numeric
s.islower()          # Check if characters are lower-case
s.isupper()          # Check if characters are upper-case
s.join(slist)        # Joins lists using s as delimeter
s.lower()            # Convert to lower case
s.replace(old,new)   # Replace text
s.rfind(t)           # Search for t from end of string
s.rindex(t)          # Search for t from end of string
s.split([delim])     # Split string into list of substrings
s.startswith(prefix) # Check if string starts with prefix
s.strip()            # Strip leading/trailing space
s.upper()            # Convert to upper case
```

More on Operators

- Python has a standard set of operators
- Have different behavior depending on the types of operands.

```
>>> 3 + 4                  # Integer addition
7
>>> '3' + '4'              # String concatenation
'34'
>>>
```

- This is why you must be careful to convert values to an appropriate type.
- One difference between Python and text processing tools (e.g., awk, perl, etc.).

Part 4

List Processing

More on Lists

- A indexed sequence of arbitrary objects

```
fields = ['IBM','50','91.10']
```

- Can contain mixed types

```
fields = ['IBM',50, 91.10]
```

- Can contain other lists:

```
portfolio = [ ['IBM',50,91.10],
              ['MSFT',200,51.23],
              ['GOOG',100,490.10] ]
```


List Manipulation

- Accessing/changing items : s[*n*], s[*n*] = *val*

```
fields = [ 'IBM', 50, 91.10 ]

name  = fields[0]        # name = 'IBM'
price = fields[2]        # price = 91.10
fields[1] = 75           # fields = ['IBM',75,91.10]
```

- Slicing : s[*start*:*end*], s[*start*:*end*] = t

```
vals = [0, 1, 2, 3, 4, 5, 6]
vals[0:4] ------------> [0, 1, 2, 3]
vals[-2:] ------------> [5, 6]
vals[:2]  ------------> [0, 1]

vals[2:4] = ['a','b','c']
# vals = [0, 1, 'a', 'b', 'c', 4, 5, 6 ]
```

List Manipulation

- Length : len(s)

```
fields = [ 'IBM', 50, 91.10 ]
len(fields) ⟶  3
```

- Appending/inserting

```
fields.append('11/16/2007')
fields.insert(0,'Dave')

# fields = ['Dave', 'IBM', 50, 91.10, '11/16/2007']
```

- Deleting an item

```
del fields[0]  # fields = ['IBM',50,91.10,'11/16/2007']
```


Some List Methods

```
s.append(x)          # Append x to end of s
s.extend(t)          # Add items in t to end of s
s.count(x)           # Count occurences of x in s
s.index(x)           # Return index of x in s
s.insert(i,x)        # Insert x at index i
s.pop([i])           # Return element i and remove it
s.remove(x)          # Remove first occurence of x
s.reverse()          # Reverses items in list
s.sort()             # Sort items in s in-place
```

Programming Problem

- Dave's stock portfolio

  Dave still can't remember his evil "get rich quick" scheme, but if it involves a Python program, it will almost certainly involve some data structures.

- Write a program that reads the stocks in 'portfolio.dat' into memory. Alphabetize the stocks and print a report. Calculate the initial value of the portfolio.

The Previous Program

```
# portfolio.py

total = 0.0
f     = open("portfolio.dat","r")

for line in f:
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float(fields[2])
    total += shares*price
    print  "%-10s %8d %10.2f" % (name,shares,price)

f.close()
print "Total", total
```

Simplifying the I/O

```
# portfolio.py

total = 0.0

for line in open("portfolio.dat"):
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float(fields[2])
    total += shares*price
    print  "%-10s %8d %10.2f" % (name,shares,price)

print "Total", total
```

Opens a file, iterates over all lines, and closes at EOF.

Building a Data Structure

```
# portfolio.py

stocks = []

for line in open("portfolio.dat"):
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float(fields[2])
    holding= (name,shares,price)
    stocks.append(holding)

# print "Total", total
```

A list of "stocks"

Create a stock record and append to the stock list

Tuples - Compound Data

```
# portfolio.py

stocks = []

for line in ope
    fields = li
    name   = fi
    shares = int(fields[1])
    price  = float(fields[2])
    holding= (name,shares,price)
    stocks.append(holding)

# print "Total", total
```

A tuple is the most primitive compound data type (a sequence of objects grouped together)

How to write a tuple:

```
t = (x,y,z)
t = x,y,z   # ()'s are optional
t = ()      # An empty tuple
t = (x,)    # A 1-item tuple
```


A List of Tuples

```
# portfolio.py

stocks = []

for line in open("p
    fields = line.s
    name   = fields
    shares = int(fi
    price  = float(
    holding= (name,
    stocks.append(h

# print "Total", to
```

```
stocks = [
    ('IBM', 50, 91.10),
    ('MSFT', 200, 51.23),
    ('GOOG', 100, 490.10),
    ('AAPL', 50, 118.22),
    ('SCOX', 500, 2.14),
    ('RHT', 60, 23.45)
]
```

This works like a 2D array

```
stocks[2] ⟶ ('GOOG',100,490.10)
stocks[2][1] ⟶ 100
```

Sorting a List

```
# portfolio.py

stocks = []

for line in open("portfolio.dat"):
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float
    holding= (name
    stocks.append(

stocks.sort()

# print "Total", t
```

.sort() sorts a list "in-place"

Note: Tuples are compared element-by-element

```
('GOOG',100,490.10)
...
('AAPL',50,118.22)
```


Looping over Sequences

```
# portfolio.py

stocks = []

for line in open("portfolio.dat"):
    fields = line.split()
    name   = fields[0]
    shares = int(fields[
    price  = float(field
    holding= (name,share
    stocks.append(holdin

stocks.sort()
for s in stocks:
    print "%-10s %8d %10.2f" % s

# print "Total", total
```

for statement iterates over any object that looks like a sequence (list, tuple, file, etc.)

Formatted I/O (again)

```
# portfolio.py

stocks = []

for line in open("portfolio.dat"):
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float(fields[2])
    holding= (name,shares,p
    stocks.append(holding)

stocks.sort()
for s in stocks:
    print "%-10s %8d %10.2f" % s

# pri
```

On each iteration, s is a tuple (name,shares,price)

```
s = ('IBM',50,91.10)
```


Calculating a Total

```
# portfolio.py

stocks = []

for line in open("portfolio.dat"):
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float(fields[2])
    holding= (nam
    stocks.append

stocks.sort()
for s in stocks:
    print "%-10s

total = sum([s[1]*s[2] for s in stocks])
print "Total", total
```

Calculate the total value of the portfolio by summing shares*price across all of the stocks

Sequence Reductions

```
# portfolio.py

stocks = []

for line in open("portfolio.dat"):
    fields = line.split()
    name
    shares
    price
    holding
    stocks.

stocks.sort
for s in st
    print "%-10s %8d %10.2f" % s

total = sum([s[1]*s[2] for s in stocks])
print "Total", total
```

Useful functions for reducing data:

sum(s) - Sums items in a sequence
min(s) - Min value in a sequence
max(s) - Max value in a sequence

List Creation

```
stocks = [                      [s[1]*s[2] for s in stocks] = [
   ('IBM',50,91.10),                      50*91.10,
   ('MSFT',200,51.23),                    200*51.23,
   ('GOOG',100,490.10),    ------------>  100*490.10,
   ('AAPL',50,118.22),                    50*118.22,
   ('SCOX',500,2.14),                     500*2.14,
   ('RHT',60,23.45)                       60*23.45
]                                       ]
```

```
    stocks.append(holding)

stocks.sort()
for s in stocks:
    print "%-10s %
```

This operation creates a new list.
(known as a "list comprehension")

```
total = sum([s[1]*s[2] for s in stocks])
print "Total", total
```

Finished Solution

```
# portfolio.py

stocks = []

for line in open("portfolio.dat"):
    fields = line.split()
    name   = fields[0]
    shares = int(fields[1])
    price  = float(fields[2])
    holding= (name,shares,price)
    stocks.append(holding)

stocks.sort()
for s in stocks:
    print "%-10s %8d %10.2f" % s

total = sum([s[1]*s[2] for s in stocks])
print "Total", total
```


Sample Output

```
shell % python portfolio.py
AAPL            50     118.22
GOOG           100     490.10
IBM             50      91.10
MSFT           200      51.23
RHT             60      23.45
SCOX           500       2.14
Total 72199.0
shell %
```

Interlude: List Processing

- Python is very adept at processing lists
- Any object can be placed in a list
- List comprehensions process list data

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

- This is shorthand for this code:

```
a = []
for i in x:
    a.append(2*i)
```


Interlude: List Filtering

- List comprehensions with a condition

```
>>> x = [1, 2, -3, 4, -5]
>>> a = [2*i for i in x if i > 0]
>>> a
[2, 4, 8]
>>>
```

- This is shorthand for this code:

```
a = []
for i in x:
    if i > 0:
        a.append(2*i)
```

Interlude: List Comp.

- General form of list comprehensions

```
a = [expression for i in s if condition ]
```

- Which is shorthand for this:

```
a = []
for i in s:
    if condition:
        a.append(expression)
```


Historical Digression

- List comprehensions come from Haskell

```
a = [x*x for x in s if x > 0]     # Python

a = [x*x | x <- s, x > 0]         # Haskell
```

- And this is motivated by sets (from math)

$$a = \{ x^2 \mid x \in s, \; x > 0 \}$$

- But most Python programmers would probably just view this as a "cool shortcut"

Big Idea: Being Declarative

- List comprehensions encourage a more "declarative" style of programming when processing sequences of data.
- Data can be manipulated by simply "declaring" a series of statements that perform various operations on it.

A Declarative Example

```
# portfolio.py

lines  = open("portfolio.dat")
fields = [line.split() for line in lines]
stocks = [(f[0],int(f[1]),float(f[2])) for f in fields]

stocks.sort()
for s in stocks:
    print "%-10s %8d %10.2f" % s

total = sum([s[1]*s[2] for s in stocks])
print "Total", total
```

Files as a Sequence

```
# portfolio.py

lines  = open("portfolio.dat")
fields = [line.split() for line in lines]
stocks = [(f[0],int(f[1]),float(f[2])) for f in fields]

stocks.sort()
for s in stocks:
    print "%-10s
total = sum([s[1]
print "Total", to
```

files are sequences of lines

```
'IBM     50     91.1\n'
'MSFT   200     51.23\n'
...
```


A List of Fields

```
# portfolio.py

lines  = open("portfolio.dat")
fields = [line.split() for line in lines]
stocks = [(f[0],int(f[1]),float(f[2])) for f in fields]
```

This statement creates a list of string fields

```
'IBM     50     91.10\n'        [['IBM','50',91.10'],
'MSFT   200     51.23\n'  ---->  ['MSFT','200','51.23'],
...                               ...
                                 ]
```

A List of Tuples

```
# portfolio.py

lines  = open("portfolio.dat")
fields = [line.split() for line in lines]
stocks = [(f[0],int(f[1]),float(f[2])) for f in fields]

stocks.sort()
```

This creates a list of tuples with fields converted to numeric values

```
[['IBM','50',91.10'],          [('IBM',50,91.10),
 ['MSFT','200','51.23'],  ->    ('MSFT',200,51.23),
 ...                            ...
]                              ]
```


Programming Problem

- "Show me the money!"

  Dave wants to know if he can quit his day job and join a band. The file 'prices.dat' has a list of stock names and current share prices. Use it to find out.

- Write a program that reads Dave's portfolio, a file of current stock prices, and computes the gain/loss of his portfolio.
- (Oh yeah, and be "declarative")

Input Files

- portfolio.dat

```
IBM      50     91.10
MSFT    200     51.23
GOOG    100    490.10
AAPL     50    118.22
YHOO     75     28.34
SCOX    500      2.14
RHT      60     23.45
```

- prices.dat

```
IBM,117.88
MSFT,28.48
GE,38.75
CAT,75.54
GOOG,527.80
AA,36.48
SCOX,0.63
RHT,19.56
AAPL,136.76
YHOO,24.10
```


Reading Data

```
# portvalue.py

# Read the stocks in Dave's portfolio
lines  = open("portfolio.dat")
fields = [line.split() for line in lines]
stocks = [(f[0],int(f[1]),float(f[2])) for f in fields]

# Read the current stock prices
lines  = open("prices.dat")
fields = [line.split(',') for line in lines]
prices = [(f[0],float(f[1])) for f in fields]
```

- This is using the same trick we just saw in the last section

Data Structures

```
# portvalue.py

# Read the stocks in Dave's portfolio
lines  = open("portfolio.dat")
fields = [line.split() for line in lines]
stocks = [(f[0],int(f[1]),float(f[2])) for f in fields]

# Read the current stock prices
lines  = open("prices.dat")
fields = [line.split(',') for line in lines]
prices = [(f[0],float(f[1])) for f in fields]
```

```
stocks = [                    prices = [
  ('IBM',50,91.10),             ('IBM',117.88),
  ('MSFT',200,51.23),           ('MSFT',28.48),
  ...                           ('GE',38.75),
 ]                              ...
                               ]
```


Some Calculations

```
# portvalue.py

# Read the stocks in Dave's portfolio
lines  = open("portfolio.dat")
fields = [line.split() for line in lines]
stocks = [(f[0],int(f[1]),float(f[2])) for f in fields]

# Read the current stock prices
lines  = open("prices.dat")
fields = [line.split(',') for line in lines]
prices = [(f[0],float(f[1])) for f in fields]

initial_value = sum([s[1]*s[2] for s in stocks])
current_value = sum([s[1]*p[1] for s in stocks
                                for p in prices
                                    if s[0] == p[0]])

print "Gain", current_value - initial_value
```

Some Calculations

```
# portvalue.py

# Read the stocks in Dave's portfolio

stocks = [                      prices = [
 ('IBM',50,91.10),               ('IBM',117.88),
 ('MSFT',200,51.23),             ('MSFT',28.48),
 ...                             ('GE',38.75),
]                                ...
                                ]

initial_value = sum([s[1]*s[2] for s in stocks])
current_value = sum([s[1]*p[1] for s in stocks
                                   for p in prices
                                       if s[0] == p[0]])

print "Gain", current_value - initial_value
```


Some Calculations

```
# portvalue.py

# Read the stocks in Dave's portfolio

stocks = [                      prices = [
 ('IBM',50,91.10),               ('IBM',117.88),
 ('MSFT',200,51.23),             ('MSFT',28.48),
 ...                             ('GE',38.75),
]                                ...
                                ]

initial_value = sum([s[1]*s[2] for s in stocks])
current_value = sum([s[1]*p[1] for s in stocks
                                   for p in prices
                                       if s[0] == p[0]])

print "Gain", current_value - initial_value
```

Some Calculations

```
# portvalue.py

# Read the stocks in Dave's portfolio

stocks = [                      prices = [
 ('IBM',50,91.10),               ('IBM',117.88),
 ('MSFT',200,51.23),             ('MSFT',28.48),
 ...                             ('GE',38.75),
]                                ...
                                ]

initial_value = sum([s[1]*s[2] for s in stocks])
current_value = sum([s[1]*p[1] for s in stocks
                                   for p in prices
                                       if s[0] == p[0]])

print "Gain", current_value - initial_value
```


Some Calculations

```
# portvalue.py

# Read the stocks in Dave's portfolio

stocks = [                      prices = [
 ('IBM',50,91.10),               ('IBM',117.88),
 ('MSFT',200,51.23),             ('MSFT',28.48),
 ...                             ('GE',38.75),
]                                ...
                                ]

initial_value = sum([s[1]*s[2] for s in stocks])
current_value = sum([s[1]*p[1] for s in stocks
                                   for p in prices
                                       if s[0] == p[0]])

print "Gain", current_value - initial_value
```

Joining two lists on a common field

Commentary

- The similarity between list comprehensions and database queries in SQL is striking
- Both are operating on sequences of data (items in a list, rows in a database table).
- If you are familiar with databases, list processing operations in Python are somewhat similar.

Part 5

Python Dictionaries

Segue: Unordered Data

- All examples have used "ordered" data
  - Sequence of lines in a file
  - Sequence of fields in a line
  - Sequence of stocks in a portfolio
- What about unordered data?

Dictionaries

- A hash table or associative array
- Example: A table of stock prices

```
prices = {
   'IBM'  : 117.88,
   'MSFT' : 28.48,
   'GE'   : 38.75,
   'CAT'  : 75.54,
   'GOOG' : 527.80
}
```

- Allows random access using key names

```
>>> prices['GE']              # Lookup
38.75
>>> prices['GOOG'] = 528.50   # Assignment
>>>
```

Dictionaries

- Dictionaries are useful for data structures
- Named fields

```
stock = {
   'name'   : 'GOOG',
   'shares' : 100,
   'price'  : 490.10
}
```

- Example use

```
>>> cost = stock['shares']*stock['price']
>>> cost
49010.0
>>>
```


Programming Problem

- "Show me the money!" - Part Deux

  Dave wants to know if he can quit his day job and join a band. The file 'prices.dat' has a list of stock names and current share prices. Use it to find out.

- Write a program that reads Dave's portfolio, the file of current stock prices, and computes the gain/loss of his portfolio.
- Use dictionaries

Solution : Part I

- Creating a list of stocks in the portfolio

```
# portvalue2.py
# Compute the value of Dave's portfolio

stocks = []
for line in open("portfolio.dat"):
    fields = line.split()
    record = {
        'name'   : fields[0],
        'shares' : int(fields[1]),
        'price'  : float(fields[2])
    }
    stocks.append(record)
```


Dictionary Data Structures

```
# portvalue2.py
# Compute the value of Dave's portfolio

stocks = []
for line in open("portfolio.dat"):
    fields = line.split()
    record = {
        'name'   : fields[0],
        'shares' : int(fields[1]),
        'price'  : float(fields[2])
    }
    stocks.append(record)
```

Each stock is a dict

```
record = {
  'name'   : 'IBM',
  'shares' : 50
  'price'  : 91.10
}
```

Lists of Dictionaries

- A list of objects with "named fields."

```
# portvalue2.py
# Compute the value of Dave's

stocks = []
for line in open("portfolio.da
    fields = line.split()
    record = {
        'name'   : fields[0],
        'shares' : int(fields[
        'price'  : float(field
    }
    stocks.append(record)
```

```
stocks = [
   {'name'   :'IBM',
    'shares' : 50,
    'price'  : 91.10 },
   {'name'   :'MSFT',
    'shares' : 200,
    'price'  : 51.23 },
   ...
]
```

Example:

```
stocks[1] → {'name'   : 'MSFT',
             'shares' : 200,
             'price'  : 51.23}

stocks[1]['shares'] → 200
```


Solution : Part 2

- Creating a dictionary of current prices

```
prices = {}
for line in open("prices.dat"):
    fields = line.split(',')
    prices[fields[0]] = float(fields[1])
```

- Example:

```
prices   {
   'GE'   : 38.75,
   'AA'   : 36.48,
   'IBM'  : 117.88,
   'AAPL' : 136.76,
   ...
}
```

Solution : Part 3

- Calculating portfolio value and gain

```
initial = sum([s['shares']*s['price']
               for s in stocks])

current = sum([s['shares']*prices[s['name']]
                  for s in stocks])

print "Current value", current
print "Gain", current - initial
```

- You will note that using dictionaries tends to lead to more readable code (the key names are more descriptive than numeric indices)

Solution : Part 3

- Calculating portfolio value and gain

```
initial = sum([s['shares']*s['price']
               for s in stocks])

current = sum([s['shares']*prices[s['name']]
                  for s in stocks])

print "Current value", current
print "Gain", current - initial
```

Fast price lookup

```
s = {
  'name'   : 'IBM',
  'shares' : 50
  'price'  : 91.10
}
```

```
prices   {
   'GE'   : 38.75,
   'AA'   : 36.48,
   'IBM'  : 117.88,
   'AAPL' : 136.76,
   ...
}
```

More on Dictionaries

- Getting an item

```
x = prices['IBM']
y = prices.get('IBM',0.0)  # w/default if not found
```

- Adding or modifying an item

```
prices['AAPL'] = 145.14
```

- Deleting an item

```
del prices['SCOX']
```

- Membership test (in operator)

```
if 'GOOG' in prices:
    x = prices['GOOG']
```


More on Dictionaries

- Number of items in a dictionary

```
n = len(prices)
```

- Getting a list of all keys (unordered)

```
names = list(prices)
names = prices.keys()
```

- Getting a list of all values (unordered)

```
prices = prices.values()
```

- Getting a list of (key,value) tuples

```
data = prices.items()
```

The Story So Far

- Primitive data types: Integers, Floats, Strings
- Compound data: Tuples
- Sequence data: Lists
- Unordered data: Dictionaries

The Story So Far

- Powerful support for iteration
- Useful data processing primitives (list comprehensions, generator expressions)
- Bottom line:

  Significant tasks can be accomplished doing nothing more than manipulating simple Python objects (lists, tuples, dicts)

Part 6

Some Subtle Details

Object Mutability

- Python datatypes fall into two categories
  - Immutable (can't be changed)
  - Mutable (can be changed)
- Mutable: Lists, Dictionaries
- Immutable: Numbers, strings, tuples
- All of this ties into memory management (which is why we would care about such a seemingly low-level implementation detail)

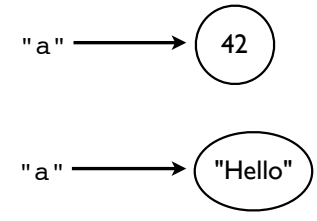
Variable Assignment

- Variables in Python are names for values
- A variable name does not represent a fixed memory location into which values are stored (like C, C++, Fortran, etc.)
- Assignment is just a naming operation

Variables and Values

- At any time, a variable can be redefined to refer to a new value

```
a = 42
...
a = "Hello"
```



- Variables are not restricted to one data type
- Assignment doesn't overwrite the previous value (e.g., copy over it in memory)
- It just makes the name point elsewhere

Names, Values, Types

- Names do not have a "type"--it's just a name
- However, values do have an underlying type

```
>>> a = 42
>>> b = "Hello World"
>>> type(a)
<type 'int'>
>>> type(b)
<type 'str'>
```

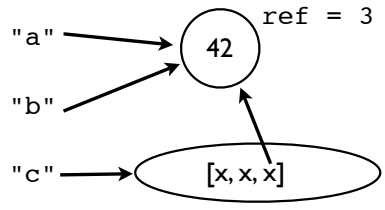
- type() function will tell you what it is
- The type name is usually a function that creates or converts a value to that type

```
>>> str(42)
'42'
```


Reference Counting

- Variable assignment never copies anything!
- Instead, it just updates a reference count

```
a = 42
b = a
c = [1,2]
c.append(b)
```



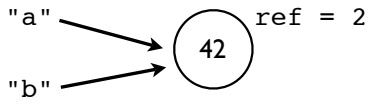
- So, different variables might be referring to the same object (check with the is operator)

```
>>> a is b
True
>>> a is c[2]
True
```

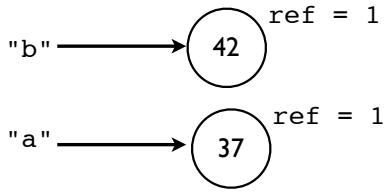
Reference Counting

- Reassignment never overwrites memory, so you normally don't notice any of this sharing

```
a = 42
b = a
```




```
a = 37
```

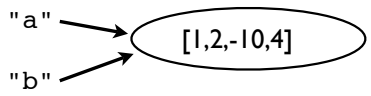


- When you reassign a variable, the name is just made to point to the new value.

The Hidden Danger

- "Copying" mutable objects such as lists and dicts

```
>>> a = [1,2,3,4]
>>> b = a
>>> b[2] = -10
>>> a
[1,2,-10,4]
```



- Changes affect both variables!
- Reason: Different variable names are referring to exactly the same object
- Yikes!

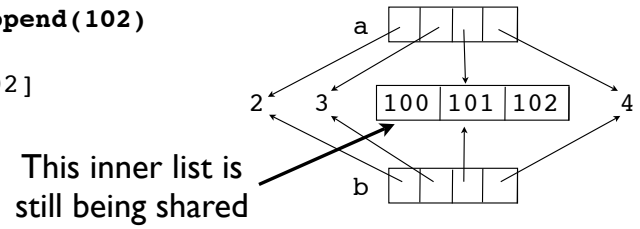
Making a Copy

- You have to take special steps to copy data

```
>>> a = [2,3,[100,101],4]
>>> b = list(a)             # Make a copy
>>> a is b
False
```

- It's a new list, but the list items are shared

```
>>> a[2].append(102)
>>> b[2]
[100,101,102]
>>>
```



- Known as a "shallow copy"

Deep Copying

- Sometimes you need to makes a copy of an object and all objects contained within it
- Use the copy module

```
>>> a = [2,3,[100,101],4]
>>> import copy
>>> b = copy.deepcopy(a)
>>> a[2].append(102)
>>> b[2]
[100,101]
>>>
```

Part 7

Dealing with Errors

Error Handling Problems

- A common problem that arrises with data processing is dealing with bad input
- For example, a bad input field would crash a lot of the scripts we've written so far

Exceptions

- In Python, errors are reported as exceptions
- Causes the program to stop
- Example:

```
>>> prices = { 'IBM' : 91.10,
...            'GOOG' : 490.10 }
>>> prices['SCOX']
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
KeyError: 'SCOX'
>>>
```

Exception

Builtin-Exceptions

- About two-dozen built-in exceptions

```
ArithmeticError
AssertionError
EnvironmentError
EOFError
ImportError
IndexError
KeyboardInterrupt
KeyError
MemoryError
NameError
ReferenceError
RuntimeError
SyntaxError
SystemError
TypeError
ValueError
```

- Consult reference

Exceptions

- Exceptions can be caught and handled
- To catch, use try-except

```
try:
    print prices["SCOX"]
except KeyError:
    print "No such name"
```

- To raise an exception, use raise

```
raise RuntimeError("What a kerfuffle")
```


The End of Part 1

- Python has a small set of very useful datatypes (numbers, strings, tuples, lists, and dictionaries)
- There are very powerful operations for manipulating data
- You write scripts that do useful things using nothing but these basic primitives
- In Part 2, we'll see how to organize your code