# CSCI: 4500/6500 Programming Languages

Python

Some material from: Stephen Ferg Bureau of Labor Statistics and Guido van Rossum Python Architect



# Evolution of Scripting Languages

- UNIX shell scripting
  - » awk, sed, ksh, csh
- Tck/Tk
- Perl
- Python
- PHP
- Ruby



Developed in 1991 by Guido van Rossum
- PEP 3000 (December 2008)

*"There should be one— and preferably only one —obvious way to do it." (remove old ways of doing stuff)*

- Mature
- Powerful / flexible
- Easy-to-learn / use
- Easy to read (in contrast to Perl ☹ )
- Open source
- Lots of documentation
- Lots of tutorials
- Lots of libraries
  - » Ruby - nice, purely object oriented, *but* harder to find libraries


Monty Python's Flying Circus Fan

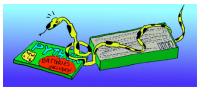
Guido Van Rossum





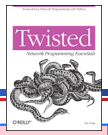
# Python

- Portable
  - » Mac, Windows, Unix (and installed on atlas.cs.uga.edu)
- Faster than C, C++, Java in *productivity*
  - » Compact language
  - » Batteries included (build in library)
- Python block indenting
  - » looks cleaner => easier to read
- Slower in execution
  - » but you can integrate C/C++/Java with Python





# Python vs. Java - seconds ( *outdated*, Java has improved – a lot )




| Test | Java | Python | Comparison |
|---|---|---|---|
| Standard Output | 138.85 | 30.58 | Python 4.5X faster |
| Hashtable | 17.00 | 8.22 | Python 2X faster |
| I/O | 56.72 | 47.36 | Python 1.2X faster |
| List | 5.94 | 14.32 | Java 2.4X faster |
| Native Methods | 2.475 | 7.92 | Java 3.2X faster |
| Interpreter Initialization | 0.25 | 0.04 | Python 6.3X faster |
| Object Allocation | 23.65 | 211.11 | Java 8X faster |
| Interpreter Speed | 0.43 | 2.29 | Java 5.3X faster |

http://www.twistedmatrix.com/users/glyph/rant/python-vs-java.html (April/2000)
http://blog.snaplogic.org/?p=55 (2007)

# More comparisons…

- furryland.org/~mikec/bench/
- Doug Bagley's Great Computer Language Shootout
  (http://web.archive.org/web/20040611035744/http://shootout.alioth.debian.org/ )

## Python vs. Java

- Python programs run *slower* than Java
- Python *programs take less time* to develop
  - » Typically a 5-10 times difference (origin, Ousterhout)
- Python is dynamically typed
  - » Programmer don't have to deal with static typing
    - – variable bound to type at compile time & optionally to an object (value of same type)
  - » Trend is now toward stronger static type checking, not less
    - – However, this is a productivity win at the cost of some risk
- Python is *compact*
- Python is *concise* (not verbose, not superfluous)
- Closures (lambda)

http://www.ferg.org/projects/python_java_side-by-side.html (February/2004)



## Weak vs. Strong Typing (there are a number of definitions)

- Variable can be of *non-specific* data type.
- Strongly typed languages puts (many) *restrictions* on how different types interact with each other
  - » 3+ 3.5 may not be allowed (only integers adds)
- Weak typing (*pliable*):
  - » the language implicitly convert (or casts) types when used (it allows type conversion) or
  - » it permits ad-hoc polymorphism (overloading)
- Examples:
  - » C is weakly typed, you can easily override the type system using casts, PHP
  - » Ruby, Python are really strongly typed
  - » Javascript (need double check – weakly, dynamically typed)



- "I spent a few weeks... trying to sort out the terminology of "strongly typed," "statically typed," "safe," etc., and found it amazingly difficult.... The usage of these terms is so various as to render them almost useless."
  - » *Benjamin C. Pierce, author of Types and Programming Languages and Advanced Types and Programming Languages (and also the maintainer of the great list of programming papers)*



## The Strong vs. the Weak

- Smalltalk, Ruby, Python, Javascript & LISP
  - » strongly typed (typing errors avoided at runtime)
- Standard ML, OCaml and Haskell
  - » Stronger than Java – on implicit type conversion
- Java
- Pascal
- C++ stronger than C
- C (supports more implicit conversions than Java and Pascal), pointer values can be cast.


and controversy…

Some argue that C, C++ are strong because they place enough restrictions on how operands of different types can be mixed



## Dynamically vs. Static Typing (more consensus on the definition here)

- Dynamically typed: majority of type checking at run time.
- Other people like static typing… trade-off is performance

I think there is a trend ...

Dynamically typed languages such as Python, Ruby, and even Smalltalk will be mainstream industrial languages in the coming years.

Robert C. Martin (2001) author of *Agile Software Development.*

Orthogonal: you can be both strongly and dynamically typed



## More Quotes…

- "When Java came out, I was excited -- I could write code twice as fast in Java as I could in C/C++. And with Python I can write code twice as fast as I can in Java."
  - – *Andy Hertzfeld (original apple computer software engineer now at google)*
- *When a 20,000 line project went to approximately 3,000 lines overnight, and came out being more flexible and robust ... I realized I was on to something really good.*
  - – Matthew "Glyph" Lefkowitz
- So the real punch line of the story is this: weeks and months after writing [python program], I could still read the code and *grok* what it was doing without serious mental effort.
  - » And the true reason I no longer write Perl for anything but tiny projects is that was never true when I was writing large masses of Perl code. I fear the prospect of ever having to modify keeper or anthologize again -- but [the above python] gives me no qualms at all.

Eric S. Raymond, author of *The Cathedral and the Bazaar*

## Is it Safe?

- Python is an "open-source" language.
  - » It has no vendor.
- Does that mean we'll have support problems?

What about...
- Vendor longevity?
- Consulting & training support?
- Books and reference materials?
- Tools? IDEs, debuggers, screen-painters?



## Who is using open-source software (e.g., LAMP)?

"LAMP"

- Linux
- Apache
- MySQL
- PHP | Perl | Python

- Apache has overwhelmingly dominated the Web server market since 1996.
- PHP is the most popular Apache module, running on almost 10 million domains (over a million IP addresses).

... and then there's ...



## Department of Defense (DoD)

- In 2002, a Mitre[1] study found 115 FOSS (free and open-source) products in use in the U.S. Dept. of Defense.

http://egovos.org/pdf/dodfoss.pdf


1. Past employer of Maria Hybinette



## ... and IBM

- In September 2003, IBM began promoting Linux with a series of television ads depicting a young boy receiving lessons from famous innovators and teachers. The boy represents the next generation of humanity, learning from teachers who – like the open-source community – freely share their accumulated expertise.




## Who is using Python?

- Industrial Light & Magic, maker of the Star Wars films, uses Python extensively in the computer graphics production process.
- Disney Feature Length Animation uses Python for its animation production applications.
- Google, a leading internet search engine, is powered by Python.
- Yahoo uses Python for its groups site, and in its Inktomi search engine.
- New York Stock Exchange (NYSE) - uses it for developing on-line systems for the floor of the exchange and for the member firm's back offices
- The National Weather Service uses Python to prepare weather forecasts.

Python spotting: http://www.pythonology.org/spotting



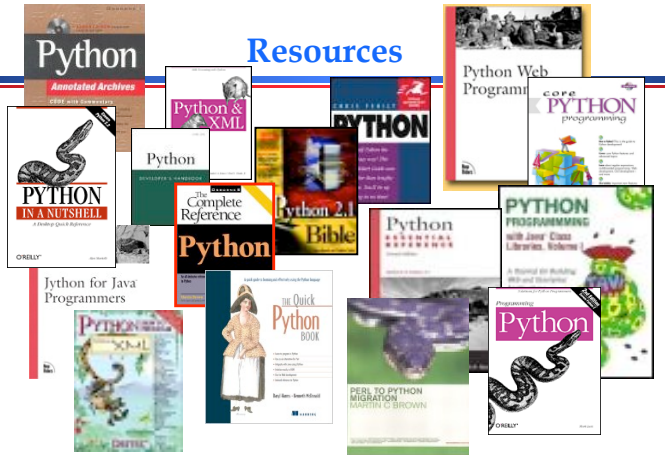
- Longevity - open source have no vendor, python is managed by the python software foundation - non-profit, produces core python distribution (blessed by Guido)

# Learning Python

- We will cover the *highlights* of python.
  - » You will have to learn more on your own.
  - » "Dive into Python"
    - – download a local copy pdf and on-line read available
    - – http://diveintopython.org/toc/index.html
  - » "Python 101" -- nice introduction (2008)
    - – http://www.rexx.com/~dkuhlman/python_101/python_101.html
- The Official Python Tutorial
  http://www.python.org/doc/current/tut/tut.html
- The Python Quick Reference
  http://rgruet.free.fr/#QuickRef



# Resources






# python™ Versions

- Current 2 production versions (here)
  - – "not really that much difference" according to python.org.
  - » Python 2.6.5 (March 19, 2010) and
  - » Python 3.1.2. (March, 2010)
- Developing environment:
  - » IDLE
    - – coded in 100% pure Python, using the tkinter GUI toolkit
    - – cross-platform: works on Windows and Unix
    - – Python shell window (a.k.a. interactive interpreter)
    - – debugger (not complete, but you can do the basics, set breakpoints, view and step)
  - » Eclipse module



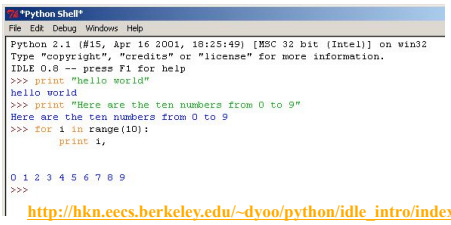
# Installing Python

- Already exists of atlas.cs.uga.edu (version 2.2)
- Easy to get and install for Win/Mac from (2.6)
  http://www.python.org
- Intro: Wikipedia's Python



# IDLE Development Environment

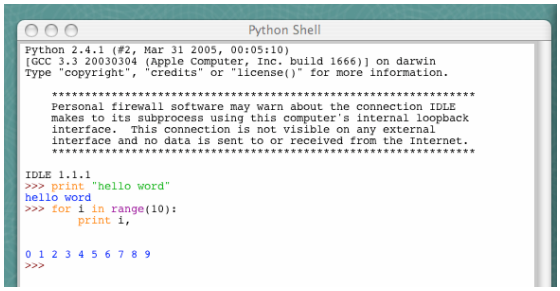
- Shell for interactive evaluation
- Text editor with color-coding and smart indenting for creating python files.
- Menu commands for changing system settings and running files.




http://hkn.eecs.berkeley.edu/~dyoo/python/idle_intro/index.html



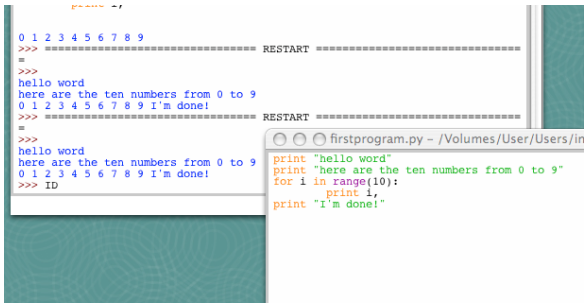
# Interpreter: On my Mac



# Working with a file.py

- **IDLE -**
  1. **File -> new window**
  2. **type commands in new window area**
  3. **save as "file name".py (typical extension)**
  4. **Run module**








# Running Programs on UNIX

- **#! /opt/sfw/bin/python (makes it runnable as an executable)**

```
{saffron:ingrid:1563} more
filename.py
#! /usr/local/bin/python
print "hello world"
print "here are the ten numbers
from 0 to 9"
for i in range(10):
        print i,
print "I'm done!"
```

```
{saffron:ingrid:1562} python filename.py
hello world
here are the ten numbers from 0 to 9
0 1 2 3 4 5 6 7 8 9 I'm done!
{saffron:ingrid:1563} filename.py
// what will happen?
```



# Look at a sample of code…

script.txt

```
x = 34 - 23                 # A comment.
y = "Hello"                 # Another one.
z = 3.45
if z == 3.45 or y == "Hello":
    x = x + 1
    y = y + "World"         # String concat.
print x
print y
```

IDLE Colors Please



# Look at a sample of code…

```
x = 34 - 23                 # A comment.
y = "Hello"                 # Another one.
z = 3.45
if z == 3.45 or y == "Hello":
    x = x + 1
    y = y + "World"         # String concat.
print x
print y
```

```
>>>
12
HelloWorld
```



# Enough to Understand the Code

- **Assignment uses = and**
- **Comparison uses ==.**
- **For numbers +-*/% are as expected.**
  - » **Special use of + for string concatenation.**
  - » **Special use of % for string formatting.**
- **Logical operators are words (and, or, not) *not symbols* (&&, ||, !).**
- **The *basic* printing command is "print."**
- **First assignment to a variable will create it.**
  - » **Variable types don't need to be declared.**
  - » **Python figures out the variable types on its own (inference).**

## Basic Datatypes

- **Integers (default for numbers)**

```
z = 5 / 2  # Answer is 2, integer division.
```

- **Floats**

```
x = 3.456
```

- **Strings**

  Can use " or ' to specify. "abc" 'abc' (Same thing.)

  Unmatched ones can occur within the string. "maria's"

  Use triple double-quotes for multi-line strings or strings that contain both ' and " inside of them: """a'b"c"""



## Whitespace

- **Whitespace is meaningful in Python: especially indentation and placement of newlines.**
  - » Use a newline to end a line of code. (Not a semicolon ; like in C++ or Java.) (Use \ when must go to next line prematurely.)
  - » No braces { } to mark blocks of code in Python… Use consistent *indentation* instead. The first line with a new indentation is considered outside of the block.
  - » Often a colon appears at the start of a new block. (We'll see this later for function and class definitions.)



## Comments

- **Start comments with # – the rest of line is ignored.**
- **Can include a "documentation string" as the first line of any new function or class that you define.**
- **The development environment, debugger, and other tools use it: it's good style to include one.**

```
def my_function(x, y):
  """This is the docstring. This
  function does blah blah blah."""
  # The code would go here...
  x = y + 1
  return x
```



## Look at more sample of code…

```
x = 34 - 23            # A comment.
y = "Hello"            # Another one.
z = 3.45
if z == 3.45 or y == "Hello":
    x = x + 1
    y = y + " World"   # String concat.
print x
print y
```



## Python and Types

Python determines the data types in a program automatically at runtime. "Dynamic Typing"

But Python's not casual about types, it enforces them after it figures them out. "Strong Typing"

So, for example, you can't just append an integer to a string. You must first convert the integer to a string itself.

```
x = "the answer is "  # Decides x is string.
y = 23                # Decides y is integer.
print x + y           # Python will complain about this.
```

```
Traceback (most recent call last):
  File "<pyshell#9>", line 1, in -toplevel-
    print x + y
TypeError: cannot concatenate 'str' and 'int' objects
```



## Naming Rules

- **Names are case sensitive and cannot start with a number. They can contain letters, numbers, and underscores.**

```
bob  Bob  _bob  _2_bob_  bob_2  BoB
```

- **There are some reserved words:**

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

## Accessing Non-existent Name

- If you try to access a name before it's been properly created (by placing it on the left side of an assignment), you'll get an error.

```
>>> y

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



## Multiple Assignment

- You can also assign to multiple names at the same time.

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



## String Operations

- We can use some methods built-in to the string data type to perform some formatting operations on strings:

```
>>> "hello".upper()
'HELLO'
```

- There are many other handy string operations available. Check the Python documentation for more.



## Printing with Python

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

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

"Print" automatically adds a newline to the end of the string. If you include a list of strings separated by a comma (,) , it will concatenate them with a space between them.

```
>>> print "abc"
abc

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



## Strings

- Concatenation
  - "Hello" + "World" -> 'HelloWorld'
- Repetition
  - "UGA" * 3 -> 'UGAUGAUGA'
- Indexing
  - "UGA"[0] -> 'U'
- Slicing
  - "UGA"[1:3] -> 'GA'
  - "UGA"[1:1] -> ''
- Size
  - len("UGA") -> 3
- Comparison
  - "Maria" < "maria" -> True
- Search
  - "i" in "maria" -> True



## Container Types

- `( 100, 200, 300 )` `# Tuple`
- `[ 42, 3.14, "hello" ]` `# List`
- `{ 'x':42, 'y':3.14 }` `# Dictionary`

**Tuple**

- a simple *immutable* ordered sequence of items

**List**

- a mutable ordered sequence with more powerful manipulations

**Dictionary -**

- a lookup table of key-value pairs

# Lists

```
>>> alist = [631, "maria" , [ 331, "maria" ]]
>>> print alist
[123, 'maria', [331, 'maria']]
```

- List items need not have the same type
- Same operators as for strings
- operations append(), insert(), pop(), reverse() and sort()



# More List Operations

```
>>> a = range(5)            # [0,1,2,3,4]
>>> a.append(5)             # [0,1,2,3,4,5]
>>> a.pop()                 # [0,1,2,3,4]
5
>>> a.insert(0, 42)         # [42,0,1,2,3,4]
>>> a.pop(0)                # [0,1,2,3,4]
42
>>> a.reverse()             # [4,3,2,1,0]
>>> a.sort()                # [0,1,2,3,4]

>>> a.append([22,33])              # [0,1,2,3,4,[22,33]]
>>> a.extend([10,20])       # [0,1,2,3,4,[22,33],10,20]
```



# More Lists

- List multiplication
  - `list = ["aa", "bb"] * 3`
- Printing out lists
  - `print "\n".join(list)  # better formatting`
- More operations
  - `list.count("aa")  # how many times`
  - `list.index("bb")  # returns the first match location`
- More on slices
  - `list[-1]  # last element`
  - `list[0:3]  # starting ele 0 and up to 2`
  - `list[3:]  # starting ele 3 to end of list`
  - `list[:]  # a complete copy of the list`



# Dictionaries

- Hash tables, "associative arrays" with key/value pairs
  - `d = {"duck": "bird", "bee": "insect"}`
- Lookup:
  - `d["duck"]  # "bird"`
  - `d["lion"]  # raises KeyError exception`
  - `d["bird"]  ?`
- Delete, insert, overwrite:
  - `del d["bee"]  # delete`
  - `d["lion"] = "cat"  # insert`
  - `d["duck"] = "unknown"  # overwrites`



# More Dictionary Ops

- Keys, values, items:
  - `d.keys()  # returns dictionary keys`
  - `d.values()  # returns all values`
  - `d.items()  # returns a list of key/value pairs`
- Presence check:
  - `d.has_key("duck") # True`
  - `d.has_key("spam") # False`
- Values of any type
- Keys almost any type (needs to be immutable – tuples OK, but not lists).

```
{
  "name":"Maria",
  "age": 25,
  42:"yes",
  "flag": ["red","white","blue"]
}
```



# Dictionary Details

- Keys must be immutable:
  - numbers, strings, tuples of immutables
    - these cannot be changed after creation
      - Keys are *hashed* (fast lookup technique)
  - not lists or other dictionaries
    - these types of objects can be changed "in place"
  - no restrictions on values
- Keys will be listed in arbitrary order
  - again, because of hashing

# Tuples

- Immutable **lists**
- Faster **than lists**

```
key = ("lastname", "firstname" )
lastname = key[0]
point = x, y, z            # parentheses optional
singleton = (1,)           # trailing comma!!!
                            # (required otherwise a value)
empty = ()                 # parentheses!
```



# Variables

- **Need to assign (initialize)**
  - use of uninitialized variable raises exception
- **No need to declare type (dynamically typed)**

```
if friendly: greeting = "hello world"
else: greeting = 12**2
print greeting
```

  - » **However once set the type matters**
    - Can't treat integer as a string



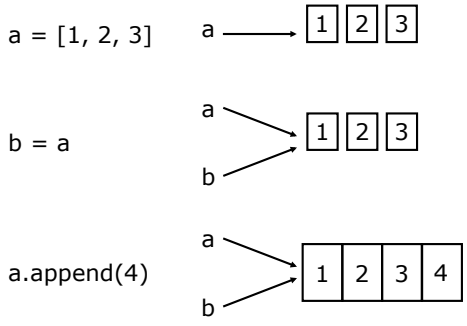
# Reference Semantics

- **Assignment *manipulates references***
  - **x = y**
    - does not make a copy **of y**
    - **makes x** reference **the object y references**
- **Very useful; but beware!**
- **Example:**

```
>>> a = [1, 2, 3]
>>> b = a
>>> a.append(4)
>>> print b
[1, 2, 3, 4]
```

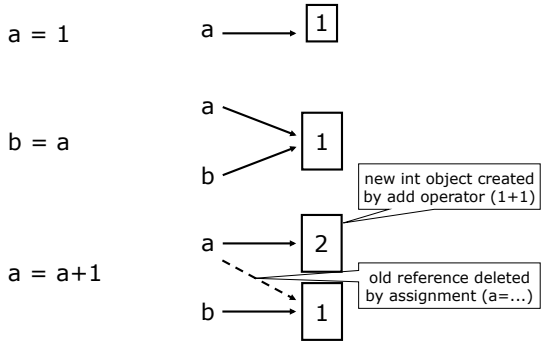


# Changing a Shared List






# Changing an *Integer*






# Control Structures

```
if condition:
    statements
[elif condition:
    statements] ...
else:
    statements
```

```
while condition:
    statements

for var in sequence:
    statements

break
continue
```

# More For Loops

- looping through list
  - `for item in list:`
  - `  print item`
- looping through counter
  - `for i in range(5):`
  - `  print i,`
- Iterating through a 'built in' dictionary
  - `import os`
  - `for k,v in os.environ.items():`
  - `  print "%s=%s" % (k,v)`
- `os.environ` is a dictionary of environment variables



# Exercise I

Print (on separate lines)

`1x1=1 1x2=2 1x3=3 .... 8x9=72 9x9=81`

but don't repeat. For example

print only `3x5=15`

but don't print `5x3=15`

so print only `if first_number <= second_num`

Hint: use range

```
for num in range(1,10):
  …
```



# Output

- 1 x 1 = 1
- 1 x 2 = 2
- 1 x 3 = 3
- 1 x 4 = 4
- 1 x 5 = 5
- 1 x 6 = 6
- ….



# Exercise Answer

```
a = range(1,10)
b = range(1,10)

for anum in a:
    for bnum in b:
        if ( anum <= bnum ):
            print str(anum),"x",str(bnum),"=",str(anum*bnum)
```

Don't really need str here



# Grouping Indentation

In Python:

```
for i in range(20):
    if i%3 == 0:
        print i
        if i%5 == 0:
            print "Bingo!"
    print "---"
```

In C:

```
for ( i = 0; i < 20; i++ )
{
    if (i%3 == 0) {
        printf("%d\n", i);
        if (i%5 == 0) {
          printf("Bingo!\n");
        }
       }
       printf("---\n");
}
```

```
0
Bingo!
---
---
---
3
---
---
---
6
---
---
---
9
---
---
---
12
---
---
---
15
Bingo!
---
---
---
18
---
---
```



# Functions, Procedures

```
def name(arg1, arg2, ...):
    """documentation"""      # optional doc string
    statements

return                       # from procedure
return expression            # from function
```

# Example Function

```
def gcd(a, b):
    "greatest common divisor"
    while a != 0:
        a, b = b%a, a      # parallel assignment
    return b

>>> gcd.__doc__            # 2 _ _ of these
'greatest common divisor'
>>> gcd(12, 20)
4
```



# Exercise II

- Phone book application
  - » 1) add
    - – Ask for name and phone number
  - » 2) print phone book
- To get input:
  - » `answer = raw_input("Enter your selection: ")`



```
intro= """
Welcome to the phone book application
choices:
    1) add new entry
    2) print phone book
    3) exit
"""

print intro

ph_d = {} # phone book dictionary

def add_entry():
    """ add new entry into phone book"""
    name = raw_input("give me a name:")
    number = raw_input("give me a number:")
    ph_d[name] = number

def print_pb():
    print "name".rjust(30)+"number".rjust(30)
    for name,num in ph_d.items():
        print name.rjust(30),num.rjust(30)

while (True):
    response = raw_input("Enter your command: ")
    if (response == '1'):
        add_entry()
    elif (response == '2'):
        print_pb()
    elif (response == '3'):
        break
    else:
        print "invalid command"
```

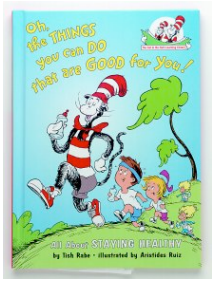
```
>>>
Welcome to the phone book application
choices:
    1) add new entry
    2) print phone book
    3) exit

Enter your command: 1
give me a name:maria
give me a number:555-1212
Enter your command: 2
                    name        number
                   maria      555-1212
Enter your command:
```



# On your own…

- modules & packages
- exceptions
- files & standard library
- classes & instances





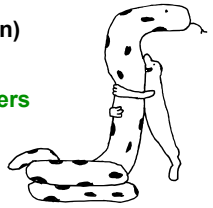

# Hands On

- www.python.org/doc/current/tut/tut.html



# Python Slogans

- Python Fits Your Brain, Bruce Eckel
- Life is Better Without Braces, Bruce Eckel
- Import This
- Batteries included (Tcl origin)
- Powered by Python
- Readability counts, Tim Peters



http://mindview.net/

# Bruce Eckel's Top 10

10. Reduced clutter.
    - Programs are read more than they are written
    - Consistent formatting is important
      - readability & compactness
      - conversation of compactness
    - Consistent use of programming idioms

09. It's not backward-compatible with other languages. (This came with some hilarious one-liners:
    - "C++'s backward compatibility with C is both its strength and its bane"; "Java causes repetitive-strain syndrome";
    - "Perl is compatible with every hacky syntax of every UNIX tool ever invented";
    - "C# and Microsoft .NET are backward-compatible with Microsoft's previous marketing campaigns"; and "Javascript is not even compatible with itself".)


08. It doesn't value performance over my productivity.
    - C++ memory leaks
    - primitive types require awkward coding

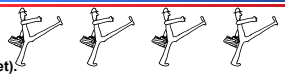


# Bruce Eckel's Top 10

07. It doesn't treat me like I'm stupid.
    - Java insists operator overloading is bad because
    - you can make ugly code with it.
    - Bruce observes, "And we all know there's no ugly Java code out there."
06. I don't have to wait forever for a full implementation of the language.
    - features invented in C+ takes a long time to appear in languages
    - Unused features don't get tested
05. It doesn't make assumptions about how we discover errors.
    - Is strong static type checking rally the only way to be sure?
    - Lack of good static typing in pre-ANSI C was troublesome
    - Doesn't mean it's the best solution



# Bruce Eckel's Top 10



04. Marketing people are not involved in it (yet).
    - Java is flawless
    - Microsoft happens "Visual" C++
    - Of-course Python isn't immune
03. I don't have to type so much.
    - But what I do type is the *right* typing.
02. My guesses are usually right.
    - I still have to look up how to open a file every time I do it in Java
    - Most things I do in Java, I have to look up.
    - Remember Python Idioms easier because they are simpler



# Bruce Eckel's Top 10

01. Python helps me focus on my concepts rather than on fighting with the language.