301AA - Advanced Programming

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AP-26: *Introduction to Python*

Full Python Tutorial

- **Developed by Guido van Rossum in the early 1990s**
  - In July 2018, Van Rossum stepped down as the leader in the language community after 30 years.
- **Named after Monty Python**
- **Available for download from http://www.python.org**

Python 1

- Installing Python & main documentation
- Useful commands
- Modules: importing and executing
- Basics of the language
- Sequence datatypes
- Dictionaries
- Boolean expressions
- Control flow
- List Comprehension

Language features

- **Indentation instead of braces**
- **Several sequence types**
  - Strings ' … ' : made of characters, immutable
  - Lists […] : made of anything, mutable
  - Tuples (…) : made of anything, immutable
- **Powerful subscripting (slicing)**
- **Functions are independent entities (not all functions are methods)**
- **Exceptions as in Java**
- **Simple object system**
- **Iterators (like Java) and *generators***

Why Python?

- **Good example of *scripting language***
- **"Pythonic" style is very concise**
- **Powerful but unobtrusive object system**
  - *Every* value is an object
- **Powerful collection and iteration abstractions**
  - Dynamic typing makes generics easy

Dynamic typing – the key difference

- **Java: *statically typed***
  - Variables are declared to refer to objects of a given type
  - Methods use type signatures to enforce contracts
- **Python**
  - Variables come into existence when first assigned to
  - A variable can refer to an object of any type
  - All types are (almost) treated the same way
  - *Main drawback*: type errors are only caught at runtime

Recommended Reading

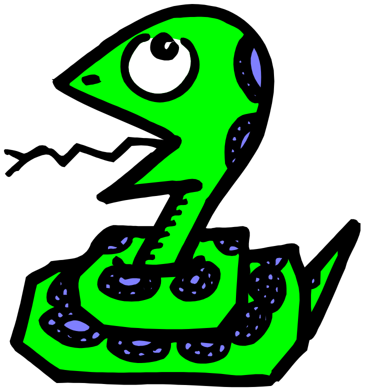
- **On-line Python tutorials**
  - The Python Tutorial (http://docs.python.org/tutorial/)
    - Dense but more complete overview of the most important parts of the language
    - See course home page for others

- **PEP 8- Style Guide for Python Code**
  - http://www.python.org/dev/peps/pep-0008/
  - The official style guide to Python, contains many helpful programming tips

- ***Many* other books and on-line materials**
  - If you have a specific question, try Google first

Technical Issues

Installing & Running Python



Which Python?

- **Python 2.7**
  - Last stable release before version 3
  - Implements some of the new features in version 3, but fully backwards compatible
- **Python 3**
  - Released in December 2008
  - Many changes (including incompatible changes)
  - *Much* cleaner language in many ways
  - Strings use Unicode, not ASCII
  - But: A few important third party libraries are not yet compatible with Python 3 right now
  - "End-of-life" date of Python 2 set initially at 2015, then postponed to 2020

The Python Interpreter

- **Download it from**

  `https://www.python.org/`
- **Current version: 3.8.0**
- **Interactive interface to Python**

  % python

```
Python 3.6.3 (v3.6.3:2c5fed86e0, Oct  3 2017, 00:32:08)
[GCC 4.2.1 (Apple Inc. build 5666) (dot 3)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

- **Python interpreter evaluates inputs:**

```
>>> 3*(7+2)
27
```

Useful commands

- **help()**
  - Enters Python interactive help utility
- **help(arg)**
  - Prints documentation about **arg**
  - Example: **help(1), help(str), help({}), help(print), help(builtins)**
- **type(arg)**
  - Prints the type of **arg**
  - Example: **type(1), type("Hello"), type(str), type(type)**
- **_ :** in the interpreter is the value of the last expression
- Since "everything is an object", try "dot-completion" to see what are the options…
  - Example: **1. <tab><tab>   "hello". <tab><tab>**
  - NB: the latter might not work. Try: "hello" <ret>; _. <tab><tab>

The `dir()` Function

- The built-in function **dir()** returns a sorted list of strings containing all names defined in a module, a class, or an object

```
>>> import sys
>>> dir(sys)          # Prints names defined in sys
['__displayhook__', '__doc__', '__excepthook__', '__loader__',
'__name__', '__package__', '__stderr__', '__stdin__',
      ...
>>> dir() # Prints names defined currently
      ...
>>> import builtins
>>> dir(builtins) #Prints built-in functions and variables

>>> dir(str) #Prints all members of class str
```

`Import` and Modules

- **Programs will often use classes & functions defined in another file**
- **A Python module is a single file with the same name (plus the *.py* extension)**
- **Modules can contain many classes and functions**
- **Access using *import***

Where does Python look for module files?

- **The list of directories where Python looks: sys.path**
- **When Python starts up, this variable is initialized from the PYTHONPATH environment variable**
- **To add a directory of your own to this list, append it to this list.**

```
sys.path.append('/my/new/path')
```

  - **Oops! Operating system dependent….**

Defining Modules

- **Modules** are files containing definitions and statements. A module defines a new namespace.
- Modules can be organized hierarchically in **packages**

```
# File fibo.py - Fibonacci numbers module
def fib(n):    # write Fibonacci series up to n
    a, b = 0, 1
    while b < n:
        print(b, end=' ')
        a, b = b, a+b
    print()

def fib2(n):   # return Fibonacci series up to n
    result = []
    a, b = 0, 1
    while b < n:
        result.append(b)
        a, b = b, a+b
    return result
```

Importing a module

```
>>> import fibo    # imports module from local file
'fibo.py'
>>> fibo.fib(6)    # dot notation
[1, 1, 2, 3, 5]
>>> fibo.__name__ # special attribute __name__
'fibo'
>>> fibo.fib.__module__    # special attribute __module__
'fibo'
```

```
>>> from fibo import fib, fib2
     # or from fibo import *
>>> fib(500)
>>> fib.__module__          # special attribute __module__
'fibo'
>>> fibo.__name__ # NameError: name 'fibo' is not defined
```

Executing a module as a script

- A module can be invoked as a script from the shell as

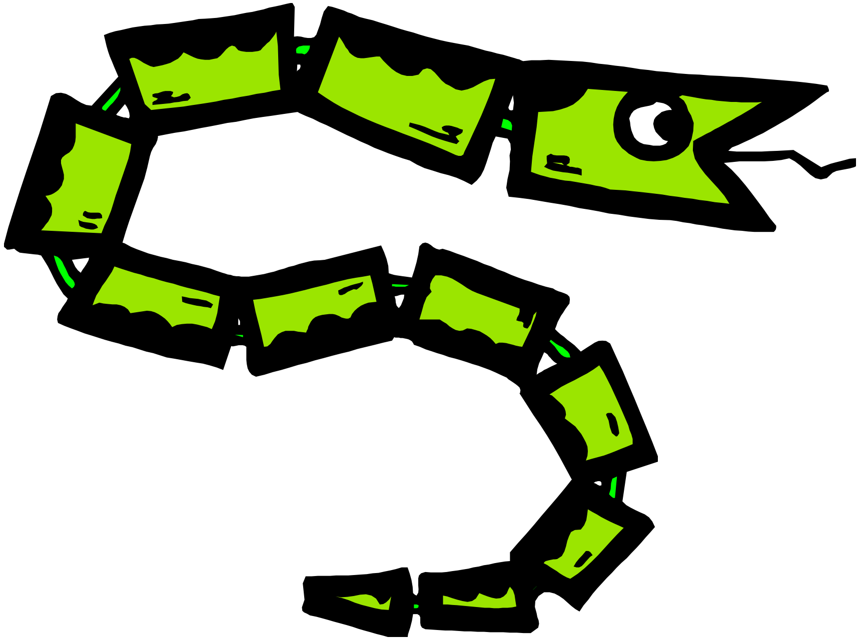
```
> python fibo.py 60
```

- Executed with __name__ set to "__main__".

```
# File fibo.py - Fibonacci numbers module
def fib(n):    # write Fibonacci series up to n
    ...
def fib2(n):   # return Fibonacci series up to n
    ...
if __name__ == "__main__": # added code
    import sys
    fib(int(sys.argv[1]))
```

```
> python fibo.py 60
1 1 2 3 5 8 13 21 34
>
```

The Basics



A Code Sample (in IDLE)

```
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)               # [Py2] also  print x, no brackets
print(y)
```

Enough to Understand the Code

- **Indentation matters to the meaning of the code:**
  - Block structure indicated by indentation
- **The first assignment to a variable creates it.**
  - Variable types don't need to be declared.
  - Python figures out the variable types on its own.
- **Assignment uses `=` and comparison uses `==`.**
- **For numbers `+ - * / %` are as expected.**
  - Special use of `+` for string concatenation.
  - Special use of `%` for string formatting (as with **printf** in C)
- **Logical operators are words (`and, or, not`) *not* symbols**
- **Simple printing can be done with `print()`.**

Basic Datatypes

- Integers (default for numbers)

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

- Floats

```
x = 3.456
k = 5 / 2  # k = 2.5 in [Py3], k = 2 in [Py2]
```

- Strings
  - Can use "" or ' ' to specify.
    `"abc"` `'abc'` (Same thing.)
  - Unmatched can occur within the string.
    `"matt's"`
  - Use triple double-quotes for multi-line strings or strings than 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.***
  - 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 less indentation is outside of the block.*
  - *The first line with more indentation starts a nested block*
- **Often a colon "`:`" appears at the start of a new block. (E.g. 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...
```

Assignment

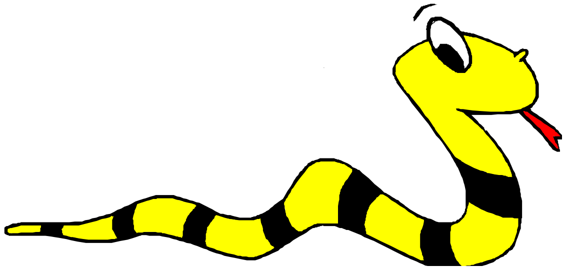
- ***Binding a variable*** **in Python means setting a** ***name*** **to hold a** ***reference*** **to some** ***object*****.**
  - *Assignment creates references, not copies (like Java)*
- **A variable is created** ***the first time*** **it appears on the left side of an assignment expression:**
  ```
  x = 3
  ```
- **An object is deleted (by the garbage collector) once it becomes unreachable.**
- ***Names in Python do not have an intrinsic type. Objects have types.***
  - Python determines the type of the reference automatically based on what data is assigned to it.

Multiple Assignment

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

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

Sequence types:
Tuples, Lists, and Strings



Sequence Types

1. Tulpes
   - A simple ***immutable*** ordered sequence of items
     - Immutable: a tuple cannot be modified once created....
   - Items can be of mixed types, including collection types

2. Strings
   - ***Immutable***
   - Conceptually very much like a tuple
   - [Py3] *UTF-8 Unicode* (type str)
   - [Py2] *8-bit chars* (type str)
UTF-16 Unicode (type unicode)
3. Lists
   - ***Mutable*** ordered sequence of items of mixed types

Sequence Types 2

- The three sequence types (tuples, strings, and lists) share much of the same syntax and functionality.

- Tuples are defined using parentheses (and commas).

```
>>> tu = (23, 'abc', 4.56, (2,3), 'def')
```

- Lists are defined using square brackets (and commas).

```
>>> li = ["abc", 34, 4.34, 23]
```

- Strings are defined using quotes (", ', or """).

```
>>> st = "Hello World"
>>> st = 'Hello World'
>>> st = """This is a multi-line
string that uses triple quotes. """
```

Sequence Types 3

- **We can access individual members of a tuple, list, or string using square bracket “array” notation.**
- ***Note that all are 0 based…***

```
>>> tu = (23, 'abc', 4.56, (2,3), 'def')
>>> tu[1]     # Second item in the tuple.
 'abc'

>>> li = ["abc", 34, 4.34, 23]
>>> li[1]      # Second item in the list.
 34

>>> st = "Hello World"
>>> st[1]   # Second character in string.
 'e'
```

Negative indices

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')
```

Positive index: count from the left, starting with 0.

```
>>> t[1]
'abc'
```

Negative lookup: count from right, starting with –1.

```
>>> t[-3]
4.56
```

Slicing: Return Copy of a Subset (1)

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')
```

Return a copy of the container with a subset of the original members. Start copying at the first index, and stop copying ***before*** the second index.

```
>>> t[1:4]
('abc', 4.56, (2,3))
```

You can also use negative indices when slicing.

```
>>> t[1:-1]
('abc', 4.56, (2,3))
```

Optional argument allows selection of every n^{th} item.

```
>>> t[1:-1:2]
('abc', (2,3))
```

Slicing: Return Copy of a Subset (2)

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')
```

Omit the first index to make a copy starting from the beginning of the container.

```
>>> t[:2]
(23, 'abc')
```

Omit the second index to make a copy starting at the first index and going to the end of the container.

```
>>> t[2:]
(4.56, (2,3), 'def')
```

Copying the Whole Sequence

To make a *copy* of an entire sequence, you can use `[:]`.

```
>>> t[:]
(23, 'abc', 4.56, (2,3), 'def')
```

Note the difference between these two lines for mutable sequences:

```
>>> list2 = list1     # 2 names refer to 1 ref
                      # Changing one affects both

>>> list2 = list1[:]  # Two independent copies, two refs
```

The ‘in’ Operator

- **Boolean test whether a value is inside a collection (often called a *container* in Python):**

```
>>> t = [1, 2, 4, 5]
>>> 3 in t
False
>>> 4 in t
True
>>> 4 not in t
False
```

- **For strings, tests for substrings**

```
>>> a = 'abcde'
>>> 'c' in a
True
>>> 'cd' in a
True
>>> 'ac' in a
False
```

- **Be careful: the *in* keyword is also used in the syntax of *for loops* and *list comprehensions*.**

The + Operator

- The + operator produces a *new* tuple, list, or string whose value is the concatenation of its arguments.

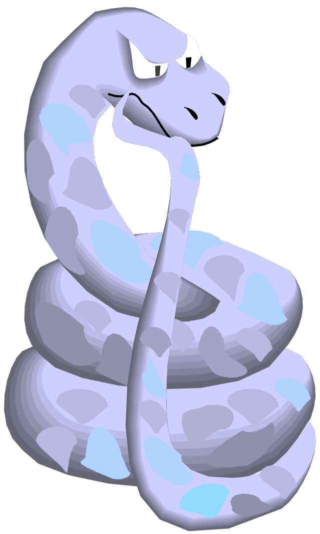
- Extends concatenation from strings to other types

```
>>> (1, 2, 3) + (4, 5, 6)
 (1, 2, 3, 4, 5, 6)

>>> [1, 2, 3] + [4, 5, 6]
 [1, 2, 3, 4, 5, 6]

>>> "Hello" + " " + "World"
 'Hello World'
```

Mutability:
Tuples vs. Lists



Lists: Mutable

```
>>> li = ['abc', 23, 4.34, 23]
>>> li[1] = 45
>>> li
  ['abc', 45, 4.34, 23]
```

- We can change lists *in place.*
- Name ***li*** still points to the same memory reference when we're done.

Tuples: Immutable

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')
>>> t[2] = 3.14

Traceback (most recent call last):
  File "<pyshell#75>", line 1, in -toplevel-
    tu[2] = 3.14
TypeError: object doesn't support item assignment
```

You can't change a tuple.

You can make a fresh tuple and assign its reference to a previously used name.

```
>>> t = (23, 'abc', 3.14, (2,3), 'def')
```

- *The immutability of tuples means they're faster than lists.*

Operations on Lists Only - 1

```
>>> li = [1, 11, 3, 4, 5]

>>> li.append('a')  # Note the method syntax
>>> li
[1, 11, 3, 4, 5, 'a']

>>> li.insert(2, 'i')
>>>li
[1, 11, 'i', 3, 4, 5, 'a']
```

The *extend* method vs the + operator

- **+ creates a fresh list (with a new memory reference)**
- ***extend*** **is just like *add* in Java; it operates on list `li` in place.**

```
>>>li
[1, 11, 'i', 3, 4, 5, 'a']
>>> li.extend([9, 8, 7])
>>>li
[1, 2, 'i', 3, 4, 5, 'a', 9, 8, 7]
```

***Confusing*:**

- ***extend*** **takes a list as an argument**
- ***append*** **t akes a singleton as an argument, *unlike Java***

```
>>> li.append([10, 11, 12])
>>> li
[1, 2, 'i', 3, 4, 5, 'a', 9, 8, 7, [10, 11, 12]]
```

Operations on Lists Only - 3

```
>>> li = ['a', 'b', 'c', 'b']

>>> li.index('b')     # index of first occurrence*
1
```

*more complex forms exist

```
>>> li.count('b')     # number of occurrences
2

>>> li.remove('b')    # remove first occurrence
>>> li
  ['a', 'c', 'b']
```

Operations on Lists Only - 4

```
>>> li = [5, 2, 6, 8]

>>> li.reverse()    # reverse the list *in place*
>>> li
  [8, 6, 2, 5]

>>> li.sort()       # sort the list *in place*
>>> li
  [2, 5, 6, 8]

>>> li.sort(some_function)
    # sort in place using user-defined comparison
```

Tuples vs. Lists

- **Lists slower but more powerful than tuples.**
  - Lists can be modified, and they have lots of handy operations we can perform on them.
  - Tuples are immutable and have fewer features.

- **To convert between tuples and lists use the list() and tuple() functions:**

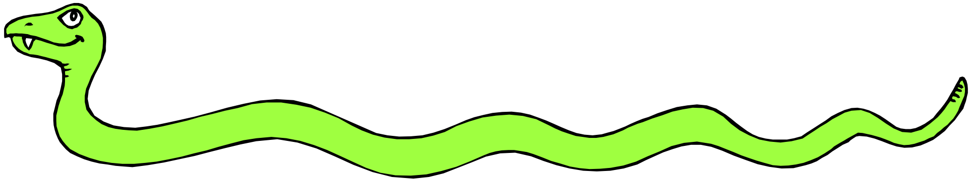
```
li = list(tu)
tu = tuple(li)
```

Sets, by examples

- Empty set: set()
- Indexing not supported
- Mixed types

```
>>> basket = {'apple', 'orange', 'apple', 'pear', 'orange',
'banana'}
>>> print(basket)                   # show that duplicates have been
removed
{'orange', 'banana', 'pear', 'apple'}
>>> 'orange' in basket              # fast membership testing
True
>>> 'crabgrass' in basket
False
>>> # Demonstrate set operations on unique letters from two words
>>> a = set('abracadabra')
>>> b = set('alacazam')
>>> a                                  # unique letters in a
{'a', 'r', 'b', 'c', 'd'}
>>> a - b                              # letters in a but not in b
{'r', 'd', 'b'}
>>> a | b                              # letters in a or b or both
{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}
>>> a & b                              # letters in both a and b
{'a', 'c'}
>>> a ^ b                           # letters in a or b but not both
{'r', 'd', 'b', 'm', 'z', 'l'}
```

Dictionaries: a *mapping* collection type



Dictionaries: Like *maps* in Java

- **Dictionaries store a** *mapping* **between a set of keys and a set of values.**
  - ***Keys can be of any immutable hashable type***
    - ***cannot contain mutable components***
  - Values can be any type
  - Values and keys can be of different types in a single dictionary
- **You can**
  - define
  - modify
  - view
  - lookup
  - delete

the key-value pairs in the dictionary.

Creating and accessing dictionaries

```
>>> d = {'user':'bozo', 'pswd':1234}

>>> d['user']
'bozo'

>>> d['pswd']
1234

>>> d['bozo']

Traceback (innermost last):
  File '<interactive input>' line 1, in ?
KeyError: bozo
```

- Keys must be unique.

```
>>> d1 = {1:7,1:5}
>>> d1
{1: 5}
```

Updating Dictionaries

- Assigning to an existing key changes the value.

```
>>> d = {'user':'bozo', 'pswd':1234}

>>> d['user'] = 'clown'
>>> d
{'user':'clown', 'pswd':1234}
```

- Assigning to a non-existing key adds a new pair.

```
>>> d['id'] = 45
>>> d
{'user':'clown', 'id':45, 'pswd':1234}
```

- Dictionaries are unordered
  - New entry might appear anywhere in the output.
- (Dictionaries work by *hashing*)

Removing dictionary entries

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

>>> del d['user']                # Remove one. Note that del is
                                 # a function.
>>> d
{'p':1234, 'i':34}

>>> d.clear()                    # Remove all.
>>> d
{}
>>> a=[1,2]
>>> del a[1]                    # (del also works on lists)
>>> a
[1]
```

Useful Accessor Methods

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

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

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

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

>>> list(d)                 # When accessing a dictionary as
                            # a list, the keys are returned
['user', 'p', 'i’]
```

Using dictionaries

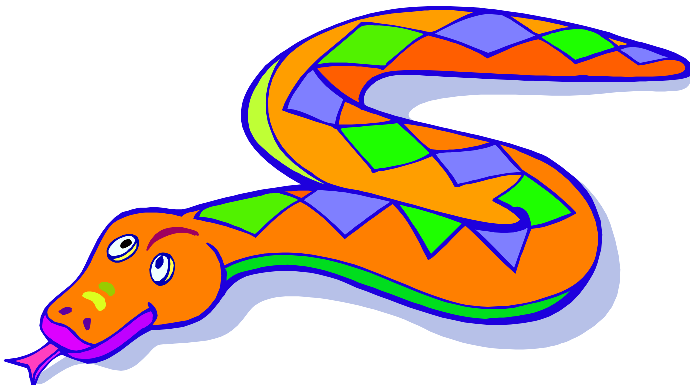
Write a program to compute the frequency of the words of a string read from the input. The output should print the words in increasing alphanumerical order.

```
freq = {}   # frequency of words in text [Python3]
line = input()
for word in line.split():
    freq[word] = freq.get(word,0)+1

words = list(freq.keys())
words.sort()

for w in words:
    print ("%s:%d" % (w,freq[w]))
```

Boolean Expressions



True and False

- ***True* and *False* are constants**

- ***Other values are treated as equivalent to either True or False when used in conditionals:***
  - *False*: zero, *None*, empty containers
  - *True*: non-zero numbers, non-empty objects
  - See PEP 8 for the most Pythonic ways to compare

- **Comparison operators: ==, !=, <, <=, etc.**
  - `X == Y`
    - X and Y have same value (like Java *equals* method)
  - `X is Y` :
    - X and Y refer to the *exact same object* (like Java ==)

Logical Operators

- **You can also combine Boolean expressions.**
  - *True* if a is True and b is True: `a and b`
  - *True* if a is True or b is True: `a or b`
  - *True* if a is False: `not a`

Conditional Expressions

- `x = true_value if condition else false_value`

- lazy evaluation:
  - **First, `condition` is evaluated**
  - **If *True*, `true_value` is evaluated and returned**
  - **If *False*, `false_value` is evaluated and returned**

Control Flow

if Statements (as expected)

```
if x == 3:
    print("X equals 3.")
elif x == 2:
    print("X equals 2.")
else:
    print("X equals something else.")
print ("This is outside the 'if'.")
```

Note:

- **Use of indentation for blocks**
- **Colon (*:*) after boolean expression**

while Loops (as expected)

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

>>>
```

break **and** ***continue***

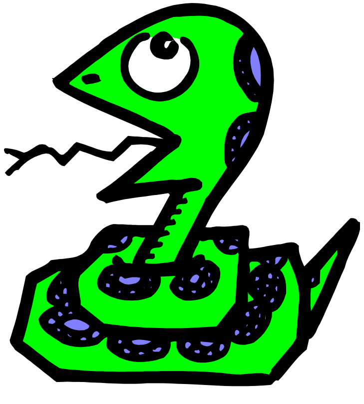
- **You can use the keyword *break* inside a loop to leave the *while* loop entirely.**
- **You can use the keyword *continue* inside a loop to stop processing the current iteration of the loop and immediately go on to the next one.**

assert

- **An *assert* statement will check to make sure that something is true during the course of a program.**
  - If the condition if false, the program throws an exception (**AssertionError**)

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

For Loops



For Loops 1

- For-each is Python’s *only* form of for loop
- A for loop steps through each of the items in a collection type, or any other type of object which is “iterable”

```
for <item> in <collection>:
  <statements>
```

- If <collection> is a list or a tuple, then the loop steps through each element of the sequence.

- If <collection> is a string, then the loop steps through each character of the string.

```
for someChar in "Hello World":
   print(someChar)
```

For Loops 2

```
for <item> in <collection>:
  <statements>
```

- **<item> can be more complex than a single variable name.**
  - If the elements of <collection> are themselves collections, then <item> can match the structure of the elements. (We saw something similar with list comprehensions and with ordinary assignments.)

```
for (x, y) in [('a',1), ('b',2), ('c',3), ('d',4)]:
  print(x)
```

For loops and the *range()* function

- We often want to write a loop where the variables ranges over some sequence of numbers. The *range()* function returns a list of n numbers from 0 up to but not including the number we pass to it.
- range(5) returns [0,1,2,3,4]
- So we can say:

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

- Variant: range(start, stop[,step])

- [Py2]: *range()* returns a list, *xrange()* returns an *iterator* that provides the same functionality, more efficiently
- [Py3]: *range()* returns an iterator, *xrange()* illegal

Abuse of the *range()* function

- **Don't use *range()* to iterate over a sequence solely to have the index and elements available at the same time**

- **Avoid:**

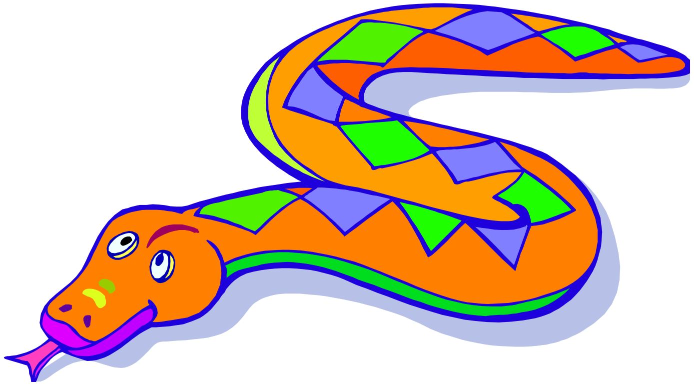
```
for i in range(len(mylist)):
    print(i, mylist[i])
```

- **Instead:**

```
for (i, item) in enumerate(mylist):
    print(i, item)
```

- **This is an example of an *anti-pattern* in Python**
  - For more, see: http://lignos.org/py_antipatterns/

Generating Lists using "List Comprehensions"



List Comprehensions 1

- **A powerful feature of the Python language.**
  - Generate a new list by applying a function to every member of an original list.
  - Python programmers use list comprehensions extensively. You’ll see many of them in real code.

[expression for name in list]

List Comprehensions 2

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

[expression `for` name `in` list]

- Where expression is some calculation or operation acting upon the variable name.
- For each member of the list, the list comprehension
  1. sets name equal to that member, and
  2. calculates a new value using expression,
- It then collects these new values into a list which is the return value of the list comprehension.

List Comprehensions 3

- If the elements of list are other collections, then name can be replaced by a *collection* of names that match the “shape” of the list members.

```
>>> li = [('a', 1), ('b', 2), ('c', 7)]
>>> [ n * 3 for (x, n) in li]
[3, 6, 21]
```

[expression for name in list if filter]

Filtered List Comprehension 1

- Filter determines whether expression is performed on each member of the list.
- When processing each element of list, first check if it satisfies the filter condition.
- If the filter condition returns *False*, that element is omitted from the list before the list comprehension is evaluated.

[expression for name in list if filter]

Filtered List Comprehension 2

```
>>> li = [3, 6, 2, 7, 1, 9]
>>> [elem * 2 for elem in li if elem > 4]
[12, 14, 18]
```

- Only 6, 7, and 9 satisfy the filter condition.
- So, only 12, 14, and 18 are produced.

Nested List Comprehensions

- **Since list comprehensions take a list as input and produce a list as output, they are easily nested:**

```
>>> li = [3, 2, 4, 1]
>>> [elem*2 for elem in
        [item+1 for item in li] ]
[8, 6, 10, 4]
```

- **The inner comprehension produces: [4, 3, 5, 2].**
- **So, the outer one produces: [8, 6, 10, 4].**

For Loops / List Comprehensions

- **Python's list comprehensions provide a natural idiom that usually requires a for-loop in other programming languages.**
  - As a result, Python code uses many fewer for-loops

- *Caveat*! **The keywords *for* and *in* also appear in the syntax of list comprehensions, but this is a totally different construction.**