Introduction to programming for Geoscientists

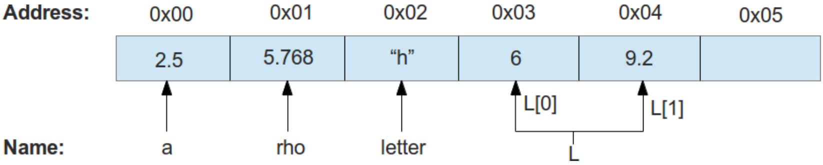
Revision Lecture 1

Variables

Definition

- Variable: a place in the computer's memory which holds a value.
  - Memory address + symbolic name
  - You define the symbolic name in your Python program.
  - e.g. If a variable called `a` does not already exist, the statement `a = 5` stores the value 5 in an un-used block of memory.
  - The value can then be referenced (i.e. accessed) using the symbolic name, e.g. `print a`.

A simplified view of variable storage:



Variables

Key points

- Always make sure variables are defined **before trying to use them**! The following block of code will not work:

  ```
  b = 5
  c = a*b
  a = 10
  ```

- Variable names:
  - are case sensitive.
  - cannot start with a digit.
  - cannot be a Python keyword: `and, as, 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, with, while, yield`.

Printing

- Data held in variables can be printed to the screen using

  ```
  b = 5.67560
  print b
  ```

- Or, to present data in a nicer way, use printf style formatting:

  ```
  print "The data held in variable b is:  %.2f" % (b)
  ```

- The format specifier `%.2f` acts like a placeholder. When printing to the screen, Python substitutes this for the data in `b` and formats it accordingly:
  - `%.2f` prints out the data in `b` to 2 decimal places (i.e. `5.67`).
  - `%d` prints out the data in `b` as an integer (i.e. `5`).
  - `%g` prints out the data in `b` to the minimum number of significant figures (i.e. `5.6756`).
- If you see numbers like `5e-2`, this is just Python's way of writing 5×10^{-2}. It has nothing to do with the mathematical constant $e \approx 2.71828$.

Integer division

- In Python, dividing an integer by another integer will result in another integer.
- Python computes the result, and drops the decimal point and everything after it. e.g. $9/5 = 1.8$ will evaluate to 1
- This is a common error made in Python programs, so watch out for it.
- If in doubt, just make the numerator or denominator (or both) floating-point numbers. e.g. $3 \rightarrow 3.0$

Variable type conversion

- Converting a variable's data from one type to another.
  - `int(5.0)` → `5`
  - `float(7)` → `7.0`
  - `str(8.15)` → “`8.15`”
  - `int("5")` → `5`
- Also known as type casting.
- You will most likely use casting:
  - to avoid integer division problems, e.g. `float(3)/5`
  - when you want to use numerical data read in from the keyboard using `raw_input`, e.g.

    ```
    a = 5
    b = raw_input("Please enter a number.")
    c = a*float(b)
    ```

Operator precedence

- Expressions like `2.0 + 3.0/5.0` are evaluated in a particular order, determined by operator precedence.

- Division has a higher precedence than addition, so `3.0/5.0` is evaluated first, and `2.0` is then added on afterwards.

- If we wanted `2.0 + 3.0` to be evaluated first, then we need to use parentheses: `(2.0 + 3.0)/5.0`.

- BODMAS: Brackets, Order, Division, Multiplication, Addition, Subtraction.

- Note: Python groups certain operators together such that they have the same precedence, and then evaluates expressions from left to right. See `http://docs.python.org/2/reference/expressions.html`.

Importing modules

- Python modules are useful when you want to split your code up to make it more manageable, or to make a piece of code available for use in other programs.
- Mathematical functions like $\sin(x)$, $\cos(x)$, $\log(x)$ are available in the `math` module.
- There are two ways of importing functions from modules:
  - `import math`: Python will import all the functions in the math module, but will keep the functions in their own separate namespace. That is, you must use prepend `math.` to the function's name to use it, e.g. `x = 0.5; y = math.sin(x)`
  - `from math import *`: Python will import all the functions in the math module into the current namespace. That is, you can simply do `x = 0.5; y = sin(x)`. But: be careful that you do not have another function named `sin` in your program!

If statement
Definition

- The if statement is a programming construct that executes different blocks of code depending on whether a boolean condition evaluates to `True` or `False`.

```
if(boolean condition):
   print "The condition is True"
else:
   print "The condition is False"
```

- Condition: it is raining (True or False)
- Possible actions: take an umbrella, don't take an umbrella.

```
if(it is raining):
   Take an umbrella.
else:
   Don't take an umbrella.
```

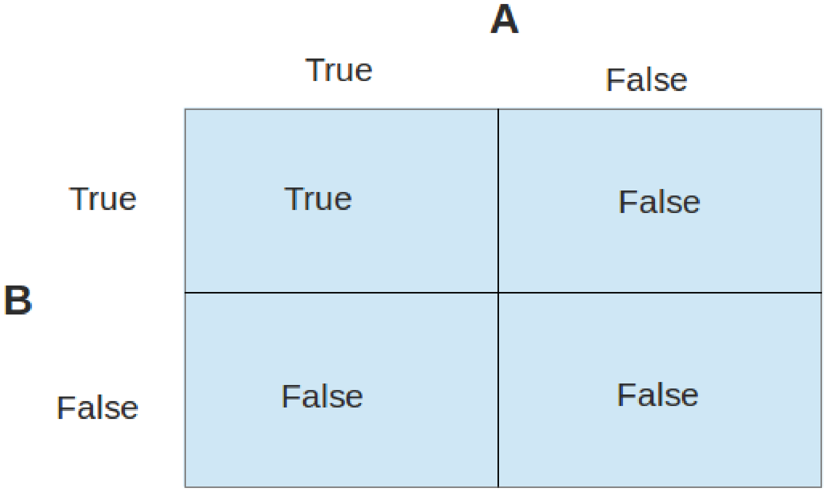
If statements

Examples of conditions

- `b = 40`
- Equality condition: `b == 40` → `True`
- Negation (also known as the logical complement):
  `b != 40` → `False`
  `not(b == 40)` → `False`
- Or condition: `b >= 40` → `True`
  `b == 40 or b > 40` → `True`
- And condition: `b > 30 and b < 70` → `True`
  `b > 30 and b < 35` → `False`

Logicals

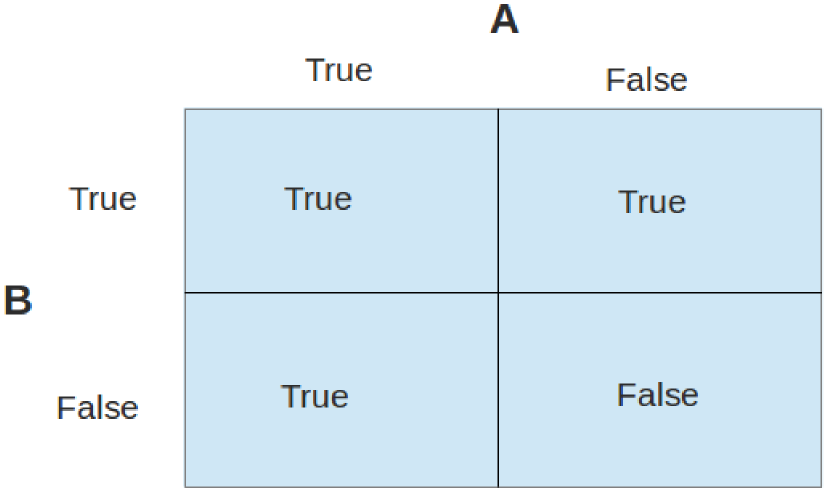
And



		A	
		True	False
B	True	True	False
	False	False	False

Logicals

Or



		A	
		True	False
B	True	True	True
	False	True	False

Lists

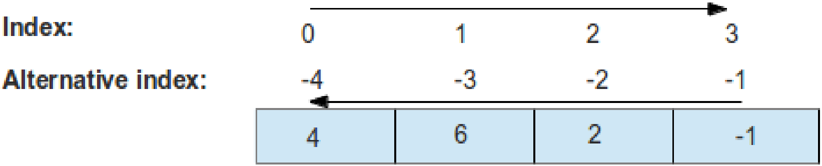
Definition

- List: a Python data structure that can hold a sequence of elements/items/values. Elements can be added to, or removed from, a list.
- A list can be defined by enclosing the elements (separated by commas) in square brackets, e.g. `L = [4, 6, 2, -1]`
- Append an element to the end of a list by using the general form: `list_name.append(value)`
- Get the length of a list using the `len` function: `len(L)` returns a value of 4.

Lists

Referencing elements

- Each element of the list is assigned an index, with the first element's index being zero.
- To reference/access an element of the list, follow the general form: `list_name[element_index]`
  - `L[0]` → `4`
  - `L[-1]` → `-1`
  - `L[len(L)-1]` → `-1`



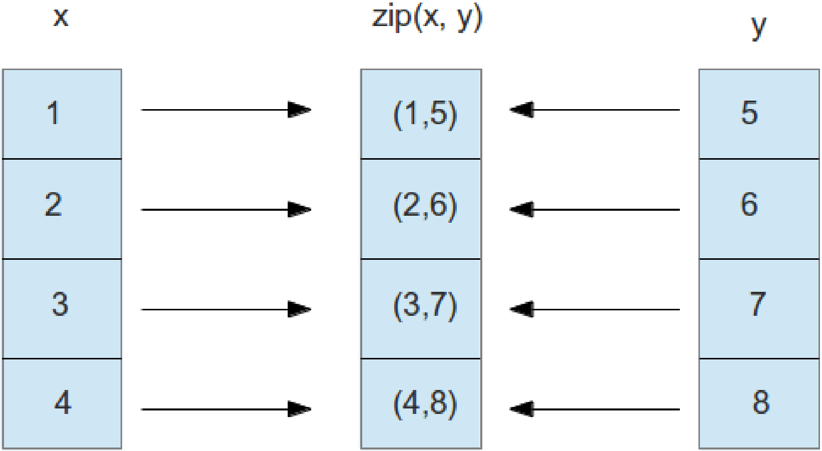
Lists
Slicing

- Sub-lists can also be extracted from a list. This is known as slicing.
- General usage: `list_name[start_index:end_index]`. By default, `start_index` is implicitly set to 0 if not provided by the user. Similarly, `end_index` is implicitly set to `len(list_name)` if not provided.
- `L[0:len(L)]` ≡ `L[:]` ≡ `L`
- Example: `L = [2, 5, 8, 0, 5, 1]`.
  `A = L[:4]` → `A = [2, 5, 8, 0]`.

Lists

Zip two lists

- Elements from two lists can be combined using the zip function to form a new list: a list of tuples.



Loops

Definition

- Loop: a programming construct that allows a block of code to be executed multiple times.
- Two types of loop: `while` and `for`.

Loops

While loop

- Iterate indefinitely while some boolean condition is `True`. This condition is called the loop invariant.
- The invariant is evaluated before the start of each iteration. If it evaluates to True, Python executes all the statements in the indented code block.
- General form:

```
while(boolean condition is True):
   Statements to be executed
   within a single loop iteration.
```

- Remember to update any variables that the boolean condition depends on within the loop, e.g. if the condition is `i < 100`, you might do `i = i + 1`. Otherwise, `i` will never increase, the boolean condition will always be True, and the loop will never end.

Loops

For loop

- For loops must have something to iterate over. This is usually a list or an array.
- General form of a for loop:

```
for iterator in iterable_object:
    Do some cool stuff, possibly involving the iterator.
```

- Example:
  - Iterator: i
  - Iterable object: range(0, 3) → [0, 1, 2]

```
for i in range(0, 3):
    print i*2
print "Out of the loop!"
```

  - Iteration 1: i = 0, Python prints out 0 to the screen.↷
  - Iteration 2: i = 1, Python prints out 2 to the screen.↷
  - Iteration 3: i = 2, Python prints out 4 to the screen.↷
  - No more elements to iterate over, so the loop ends.
  - Python prints "Out of the loop!"

Functions

Definition

- Function: a programming construct that expects zero or more inputs, and returns zero or more outputs.

- General form:

```
def function_name(input1, input2):
    The function's body.  Compute any output values here.
    return output1, output2, output3
```

- The inputs are known as arguments.

- Example: the function `len` takes in 1 argument (a list/tuple/string/...) and returns 1 value (the length of that list/tuple/string).

User input

- User input can be read from the keyboard using the `raw_input` function. This takes 1 argument (a message that you want to show to the user, e.g. "Enter a number between 1 and 10"), and gives 1 output (the user's input).

- This return/output value of the `raw_input` function is always a string.

- Remember: numerical data in string form needs to be converted, or casted, to a float or integer.

Exception handling

Definition

- Exceptions: errors that occur when Python cannot properly execute a line of code at run-time.
- Common examples include:
  - Trying to reference an element in a list that doesn't exist. e.g. `L = [1, 2]; print L[2]`
  - Trying to divide by zero.
- It is important that we handle these errors gracefully, because:
  - The standard exception error message will probably confuse an average user.
  - The program might not be able to continue executing properly.

Exception handling

try-except blocks

- try-except blocks are used to handle exceptions.
- Identify lines of your code where an exception may occur, and wrap them in a `try` block.
- In the `except` block, we decide how to handle the error. e.g.

```
try:
   number = float(raw_input("Enter a number:")
except ValueError:
   print "Error:  you didn't enter a number."
```