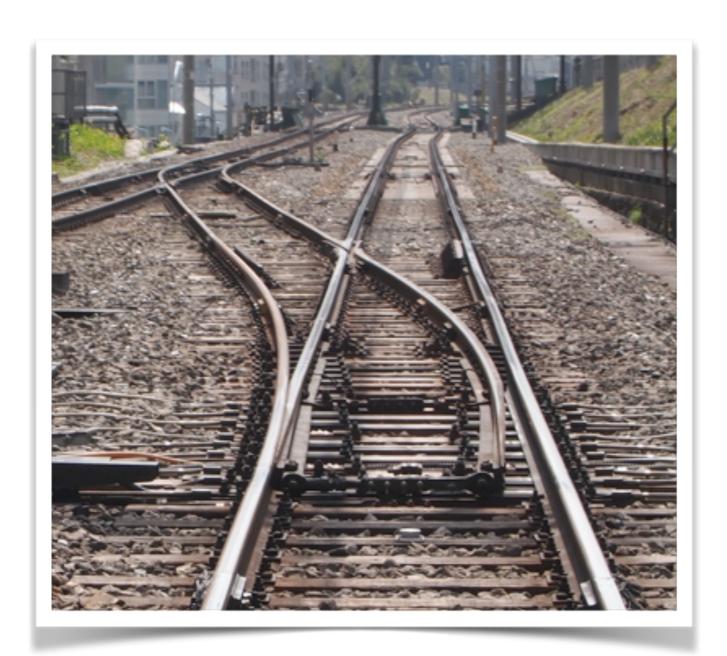
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INTRODUCTION TO NUMERICAL ANALYSIS

Lecture 1-2: Control flow

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CONTROL FLOW



You are not always on the same route, do you?

CONDITIONAL EXECUTION

- One definitely needs the ability to check some certain conditions and change the behavior of the program accordingly.
- Conditional statements give us this ability.
- The simplest form is the <u>if statement</u>:

```
if x > 0:
    print('x is positive!')
```

- The <u>boolean expression</u> (x>0) after if is called the <u>condition</u>.
- If it is true, then the indented statement (print) gets executed. Otherwise nothing will happen.

THE STRUCTURE

The condition, which must be a boolean expression.

header is ending with a colon (:)

```
if x > 0:
    print('x is positive!')
```

Body has to be indented.

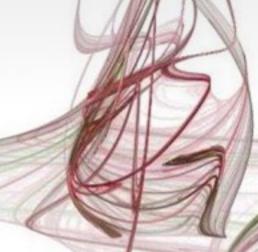
The body can contain any number of statements.

HEADER

BODY

Indentation is important. The lines started with the same indentation is treated as a group. The convention is four spaces, but this is not restricted.

BOOLEAN EXPRESSIONS



- A boolean expression is either true or false.
- For example, the basic operator "==" compares two operands and produces True if they are equal:

```
>>> 5==5
True
>>> 5==6
False
```

■ The True and False (T,F must be capital) belong to bool type:

```
>>> type(True)
<class 'bool'>
```

RELATIONAL OPERATORS

■ The == operator is one of the relational operators; the others are:

```
x != y  # x is not equal to y
x > y  # x is greater than y
x < y  # x is less than y
x >= y  # x is greater than or equal to y
x <= y  # x is less than or equal to y</pre>
```

- A common error is to use a single equal sign "=" instead of a double equal sign "==".
- There is no "=<" or "=>".

LOGICAL OPERATORS

- There are three logical operators: "and", "or", "not".
- The operands of the logical operators should be boolean expressions, but Python is not very strict any nonzero number is interpreted as True.

```
x > 0 and x < 10 True 0 < x < 10
False otherwise

n % 2 == 0 or n % 3 == 0 True if n is multiple of 2 or 3
False otherwise

not (x > y) True if x is less or equal to y
False x > y
```

ALTERNATIVE EXECUTION

- Alternative execution with two possibilities and the condition determines which one gets executed.
- The syntax:

```
if x%2 == 0:
    print('x is even')
else:
    print('x is odd')
```

■ Since the condition must be true or false, exactly one of the **branches** will be executed.

CHAINED CONDITIONALS

■ Sometimes there are more than two possibilities — one way to express a computation like that is a chained conditional:

```
if x < y:
    print('x is less than y')
elif x > y:
    print('x is greater than y')
else:
    print('x and y are equal')
```

- Exactly one branch will be executed. There is no limit on the number of elif ("else if") statements.
- If there is an else, it has to be at the end.

NESTED CONDITIONALS

■ One conditional can also be nested within another. For example:

indentation of the statements define the blocks.

The first branch contains a simple statement. The second branch contains another if statement, which has two branches of its own.

NESTED CONDITIONALS (II)

- Indentation makes the structure apparent. But nested conditionals become difficult to read very quickly. Good to avoid them.
- Logical operators often provide a way to simplify nested conditional statements.

```
if 0 < x:
    if x < 10:
        print('x is a positive single-digit number.')</pre>
```

Simplified with "and":

```
if 0 < x and x < 10:
    print('x is a positive single-digit number.')</pre>
```

COMMENT: INDENTATION

- Leading whitespace at the beginning of lines is used to define the indentation level of the line, which is used to determine the grouping of statements.
- Due to the nature of various text editors, it is unwise to use a mixture of spaces and tabs for the indentation.

Example of a correctly (but confusingly?) indented code:

```
def perm(l):
    if len(l) <= 1:
        return [l]
    r = []
    for i in range(len(l)):
        s = l[:i] + l[i+1:]
        p = perm(s)
        for x in p:
            r.append(l[i:i+1] + x)
    return r</pre>
```

INTERMISSION



```
>>> a = 1.0/3.0
>>> b = 1.0 - 2.0/3.0
>>> a == b
```

Do you see **True** or **False**? Why?

```
>>> not (((True and (True or False) and True) and False) or False) and False or True
```

Do you see **True** or **False**? Why?



INTERMISSION (II)

■ Try this kind of "weird-indented" programs?

```
print "a"
   print "aa"
   print "aaa"
   print "aaaa"
```

or

```
x = 3
if x < 4:
    print('x is smaller than 4.')
    if x > 1:
        print('x is greater than 1.')
```

Which line do you expect to see the (syntax) error?



INTERMISSION (III)

■ Try this kind of "weird-indented" programs?

```
x = y = 2
if x > 1:
    if y < 4:
         x += y \leftarrow x += y is the same as x = x + y
         y += 4  y += 4 is the same as y = y + 4
    elif x + y > 1:
         y = (x + y) *2
    else:
       x -= (y / 2)
elif y == x % 2:
   y = x**2
else:
   x = y**2
print(x,y)
```

What do you expect to see in the end (x,y)?

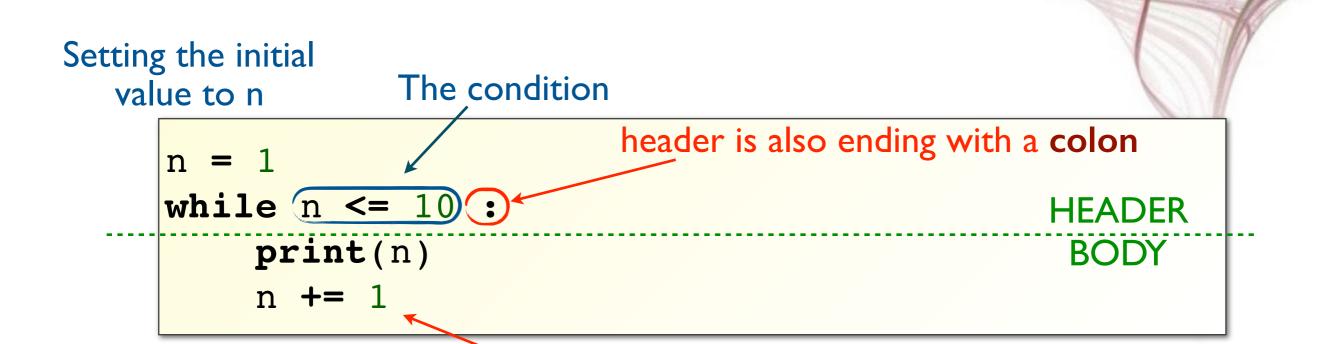


ITERATION

- Computers are often used to automate repetitive tasks: repeating identical or similar tasks.
- Because iteration is so common, Python provides several language features to make it easier:
 - □ The while statement, which can be used as general loops.
 - □ The **for** statement, which is usually used to run through a block of code for **each item in a list** sequentially.
- An example (printing 1 to 10 on the screen):

```
n = 1
while n <= 10:
    print(n)
    n += 1</pre>
```

THE "WHILE" STATEMENT



- The flow of execution for a while statement:
 - □ Evaluate the condition, yielding **True** or **False**.
 - ☐ If the condition is false, exit the while statement.
 - □ If the condition is true, execute the body and then go back to step 1.

n += I is the same as n = n + I,

means n should be updated with n+1

TERMINATION OF THE LOOP

- The loop should change some of the variables so that eventually the condition becomes false and ends the loop (e.g. the n+=1 statement).
- Otherwise the loop will repeat forever as **an infinite loop**.
- Or use the **break** statement to jump out of the loop:

CONTINUETHE LOOP

- *Break* versus *Continue* (can be confusing for beginners):
 - The break statement, which should jump out of the loop can continue to execute the next statement.
 - □ The **continue** statement, which should jump back to the head of the loop, check the condition, and continue to the next iteration.

```
n = 0
while True:
    n += 1
    if n > 10:
        break
    if n % 2 == 0:
        continue
    print(n)
print('the end!')
continue
```

LOOP – ELSE STATEMENT

- Similar to the if statement, else can be attached to the end of loop.
- The code block after else will be executed if the loop ended normally (without calling the break statement):

THE "PASS" STATEMENT

- The pass statement does nothing. It can be used when a statement is required syntactically but the program requires no action.
- For example:

```
while True:
    pass # this is a do-nothing, infinite loop
```

```
if n == 1:
    print('One!')
elif n == 2:
    print('Two!')
elif n == 3:
    print('Three!')
else:
    pass 
    do nothing, simply a placeholder for now
```

THE "FOR" STATEMENT

- The **for** statement in Python differs a bit from what you may be used to in C it iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence.
- An example (iterating the letters in a string):

Output:

back hack Jack lack mack pack rack sack tack yack

ACCESSING A LIST

■ The for statement can access to the elements in a list. For example:

```
animals = ['cat','dog','horse','rabbit','mouse']
for a in animals:
    print(a)

odd_numbers = [1,3,5,7,9]
for n in odd_numbers:
    print(n)
```

The list "odd_number" can be actually replaced by a simple call to the built-in function range()

THE RANGE() FUNCTION

■ If you do need to iterate over a sequence of numbers, the built-in function range() comes in handy. It can generate lists containing arithmetic progressions:

```
>>> range(10)
range(0, 10)
>>> type(range(10)) \( \infty\) since python 3 range() has its own type!
<class 'range'>
>>> list(range(10))
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> list(range(5, 10))
[5, 6, 7, 8, 9]
>>> list(range(0, 10, 3))
[0, 3, 6, 9]
>>> list(range(-10, -100, -30))
[-10, -40, -70]
```

The given end point (e.g. 10) is never part of the generated list.

RANGE() + FOR



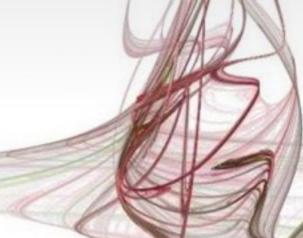
```
for n in range(1,10,2):
    print(n)
```

■ To iterate over the indices of a sequence, you can combine range() and len() as follows:

```
animals = ['cat','dog','horse','rabbit','mouse']
for i in range(len(animals)):
    print(i,'=>',animals[i])
```

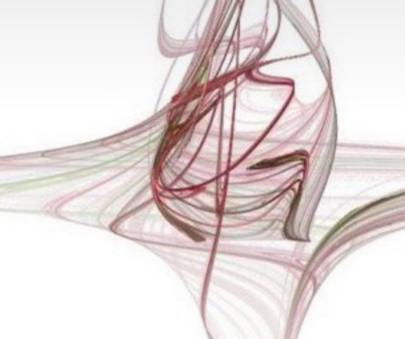
The function **len()** return the number of elements in a list or how many characters in a string.

A LITTLE BIT MORE ON THE LIST



■ Python has a number of data types, used to group together other values. The most versatile is the **list**. For example:

A LITTLE BIT MORE ON THE LIST (CONT.)



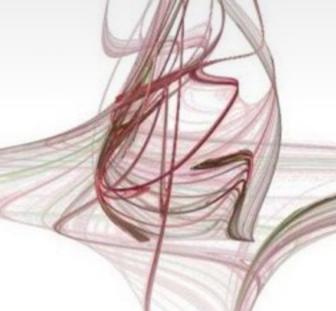
■ Few more operations with python list:

```
>>> b = ['spam', 'eggs', [1,2,[3,4,5]]] \Leftarrow anything can be in a list;
>>> b
                                                   including another list!
['spam', 'eggs', [1, 2, [3, 4, 5]]]
>>> b[0] = 'foo' \Leftarrow list is mutable!
>>> b
['foo', 'eggs', [1, 2, [3, 4, 5]]]
>>> b.append(1+3j)
>>> b
['foo', 'eggs', [1, 2, [3, 4, 5]], (1+3j)]
>>> len(b) \Leftarrow there are 4 items!
4
```

A LITTLE BIT MORE ON THE STRING

- The basic operations on the string are quite similar to that of list.
- A similar way can be used to access individual characters, or a sub-string.

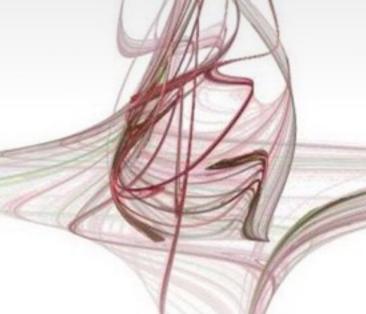
A LITTLE BIT MORE ON THE STRING (CONT.)



■ Few more operations with python string:

```
>>> fruit = 'banana'
>>> fruit
                                     Python string/list features are
                                        actually very powerful!
'banana'
                                   We will come back to discuss them
>>> fruit.upper()
                                    in details at a upcoming lecture.
'BANANA' ← return the upper case
>>> fruit[0]
'b'
>>> fruit[0] = 'c'
                                 TypeError: 'str' object does
                                   python strings are immutable!
not support item assignment
>>> 'c'+fruit[1:] \Leftarrow you can only do this
'canana'
```

PUT IT ALL TOGETHER



■ Testing prime numbers:

```
17 is a prime number
...
187 is a multiple of 11
```

PUT IT ALL TOGETHER (II)

■ Or one can get the testing number with the raw_input function:

```
inp = input('Please enter a number: ')
m = int(inp)
for n in range(m):
    if n<2:
        continue
    if m%n == 0:
        print (m,'is a multiple of',n)
        break
else:
    print (m,'is a prime number')</pre>
```

```
Please enter a number: 127 ← input by keyboard
127 is a prime number
```

INTERMISSION

- Please try to find out:
 - Is 1237 a prime number?How about 12347, 123457, and 1234567?
 - □ Print out all of the factors of **12345678**.



- Up to now we have gone through:
 - The basic structure and syntax of python
 - Variables and operators
 - □ Branching, conditionals, and iterations
- You should be able to write a meaningful program and carry out some interesting calculations already!
- Let's start our 2nd round of hands-on session now!



■ Practice 1:

Print a multiplication table up to 12x12 on your screen:

```
2x1 = 2
2x2 = 4
2x3 = 6
2x4 = 8
2x5 = 10
2x6 = 12
...
12x12 = 144
```



Find out all of the prime numbers which are smaller than 10000.

```
2 3 5 7 11 13 17 19 23 29 31 37 41
43 47 53 59 61 67 71 73 79 83 89
97 ... 9973
```



■ Practice 3:

A score and grade mapping is given below:

```
90–100: A+ 85–89: A 80–84: A–77–79: B+ 73–76: B 70–72: B–
```

67–69: C+ 63–66: C 60–62: C–

50–59: D 40–49: E 0–39: F

Please write a small program which can convert the score to grade levels, e.g.: