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Introduction to Python

THE APTAMER STREAM

Spring 2016

"Ars longa, vita brevis." (Art is long, life is short.)

Week 1: A 50-Minute Language Overview

Course overview

- Lectures will be fast-paced (at first) so you can have exposure to enough material to be able to write interesting programs
- Lectures are for *exposure*, exercises are for *learning*
  - Feel free to ask questions during lectures
- I am not assigning grades; this course is for your own personal development and enrichment
  - This means that you should focus on work for your actual classes first
- Topics: Python syntax, programming concepts, (very) basic data structures and algorithms, applications to biology
- Recommended: try solving bioinformatics problems on Rosalind (http://rosalind.info/)
  - Some of the exercises I assign may be inspired by Rosalind problems
- Set up a convenient folder (in Dropbox, on the Desktop, etc…) for your Python scripts
- Independent effort on your part is required
- You can collaborate with others, but struggle on your own first

Installing Python

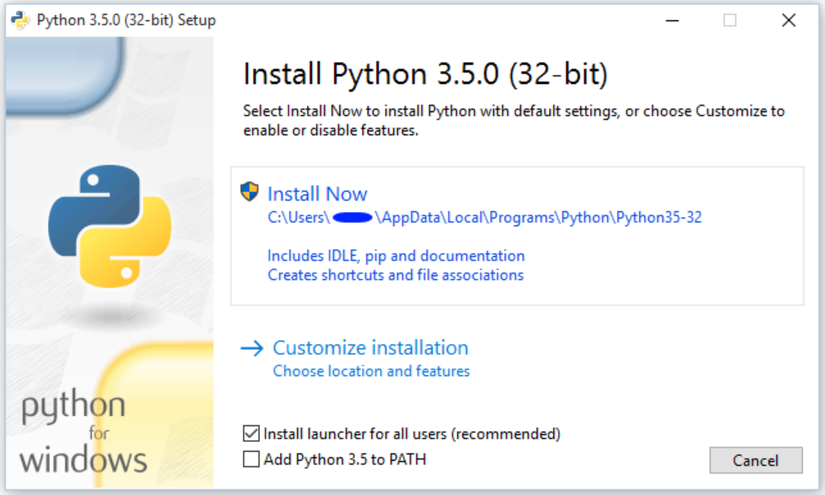
Visit https://www.python.org/downloads/

Directions linked on the mini-course website under "Readings"

Mac OS and Linux users may already have Python

- However, do not use Python 2.x
- Type `python --version` in Terminal to check which version you have

Make sure to use **Python 3.x** (latest: **3.5.1** as of March 2016)



Python 3.5.0 (32-bit) Setup

Install Python 3.5.0 (32-bit)

Select Install Now to install Python with default settings, or choose Customize to enable or disable features.

Install Now
C:\Users\[redacted]\AppData\Local\Programs\Python\Python35-32

Includes IDLE, pip and documentation
Creates shortcuts and file associations

→ Customize installation
Choose location and features

☑ Install launcher for all users (recommended)
☐ Add Python 3.5 to PATH

http://python.readthedocs.org/en/latest/using/windows.html

Interactive mode

In Command Prompt/PowerShell/Terminal: type `python` to enter Python's interactive mode

In IDLE: IDLE automatically launches in interactive mode

Expressions are combinations of values, variables, and operators

Expressions to try in interactive mode (use Python as a calculator):

`2 + 2`	`2 ** 3`
`3.6 / 3`	`7 – 9 * 8`
`3.6 // 3`	`(7 – 9) * 8`
`17 % 4`	`9 + 2 // 3`

What do you think `//`, `%`, and `**` do?

Each expression in the table above **returns** a **value**

Three distinct numeric **types**: **int** (integers), **float** (floating-point numbers), and **complex** (complex numbers, which we will likely not use in this course)

- Integers: 4, 99, -2, 0
- Floating-point numbers: 3.3, 3.33, 7.0, -2.3, 7e9

First program (script mode)

In IDLE, go to File > New File to begin writing a new script. Type the following line.

```
print("Hello world!")
```

Save this in a folder with a sensible name, like "hello.py".

Then, run your program (in IDLE, go to the Run > Run Module or press F5).

`print()` is a **function** (more on functions later).

`"Hello world!"` is a **string** that is passed to the `print()` function as a **parameter**.

You can print out multiple items on the same line using `print()` as long as the items are separated by a comma.

Strings

Strings are basically sequences of characters.

They are surrounded by straight quotation marks (single or double, as long as they match on both sides of the string).

Do not use curly quotes.

Examples of strings:

```
"Hello"
"test string"
"12345"
"testing"
"2 + 2"
"ACTGGTCGATCGAT"
```

" " (straight)

“ ” (curly)

Variables

If you want to hold on to data, **assign** it to a **variable.**

Examples:

```
pi = 3.14159
greeting = "Bonjour."
```

Variable **identifiers** (names) are often lowercase and derived from English words, but you can use almost any sequence of letters, numbers, and underscores, as long as the sequence **begins with a letter** and is **not a reserved keyword** (a word reserved for the Python language).

Not valid names:

```
    2chainz
    #winning
    space bar
```

Reserved keywords

```
False      class      finally    is         return
None       continue   for        lambda     try
True       def        from       nonlocal   while
and        del        global     not        with
as         elif       if         or         yield
assert     else       import     pass
break      except     in         raise
```

Don't try to use any of these for variable names!

Variables cont.

You can reassign values to variables you have already assigned values to.

Example:

```
number = 2
print(number)
number = 7 * 7
print(number)
number = "This is a string."
print(number)
```

Variable updating

You can update variables by adding a value to the value already stored by the variable.

Example:

```
x = 4
print(x)
x = x + 2
print(x)
x += 2
print(x)
```

Besides addition, you can also subtract, multiply, divide, and even use the modulo (remainder) operator (%).

String concatenation

The + operator is useful for more than adding numbers; you can also use it to **concatenate** (combine) strings, creating a new string.

```
string_one = "Hello "
string_two = "world!"
print(string_one + string_two)
```

You cannot "subtract" a string from another string the way you can concatenate strings together.

You cannot concatenate a string and an integer without converting the integer to a string first using `str()`.

Comments

Use the pound sign (#) to mark off the rest of the line as a comment that will not affect the running of the program. This is useful for leaving notes to yourself or for disabling code while debugging.

Example:

```
number = 3
# number = 4
print(number) # TODO: add new features
```

Commenting is very important! Why?

You might leave a project for a few months, then come back to it and not remember why you wrote the original code that way.

You may work on a team where other people may have to build upon your code but have not seen it before and need to get up to speed quickly.

Getting user input

You can prompt the user to type in something, like his/her name, and save the value that is given.

This is useful for numerous things, like text-based games.

Use the `input()` function to get input ; like `print()`, `input()` accepts a string **parameter** (or **argument**).

```
name = input("Enter your name: ")
print("Hello " + name + "!")
```

The string passed as a parameter to `input()` is the prompt that will be displayed to the user.

Try to come up with some creative ideas for using user input!

Logic and control flow

- Logic
  - `if` statement
  - `else` statement
  - `elif` statement
- Preview of lists
- Loops
  - `for` loops (`range()` function in Week 2)
  - `while` loops
- More control flow
  - `break`, `continue`, `pass` statements (Week 2)

Boolean values (`True` and `False`)

In Python, the objects `True` and `False` are **Boolean values**.

When you perform a test using **relational (comparison) operators** (like `<`, `>=`, or `!=`), the test returns one of these values.

Examples:

```
3 > 2 # returns True
3 < 2 # returns False
```

At home: what do you think would happen if you tried to add a number to a Boolean value in Python?

Examples:

```
1 + True # can you guess what happens?
3 + False # what happens here?
```

`if` statements

`if` statements allow certain actions to be performed when a specific **condition** is met.

Example:

```
x = 5
if x > 2:
    print("x is greater than 2")
```

Here, `x > 2` is the condition. The `if` statement checks if the condition is **true** or **false**; if the condition is true, the code under the `if` statement is executed.

Specifically, `x > 2` returns a value of `True` in the case above because x was assigned the value of 5.

At home: Truth values

What will this code output?

```
if 238:
    print("success!")
```

How about this?

```
if 0:
    print("success!")
```

How about this?

```
if -49:
    print("success!")
```

`else` statements

`else` statements are often seen with `if` statements. The code under an `else` statement runs when a condition is not met.

```
name = input("Please enter your name: ")
if name == "Paul":
    print("Greetings, " + name + "!")
else:
    print("Hello, " + name + ".")
```

Nesting `if` statements

When you have multiple conditions you want to check, one thing you can do is **nest** `if` statements.

```
if grade > 90:
    if grade > 93:
        if grade > 97:
            print("Grade = A+")
        else:
            print("Grade = A")
    else:
        print("Grade = A-")
else:
    print("Grade is less than A-")
```

(There are better ways to write this code, by the way.)

`elif` statements

`elif` is short for "else if" and helps reduce the indentation you need.

```
if name == "Paul":
    print("Greetings, " + name + "!")
elif name == "Farzam":
    print("Salutations, " + name + "!")
else:
    print("Hello, " + name + ".")
```

Logical operators: and

You can evaluate whether multiple conditions are all true by using the **logical operator** and.

Example:

```
x = 20
if x > 5 and x < 21:
    print("Success 1")
    # "Success 1" is printed
if x > 5 and x > 21:
    print("Success 2")
    # "Success 2" is not printed
```

Logical operators: or

You can evaluate whether *at least* one condition in a set of conditions is true by using the **logical operator** or.

Example:

```
x = 20
if x > 5 or x < 21:
     print("Success 1")
     # "Success 1" is printed
if x < 5 or x < 21:
     print("Success 2")
     # "Success 2" is printed even though the first
     # condition is false
if x < 5 or x > 21:
     print("Success 3")
     # "Success 3" is not printed
```

Logical operators: not

`(not a)` returns `True` if a returns `False` and returns `False` if a returns `True`. This is called **negation**.

Example:

```
x = 20
print(x > 3) # prints "True"
print(not (x > 3)) # prints "False"
if x > 5 or x < 21:
     print("Success 1")
     # "Success 1" is printed
if not (x > 5 or x < 21):
     print("Success 2")
     # "Success 2" is not printed
```

At home: summary (truth table)

`a`	`b`	`a and b`	`a or b`	`not a`
`True`	`True`	`True`	`True`	`False`
`True`	`False`	`False`	`True`	`False`
`False`	`True`	`False`	`True`	`True`
`False`	`False`	`False`	`False`	`True`

"Carpe noctem." (Please fill out the survey!)

Week 2: Functions, Strings, and Loops

Notes

- Gone on 4/15 because of the Undergraduate Research Forum; Farzam will be holding a problem solving/coding practice session (let us know if you plan on coming)!
- Skipping object-oriented programming for now, but we will be talking about writing basic functions
- Questions about problems 1 or 2? (the whole set is due next week)
- Paul Points system (suggested by Rishabh Kothari)

Functions

Very important concept!

Functions generally take inputs and do something with them; they may also **return** an output.

- `print()` is a function.
- `type()` is a function that tells you the type of a value.

Examples (type conversion, integer to string):

```
a = 74
b = str(a)
type(a)
type(b)
```

Similar functions: `int()`, `float()`

Note: `int()` does not round; it simply removes the fractional part of a number!

```
c = int(5.55) # returns 5
```

Examples of built-in functions

`abs(x)` – returns the absolute value of a number

`len(x)` – returns the length of an object (the number of items)

This is useful for working with strings and lists!

`pow(x, y)` = returns x to the power y (equivalent to `x**y`, which we have seen before)

Defining custom functions

```
def myfunction():
     print("This is my function.")
     print("There are many like it.")
     print("But this one is mine.")

myfunction() # call our function
```

Notice the indentation on the `print()` lines. Python uses indentation to indicate lines of code in the same **block**, while other languages would surround blocks with braces instead. Most of our blocks will be **function bodies** (the code in functions). You can indent with either a tab character or a fixed number of spaces (typically 2 or 4).

This function does not take any arguments, but you could easily make it so that it does (stay tuned). This function also does not return anything.

Function with a return value

```
def addTwo(x):
    return x + 2
addTwo(4)
```

Here's a function that takes a number and **returns** the value of that number plus two. To indicate a return value, use the `return` keyword.

Many programs operate by primarily making use of this basic principle; functions return values that can be used as parameters to other functions. There is an even entire branch of programming called *functional programming*. See Haskell and R for examples of where this can be done.

Scope

Variables assigned a value in a block do not exist with that value outside of the block. Variables defined in a block are only accessible while you are inside the block (the variable has **local scope**). Variables defined outside of blocks are accessible to every block inside.

```
a = 3 # this a is in global scope
def myfunction():
    a = 4         # a and b are in local scope
    b = 5         # when working with this function
    print(a + b) # uses the a in local scope
                  # not the a in global scope
myfunction() # prints 9
print(a)     # prints 3, not 4
print(b)     # NameError
```

String review

A **string** is an immutable sequence of characters. Immutable means that you cannot change the characters that make up a particular string. You can reassign a new string to a variable, but this is not the same thing as actually changing the original string itself. (whiteboard)

Strings are zero-indexed, meaning that the first item in a list has index 0, the next item has index 1, and so on…

Let's look at one string example.

```
stream = "Aptamer"
```

Character	A	p	t	a	m	e	r
Index	0	1	2	3	4	5	6

Note that "A" is not equal to "a"; these are distinct characters.

Strings cont.

You can retrieve the first item from the string `stream` by typing `stream[0]`. You can retrieve the last item from stream by typing `stream[6]` (the string is seven characters long, but the last index is 6).

```
stream = "Aptamer"
```

Character	A	p	t	a	m	e	r
Index	0	1	2	3	4	5	6

```
print(stream[0]) # prints A
print(stream[3]) # prints a
print(stream[2+2]) # prints m
```

String of unknown length

What do you do if you want the last character of a string that the user has input into your program, but you don't know the length of the string? Use len()!

```
name = input("What is your name?")
print("The last letter is " + name[len(name) – 1])
```

Why do we need to subtract 1?

Notice that we are using the value that len(name) returns as part of the expression for the index for the last character.

Escape characters

Certain characters in strings have special meaning. For example, "\n" means to produce a new line. "\n" is an **escape character**. This looks like two characters, but really, the whole thing is treated as one special character.

```
string = "Hello\nworld!"
print(string)
```

String slicing!

What do you do if you just want the third through fifth characters of a string? Use slicing! Slice syntax looks similar to the syntax for accessing an element. To get a slice of string `string` from index a to index `b`, use `string[a:b]`. Just like range(), you can also add a step parameter! The syntax is `string[start:stop:step]`.

```
stream = "Aptamer"
slice = stream[2:5] # why 2 and 5?
print(slice)
```

What happens if you use -1 for step?

Think about range()!

Strings: method demonstrations

```
name = "paul nguyen"
name.capitalize() # only affects first letter
name.upper()
name.lower()
name.find("ng")
name.find("z")

test = "    Hello world!    "
test.strip()
test.lstrip()
test.rstrip()
```

for loop syntax

for loops sort of read like English statements. For every "thing" in a sequence, like a list of numbers or names, we want to do something with that "thing".

```
for name in names:
    print name
```

`name` is a variable that only exists in the for loop. `names` is a list of strings – in this case, the strings represent names of people.

for loops with range()

Looping over a sequence is a common concept in programming. Let's talk about looping over a sequence of integers using for loops and range().

The range() function takes three parameters: a start integer (optional), a stop integer (required), and the step size (optional). If you don't include a start and step, Python uses 0 for the start and 1 for the step.

Note that the stop integer is not included in the sequence, but the start integer is (e.g., range(1, 10) can be thought of as the sequence 1, 2, 3, 4, 5, 6, 7, 8, 9; this is not quite correct in Python 3, but let's go with it for now).

What do you think this code might print?

```
for i in range(5, 12):
    print(i)
```

Note on range()

In Python 2, range() was called xrange() and range() meant a different function that is not used in Python 3, so if you are looking at old code, keep this in mind.

range() with step size

```
for i in range(0, 10, 2):
    print(i) # print the even numbers from
             # 0 to 10, not including 10
```

range() in reverse

```
for i in range(10, 0, -1):
    print(i) # print the numbers from 0 to
             # 10, not including 0, in
             # reverse order
```

for loops with sequences

for can be used to **iterate** over sequences such as strings, which are basically sequences of characters. This is extremely powerful; we will talk more about iteration in the future.

```
vowels = "AEIOU"
word = "facetiously"
vowel_count = 0
for letter in word.upper(): # make string uppercase
     if letter in vowels:
          vowel_count += 1
print("The number of vowels is: " + str(vowel_count))
```

`while` loops

`while` loops continually execute the statements within while a condition is met. Be careful about accidentally writing infinite loops! You should either update the condition that the `while` loop is checking or otherwise `break` out of the loop.

```
x = 0
while x <= 5:
    print(x, x*x)
    x += 1
```

If we have time…

Python data model:
https://docs.python.org/3/reference/datamodel.html

for loops

for can be used to **iterate** over sequences such as lists! This is extremely powerful. We will talk more about iteration in the future.

```python
fruits = ["apple", "banana", "cherry"]
for fruit in fruits:
     print(fruit)

numbers = [2, 3, 4, 5]
for number in numbers:
     number = number * 2
     print(number)
print(numbers)
```

Something to think about…

Notice that strings are sequences of characters (as mentioned earlier), while lists are sequences of items!

Just like with indices for list items, you can use [] with indices for characters in strings.

```
string_one = "ABCDEFG"
```

```
string_one[1] # returns "B"
```

In the future, we will talk about **slicing** as well as about **tuples**, another built-in sequence type in Python. We will also talk more about useful sequence operations.

A sneak peek at lists

A **list** is a **mutable** sequence of items. By "mutable," we mean that you can change the list (such as by adding items to the list or changing the items in the list).

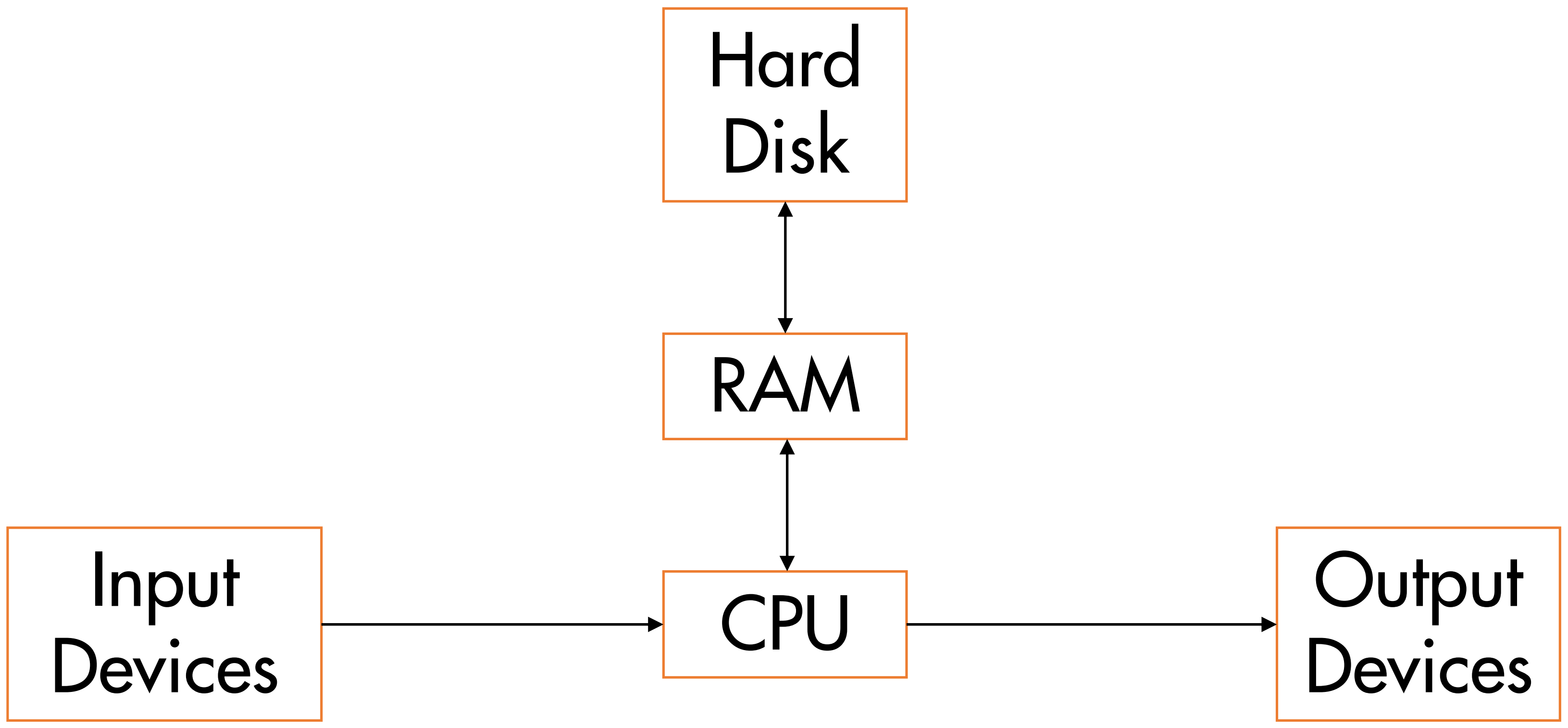
You can construct lists with brackets. Lists are zero-indexed, meaning that the first item in a list has index 0, the next item has index 1, and so on…

You can retrieve the first item from list a by typing `a[0]`.

Examples:

```
a = [] # empty list
b = [2, 3, 5, 7]
c = ["Hello", "Goodbye"]
d = ["Hello", 32]   # lists can contain items of
                    # different types
```

Introduction to computers



Variables and memory

Basically, values are stored in RAM (which serves as **main memory** or **primary memory**). There are many locations in RAM at which to save values, and each location has a **memory address**. A variable name is essentially a label for an address. When you reassign a variable, you are changing the address that the "label" is referring to.

Python takes care of memory management for our needs, so we are likely not going to talk about manual memory allocation in this course (specifically, Python uses a garbage collector to reclaim memory).

Relevant links:

- https://en.wikipedia.org/wiki/Computer_data_storage#Primary_storage
- https://en.wikipedia.org/wiki/Memory_address

*Notes on floating-point

*"On a typical machine running Python, there are **53 bits of precision available** for a Python float…" – Python Documentation (emphasis added)*

When you print floating-point numbers in Python, the output can be misleading because a) Python uses binary fractions (base 2 instead of base 10) to store floats and b) there are only a limited number of bits available.

From the documentation:

If Python were to print the true decimal value of the binary approximation stored for 0.1, it would display

```
>>> 0.1
0.1000000000000000055511151231257827021181583404541015625
```

This is a lot of digits, so Python displays a rounded number instead.

```
>>> 0.1
0.1
```

Try adding 0.1 to 0.2 and see what happens. Compare what happens when you add together ten copies of 0.1 and when you just multiply 0.1 by 10.

Other languages have this problem, so just keep this in mind when dealing with precise numbers. Use integers when you only need to deal with integers!

To be continued…

The `math` module

- Python has a useful module called `math` that provides you with extra functions you might want for calculations.
- First, in your script or in interactive mode, type the following: `import math`
  - This loads the `math` module so that you can use certain functions in your program.
  - Functions from modules are (traditionally) accessed by typing the name of the module, a dot, and the function name.
    - Example: `math.sqrt(16)`
    - This is useful because it prevents you from accidentally calling the wrong function in case you have imported another module with a function with the same name as the one you meant to use.
    - `math.sqrt()` is a function that returns a value. We can use this value inside other functions!
    - Example: `math.pow(math.sqrt(16), 3)`

At home: short-circuiting (might be slightly confusing at first)

When `and` is used, if the first argument is false, then the second argument will not even be checked.

Similarly, with `or`, if the first argument is true, then the second argument will not be checked.

Why is this useful?

Sometimes the arguments are functions that take in data and will return True or False, and perhaps the second function should only be run if the first function returns `True` to indicate that the data is valid (for example, when checking to see if a file has a certain word, your first function could check whether the file exists; if it doesn't, then the second function (the one checking for the word) won't even run due to short-circuiting).

Relevant link: https://en.wikipedia.org/wiki/Short-circuit_evaluation