

Intermediate Python

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Welcome and icebreaker

- Thank you for joining!
- 3-hours course (10am-13pm); a coffee-break for 10 minutes
- Icebreaker introduction

Course structure

- 'Beginners Python' recap
 - variables, lists, control flow statements, and functions
- 'Pythonic' concepts
 - List comprehension, ternary expressions, *args and **kwargs
 - Lambda functions
- More advanced string manipulation
- Introduction to libraries and modules
- Data structures and containers
 - Mutability
- Brief introduction to classes

Python Setup

- In this lesson, we will be using Python 3
- As an interactive computing environment to run Python exercises, there are several options:
 - a web-based interactive environment: *jupyter notebook*
 - the standard interactive shell: *python*
 - an enhanced interactive shell: *ipython*

```
dmitry@dmitry-Latitude-5430:~$ ipython3
Python 3.8.10 (default, Mar 13 2023, 10:26:41)
Type 'copyright', 'credits' or 'license' for more information
IPython 7.13.0 -- An enhanced Interactive Python. Type '?' for help

In [1]:
```

Recap(a): Python fundamentals

- **Variables:** a name for a value (`[A-Za-z0-9_]`, case-sensitive)
 - *# this is a comment*
- **Basic data types:** integers, floating-point numbers, strings, bool
 - `pi = 3.14`, `n = 5`, `name = "John"`
 - `n = n + 1`, `n += 1`
 - `str(37)`, `float('3.14')`, `int(pi)`
 - Expressions and operators: `+`, `-`, `*`, `/`, `//`, `%`, `**`
 - Assignment statements:
 - `degreesC = 5/9*(degreesF - 32)`
 - `w = x = y = z = 0` *# chain assignment*
 - `x, y, z = 100, -45, 0` *# tuple assignment*
- **Built-in functions:** `type`, `print`, `input`, `eval`, `int`, `float`, `str`, `len`, `range`, ...
 - `print(type(str(1.234)))`
 - `value1 = eval(input('Please enter a number: '))`

$$^{\circ}\text{C} = \frac{5}{9} \times (^{\circ}\text{F} - 32)$$

Recap(b): Lists

- **List:** a mutable sequence type
- Holds a collection of objects in a defined order (indexed by integers)
- A user-friendly data container to store objects of any type, even a mix of types
- Dynamic type system:
 - no need to declare the type of a variable explicitly

```
random_stuff = [1, 'apples', 3.14, ['Mars', 'Venus', 'Pluto']]
print(random_stuff[3][2])
```

Pluto

```
L = [1, 2, 3, 4, 5]
print(type(L))
<class 'list'>
```

Appending to lists:

```
chem_elements = ["oxygen"]
for i in range(2):
    chem_elements.append("hydrogen")
print(chem_elements)
```

- Easy to process lists in *for* loops (in the next slides)

Recap(b): Lists (cont.), similarities to strings

- `len` function: the number of items in a list/string
- `in` operator: tells if a list/string contains something
- `+` and `*` operators: concatenating and repeating
- **Indexing**: simple to “grab” an item/character in a list/string if you know where it sits:

```
[7,8]+[3,4,5]
```

```
[7, 8, 3, 4, 5]
```

```
[0]*5
```

```
[0, 0, 0, 0, 0]
```

```
L = ['a','b','c','d','e','f','g','h','i','j']  
print(L[4])
```

e

```
L = "abcdefghij"  
print(L[4])
```

e

The `:stop` value represents the first value not in the slice

- **Slicing**: use `:` to “grab” a range defined subsection of a list/string:
- **Looping**:

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

```
for item in L:  
    print(item)
```

```
start=3  
stop=7
```

```
print(L[start:stop]) # items start to stop-1
```

```
['d', 'e', 'f', 'g']
```

```
print(L[start:]) # items start to the end of list
```

```
['d', 'e', 'f', 'g', 'h', 'i', 'j']
```

```
print(L[:stop]) # items from beginning of list to stop-1
```

```
['a', 'b', 'c', 'd', 'e', 'f', 'g']
```

```
print(L[:]) # whole list
```

```
['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j']
```

Recap(c): Control Flow

- Conditional statements:
if, elif, else

```
grade = eval(input( ' Enter your score: ' ))
if grade>=90:
    print('A')
elif grade>=80:
    print('B')
else:
    print('C')
```

- Loop control statements:
break, continue

```
a = ['Mary', 'had', 'a', 'little', 'lamb', '.']
for i in range(len(a)+2):
    if(i < len(a)):
        print(i, a[i])
    elif (i == len(a)):
        print("The sentence has ended,")
        continue #break
    else:
        print("The end.")
```

- Loop statements: *for, while*

```
for i in range(10):
    print(i)
```

```
i=0
while i<10:
    print(i)
    i=i+1
```

- Nested loops

```
for x_axis in range(2):
    for y_axis in range(2):
        print('(' + str(x_axis) + ',' + str(y_axis) + ')')
```

- Range objects:

range(stop), range(start, stop[, step])

```
range(5)
```

```
range(0, 5)
```

```
list(range(5))
```

```
[0, 1, 2, 3, 4]
```

```
list(range(1,10,2))
```

```
[1, 3, 5, 7, 9]
```

```
len(range(5))
```

```
5
```

```
len(random_stuff)
```

```
4
```


Recap(c): Control Flow (cont.), iterators

But what is the *for* loop doing under the hood?

1. *iter()* is called on the container object
returning an iterator object
2. The iterator object defines a `__next__()` function
which facilitates access to elements one at a time
3. `__next__()` tells for loop when there are no more elements
raising *StopIteration* exception

```
uni = 'Durham'  
it = iter(uni)  
it  
  
<str_iterator at 0x7f1208f38f70>
```

```
next(it)
```

```
'D'
```

```
next(it)
```

```
'u'
```

```
next(it)
```

```
'r'
```

```
next(it)
```

```
'h'
```

```
next(it)
```

```
'a'
```

```
next(it)
```

```
'm'
```

```
next(it)
```

```
-----  
StopIteration                                Traceback (most recent call last)  
<ipython-input-31-bc1ab118995a> in <module>  
----> 1 next(it)
```

```
StopIteration:
```

Recap(d): Functions

- Principle of encapsulation

- Enables maintainability and readability alongside complexity

```
def name ( parameter list ):  
    block
```

- Reusable code

Why to write functions:

- It is difficult to write correctly
- It is difficult to debug
- It is difficult to extend

- Important parts of **function** definition:

- **Name**
- **Parameters**
- **Body**
- **Indentation**

```
# function definition  
def increment(number):  
    number += 1  
    new_number = number  
    return new_number  
  
# function invocation  
print("4+1 =", increment(4))
```

4+1 = 5

```
# only function invocation  
from math import sqrt  
print(sqrt(16.0))
```

4.0



- Every Python function has two aspects:

- 1) Function definition
- 2) Function invocation

Building on the above(a): **args* and ***kwargs*

- Collecting an arbitrary number of arguments into a tuple, when number of arguments is unknown, **args*:

```
def product(*nums):  
    prod = 1  
    for i in nums:  
        prod *= i  
    return prod  
print(product(3,4), product(2,3,4), sep=' ')
```

12 24

- Collecting an arbitrary number of keyword arguments into a dictionary, ***kwargs*:

```
def f(**kwargs):  
    for k in kwargs:  
        print(k, '**2 : ', kwargs[k]**2, sep=' ')  
f(x=3, y=4, z=5)
```

x**2 : 9
y**2 : 16
z**2 : 25

```
def f(**kwargs):  
    for key, value in kwargs.items():  
        print(key, "=", value, sep=' ', end=" ")  
f(x=3, y=4, z=5)
```

x=3, y=4, z=5,

Building on the above(b): more on expressions and lists

- Ternary expressions

```
hungry = True
state = "grumpy" if hungry else "content"
print(state)
```

grumpy

- List comprehension

```
multiples_of_three = [i for i in range(20) if i%3==0]
print(multiples_of_three)
```

[0, 3, 6, 9, 12, 15, 18]

- List methods (more after exercise)

```
L = [33, 84, 57, 11, 29, 0, 57]
L.remove(57)
print(L)
```

[33, 84, 11, 29, 0, 57]

```
L.remove(57)
print(L)
```

[33, 84, 11, 29, 0]

Exercises

Ask us questions!

Building on the above(c): list methods

- Inserting an element
- Reversing
 - Note: `reversed()` returns a 'reverse iterator' that then needs to be turned back into a list with `list()`
- Sorting
- Searching
- Emptying
- Removing duplicates
 - by converting list→set→list
 - Note: As we can see from examples, some functions actively modified whereas some returned a copy of the modified list

```
L = [33, 84, 11, 29, 0]
L.insert(2, 57)
print(L)
```

```
[33, 84, 57, 11, 29, 0]
```

```
print(list(reversed(L)))
[0, 29, 11, 57, 84, 33]
```

```
print(sorted(L))
[0, 11, 29, 33, 57, 84]
```

```
if 57 in L:
    position = L.index(57)
    print("57 is in the list. "
          "It is at position", position)
```

```
57 is in the list. It is at position 2
```

```
print(L.clear())
None
```

```
L2 = [1, 2, 2, 2, 3, 3]
print(list(set(L2)))
[1, 2, 3]
```

Building on the above (d): lambda functions

- **Lambda functions** for compact inline function definitions
- Useful when you don't want to use a function twice

lambda arguments : expression

Or more generally:

Functionally
equivalent

```
somefunc = lambda a1, a2, ...: some_expression
```

```
def somefunc(a1, a2, ...):  
    return some_expression
```

- Example

$$f''(x) \approx \frac{f(x-h) - 2f(x) + f(x+h)}{h^2}$$

```
def diff2(f, x, h=1E-6):  
    r = (f(x-h) - 2*f(x) + f(x+h))/float(h*h)  
    return r
```

```
def f(x):  
    return x**2 - 1  
  
df2 = diff2(f, 1.5)  
print(df2)
```

equivalent
t

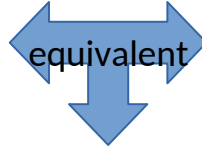
```
df2 = diff2(lambda x: x**2-1, 1.5)  
print(df2)  
  
1.999733711954832
```

Building on the above (d): lambda functions (cont.)

- **Map** applies a function to all the items in an iterable:

map(function_to_apply, list_of_inputs)

```
items = [1, 2, 3, 4, 5]
squared = []
for i in items:
    squared.append(i**2)
print(squared)
```



```
squared = list(map(lambda x: x**2, items))
print(squared)
```

[1, 4, 9, 16, 25]

```
squared = [x**2 for x in items]
```

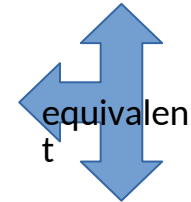
- **Filter** creates a list of elements for which a function returns true:

*Note: **list comprehensions** can accomplish everything what **map** and **filter** do*

```
number_list = range(-5, 5)
less_than_zero = list(filter(lambda x: x<0, number_list))
print(less_than_zero)
```

```
def is_less_than_zero(x):
    return True if x<0 else False

negative_nums = []
for num in number_list:
    if is_less_than_zero(num):
        negative_nums.append(num)
print(negative_nums)
```



```
negative_nums = [num for num in number_list if num < 0]
print(negative_nums)
```

[-5, -4, -3, -2, -1]

Mastering strings (a)

- Adjusting case
- Formatting strings
 - *Note: Modification requires assignment, because these functions return a copy, not modifying the original string*

```
line = "the quick brown fox jumped over a lazy dog"
print(line.find('fox'))
print(line.startswith('the'))
print(line.endswith('fox'))
print(line.replace('brown', 'red'))
print(line.split())
try:
    index = line.index('bear')
    print(index)
except ValueError:
    print("A bear isn't mentioned in the text")
```

```
16
True
False
the quick red fox jumped over a lazy dog
['the', 'quick', 'brown', 'fox', 'jumped', 'over', 'a', 'lazy', 'dog']
A bear isn't mentioned in the text
```

```
arc_update = "ThE HAmILton suPercompUTER is beiNg UPGraded"
print(arc_update.upper())
print(arc_update.title())
print(arc_update.capitalize())
print(arc_update)
arc_update = "    RSE    "
print(arc_update.strip())
print(arc_update.rstrip())
print(arc_update.lstrip())
```

```
THE HAMILTON SUPERCOMPUTER IS BEING UPGRADED
The Hamilton Supercomputer Is Being Upgraded
The hamilton supercomputer is being upgraded
ThE HAmILton suPercompUTER is beiNg UPGraded
RSE
RSE
RSE
```

- *Find()* and *index()*: return index of a substring, but the latter raises a *ValueError* exception when not found (**exception handling**)
- Querying the existence, replacing, splitting



Mastering strings (b)

- The canonical way to search a string (if not interested in the index) is very simple:

```
line = "the quick brown fox jumped over a lazy dog"
if "fox" in line:
    print("A fox has been seen")
```

A fox has been seen

- F-strings** provide a way to embed expressions inside string literals, using a minimal syntax
 - expressions are evaluated at runtime and replaced with their values

```
interests = ["football", "zoom"]
print(f"Bob enjoys {interests[0]} and {interests[1]}")

weekdays = ['Mon', 'Tue', 'Wed', 'Thu', 'Fri']
for weekday in weekdays:
    print(f"Today is {weekday}")

age = 70
print(f"Soon I'll be {age+1}!")
```

Bob enjoys football and zoom
Today is Mon
Today is Tue
Today is Wed
Today is Thu
Today is Fri
Soon I'll be 71!

Exercises

Ask us questions!

Modules

- Several ways of importing **modules**:

```
import os, sys, time # several modules at once
import numpy as np # changing module name
import math # the whole module

print(math.sqrt(16.0))
```

`import` *module list*

- Another example

`from` *module* `import` *function list*

```
from math import sqrt # only specific functions from a module
print(sqrt(16.0))
```

```
from math import * # all functions from a module
from math import log as ln # changing function name
```

Some standard and 3rd-party modules

- **math**: contains familiar math functions including:
 - *sin* , *cos* , *tan* , *exp* , *log* , *log10* , *factorial* , *sqrt* , *floor* , *ceil*
- **numpy**: fundamental package for scientific computing
 - a multidimensional array object, various derived objects (such as masked arrays and matrices), and an assortment of routines for fast operations on arrays, including mathematical, logical, shape manipulation, sorting, selecting, I/O, discrete Fourier transforms, basic linear algebra, basic statistical operations, random simulation and much more
- **scipy**: a collection of mathematical algorithms and convenience functions built on the NumPy extension

high-level commands and classes for the manipulation and visualization of data

- **matplotlib**: library for plotting
- **sympy**: symbolic computations
- Other useful modules: **os**, **random**, **itertools**, **time**, **datetime** and many more
- Python comes with a program called *pip* which will automatically fetch packages released and listed on PyPI: *pip install <some-module>*

Other useful modules in the standard library

- Tools for interfacing with the operating system: **os**

Facilitates
portability

```
import os
root = "/Users"
print(os.path.join(root, os.environ["USER"], "holiday_planning"))
# out /Users/kqkc25/holiday_planning
```

```
os.listdir("Desktop")
```

```
if not os.path.exists("blahblahblah.txt"):
    print("File not found")
    exit(1)
```

Very useful when processing
multiple data files

Using the csv module (part 1)

- Very convenient module for parsing and writing csv files
- Writing a csv

```
import csv

with open("example.csv", "w") as out_f:
    writer = csv.writer(out_f, delimiter=",")
    writer.writerow(["x_axis", "y_axis"])
    x_axis = [x * 0.1 for x in range(0, 100)]
    for x in x_axis:
        writer.writerow([x, math.cos(x)])
```

For the sake of visualization, here is the first part of the csv we just made:

x_axis	y_axis
0	1
0.1	0.99500417
0.2	0.98006658
0.3	0.95533649
0.4	0.92106099
0.5	0.87758256
0.6	0.82533561
0.7	0.76484219
0.8	0.69670671
0.9	0.62160997
1	0.54030231
1.1	0.45359612
1.2	0.36235775
1.3	0.26749883
1.4	0.16996714
1.5	0.0707372

Using the csv module (part 2)

- Now let's extract the value for y_axis when x_axis is 1.0 for the csv we just wrote:

```
import csv

with open("example.csv", "r") as in_file:
    reader = csv.reader(in_file, delimiter=",")
    next(reader) # skip header
    for row in reader:
        if row[0] == "1.0":
            print(row[1])
            break

# out: 0.5403023058681398
```

Other data structures

- **Dictionaries:** flexible mappings of keys to values
 - an unordered collection of key-value pairs
 - dictionary items are colon-connected (:) key-value pairs
 - an associative container permitting access based on a key (not an index)

```
capitals = {'Norway':'Oslo','Sweden':'Stockholm','France':'Paris'}  
# capitals = dict(Norway='Oslo', Sweden='Stockholm', France='Paris') # the same  
capitals['Germany'] = 'Berlin' # instead of append() for list  
for country in capitals:  
    print(f'The capital of {country} is {capitals[country]}')
```

```
The capital of Norway is Oslo  
The capital of Sweden is Stockholm  
The capital of France is Paris  
The capital of Germany is Berlin
```

Other data structures

- **Sets:** unordered collections of unique elements
 - represents a mathematical set
 - curly braces (`{}`) enclose the elements of a literal set

```
S = {10, 3, 7, 2, 11}
```

```
S
```

```
{2, 3, 7, 10, 11}
```

```
L = [10, 13, 10, 5, 6, 13, 2, 10, 5]
```

```
S = set(L)
```

```
L
```

```
[10, 13, 10, 5, 6, 13, 2, 10, 5]
```

```
S
```

```
{2, 5, 6, 10, 13}
```

Other data structures

- **Tuples:** immutable sequences
 - essentially a constant list which can't be changed

```
t = (2, 4, 6, 'temp.pdf')  
t = 2, 4, 6, 'temp.pdf' # can skip parentheses  
t
```

(2, 4, 6, 'temp.pdf')

- much of the same functionality as lists, including **indexing** and **slicing**

```
t = t + (-1.0, -2.0)  
t
```

(2, 4, 6, 'temp.pdf', -1.0, -2.0)

```
t[1]
```

4

```
t[3:]
```

('temp.pdf', -1.0, -2.0)

```
6 in t
```

True

- Lists are typically for homogeneous data sequences (ingredients, names) whereas tuples are ideal for heterogeneous data (entries with different meanings)

Other data structures

- **Namedtuple** is handy, but also immutable
- Namedtuple is a factory function for making a tuple class
 - In the example, *NI*Number becomes a factory function that can encapsulate data from any employee

```
from collections import namedtuple
NINumber = namedtuple('national_insurance_number', 'name NI')
employee_data = NINumber('Simon', '12345678')
print(f'Employee {employee_data.name} has NI: {employee_data.NI}')
```

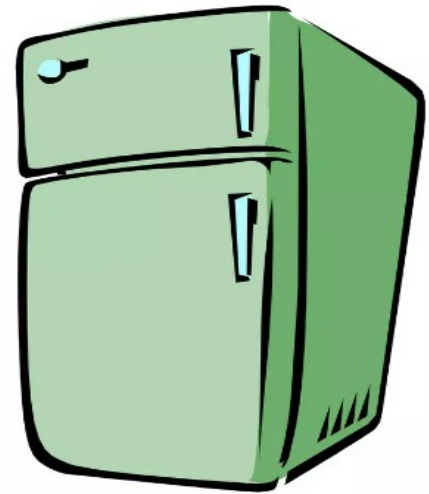
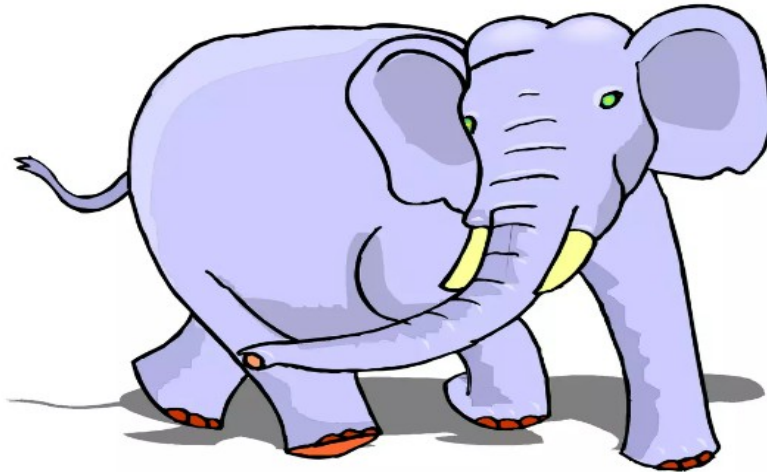
```
# assignment creates error!
# employee_data.NI = '4444'
```

Python Classes/Objects

- Python is an object oriented programming language.
- Almost everything in Python is an object, with its properties and methods.
- A Class is like an object constructor, or a "blueprint" for creating objects.

What is OOP?

Q: How do you put an elephant into a refrigerator?





```
# define element size
elephant_x = 5
elephant_y = 5
elephant_h = 5

# define refrigerator size
refrigerator_x = 6
refrigerator_y = 6
refrigerator_h = 6

def open_refrigerator_door():
    print('Refrigerator door is opened')

def package_elephant():
    print('Elephant is packaged')

def put_elephant_to_refrigerator():
    print('Elephant is in the fridge already')

def close_refrigerator_door():
    print('Close the refrigerator door')

# compare size
if elephant_x < refrigerator_x and elephant_y < refrigerator_y and elephant_h < refrigerator_h:
    open_refrigerator_door()
    package_elephant()
    put_elephant_to_refrigerator()
    close_refrigerator_door()
else:
    print('refrigerator is too small to put elephant')
```



```
class Elephant:
    def __init__(self, x, y, h):
        self.x = x
        self.y = y
        self.h = h

    def package(self):
        print('Elephant is packaged')
```

```
class Refrigerator:
    def __init__(self, x, y, h):
        self.x = x
        self.y = y
        self.h = h
        self.is_door_open = False

    def open_door(self):
        self.is_door_open = True
        print('Refrigerator door is opened')

    def close_door(self):
        self.is_door_open = False
        print('Close the refrigerator door')

    def put_elephant(self, elephant):
        if not self.is_door_open:
            self.open_door()
        if elephant.x < self.x and elephant.y < self.y and elephant.h < self.h:
            elephant.package()
            print('Elephant is in the fridge already')
        else:
            print('Refrigerator is too small to put elephant')
        self.close_door()
```

```
# Define element sizes
```

```
elephant_x = 5
elephant_y = 5
elephant_h = 5
```

```
# Define refrigerator sizes
```

```
refrigerator_x = 6
refrigerator_y = 6
refrigerator_h = 6
```

```
# Create instances of Elephant and Refrigerator classes
```

```
elephant = Elephant(elephant_x, elephant_y, elephant_h)
refrigerator = Refrigerator(refrigerator_x, refrigerator_y, refrigerator_h)
```

```
# Put the elephant in the refrigerator
```

```
refrigerator.put_elephant(elephant)
```

Practise

Attributes:

- make: The make of the car (e.g., Toyota, Honda).
- model: The model of the car (e.g., Camry, Civic).
- year: The year the car was manufactured.
- color: The color of the car.
- mileage: The current mileage of the car.

Methods:

- __init__: The constructor method to initialize the attributes.
- drive(distance): A method that takes a distance in miles as a parameter and increases the mileage of the car accordingly.
- paint(new_color): A method that changes the color of the car.
- display_info(): A method that displays all the information about the car (make, model, year, color, and mileage).

Exercises

Ask us questions!

Thank you!

- Feedback would really be appreciated:
https://bit.ly/arc_trainingfeedback2024
- Other training courses at ARC
- RSE support