

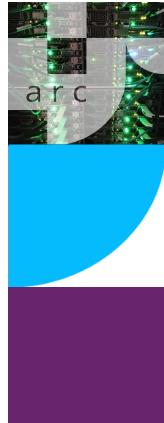
# Intermediate Python

Mark Turner  
Advanced Research Computing

March 10, 2022

# Welcome and icebreaker

- Thank you for joining!
- 2-hour course (10am-12pm); break for 10 minutes around 11am
- Mute when not talking, but please do post in the chat or speak up when questions arise
- Introductions (post in the chat)
- Link to the exercises for today:  
[https://colab.research.google.com/github/DurhamARC/Intermediate-Python/blob/main/exercises/intermediate\\_python\\_exercises.ipynb](https://colab.research.google.com/github/DurhamARC/Intermediate-Python/blob/main/exercises/intermediate_python_exercises.ipynb)



# Course structure

- 'Beginners Python' refresher
  - Loops, lists, functions
- 'Pythonic' concepts
  - List comprehension, ternary expressions, \*args and \*\*kwargs
  - Lambdas
- More advanced string manipulation
- Introduction to modules and packages
- Data structures and containers
  - Mutability
- Brief introduction to classes



# Recap (a): Control Flow

- Conditional statements: `if, elif, else`
- Loop statements: `for, while`
- `break, continue` statements
  - How would the example's behaviour differ if `break` was swapped for `continue`?

```
for val in range(10):  
    if val > 5:  
        break  
    else:  
        print(val, end=' ')
```

# out: 0 1 2 3 4 5



# Recap (a) cont.

- Nested loops

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

# out:  (0,0)
#       (0,1)
#       (1,0)
#       (1,1)
```



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



# Control Flow (iterators)

1. `iter()` is called on the container object
2. This returns an iterator object
3. The iterator object defines a `__next__()` function
  - Facilitates access of elements one at a time
4. `__next__()` tells for loop when there are no more elements (raises `StopIteration` exception)

```
>>> uni = 'Durham'  
>>> it = iter(uni)  
>>> it  
<str_iterator object at 0x10490ce20>  
>>> next(it)  
'D'  
>>> next(it)  
'u'  
>>> next(it)  
'r'  
>>> next(it)  
'h'  
>>> next(it)  
'a'  
>>> next(it)  
'm'  
>>> next(it)  
Traceback (most recent call last):  
  File "<stdin>", line 1, in <module>  
StopIteration
```



## Recap (b): Lists

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

- Quick and easy way to store objects
- Can contain objects of any type, or **even a mix of types**
  - Python's dynamic type system makes things easy!

```
random_stuff = [1, 'APPLES', 3.14, ['Mars', 'Venus', 'Pluto']]
print(random_stuff[3][2])
# OUT: 'Pluto'
```



## Recap (b) cont.

- Easy to process lists using *for* loops
- Appending to lists

```
L = [1, 2, 3, 4, 5]
for val in L:
    print(val ** 2, end=" ")
# out: 1, 4, 9, 16, 25
```

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



# Recap (b) cont.: Semantics of slicing

- Simple to grab object in list if you know where it sits:

```
L = ['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j']
print(L[0]) # 1st letter
print(L[4]) # 5th letter
```

- Use `:` to grab a range defined subsection of the list (slicing):

```
start = 3
stop = 7
print(L[start:stop]) # items start to stop-1
# out: ['d', 'e', 'f', 'g']
print(L[start:]) # items start to the end of list
# out: ['d', 'e', 'f', 'g', 'h', 'i', 'j']
print(L[:stop]) # items from beginning of list to stop-1
# out: ['a', 'b', 'c', 'd', 'e', 'f', 'g']
print(L[:]) # whole list
# out: ['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j']
```

Key - the `:stop` value represents the first value not in the slice



# Recap (c): Functions

- Principle of **encapsulation**
  - Enable maintainability and readability alongside complexity
- **Reusable** code
- The **def** statement
- The importance of indentation
- The **return** statement

```
def increment(number):  
    return number + 1  
  
print("4+1 =", increment(4))  
# out: 4+1 = 5
```

# Building on the above (a)

- \*args and \*\*kwargs
  - \*args for non-keyworded variables
  - \*kwargs for keyworded variables

```
def print_shopping_list(*args):  
    for arg in args:  
        print(arg, end=" ")  
  
print_shopping_list("spam", "eggs", "apples")
```

# out: 'spam eggs apples'

```
def print_shopping_list(**kwargs):  
    for key, value in kwargs.items():  
        print(key, "=", value, end=" ")
```

```
print_shopping_list(protein="eggs", fruit="apples")  
# out: 'protein = eggs veg = apples'
```

Notice: python functions can initialize multiple variables upon return



# Building on the above (b)

- Ternary expressions

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

- List comprehension

```
multiples_of_three = [i for i in range(20) if i % 3 == 0]  
print(multiples_of_three)  
# out: [0, 3, 6, 9, 12, 15, 18]
```

- Inbuilt functions that come with list
  - (We'll see more in the next slide)

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



# More inbuilt list functions

- Inserting an element

```
L = [33, 84, 11, 29, 0]
```

```
L.insert(2, 57)
```

```
print(L)
```

```
# out: [33, 84, 57, 11, 29, 0]
```

- Reversing

- Note: `reversed()` returns a ‘reverse iterator’ that then needs to be turned back into a list with `list()`

```
print(list(reversed(L)))
```

```
# out: [0, 29, 11, 57, 84, 33]
```

```
print(sorted(L))
```

```
# out: [0, 11, 29, 33, 57, 84]
```

- Sorting

- Searching

- Emptying

- Removing duplicates

```
if 57 in L:
```

```
    position = L.index(57)
```

```
    print("57 is in the list. "
          "It is at position", position)
```

```
# out: 57 is in the list. It is at position 2
```

```
print(L.clear()) # out: None
```

```
L2 = [1, 2, 2, 2, 3, 3]
```

```
print(list(set(L2))) # out: [1, 2, 3]
```



# Important distinction

e.g.  
L.empty()

- Some of these functions actively modified our list while others returned a copy of the modified list, leaving the original list untouched

- So, to reverse our list permanently with *reversed()* we must use assignment

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

- All *reversed()* does is return a reverse iterator!

```
print(L)
# out: [33, 84, 57, 11, 29, 0]
```

```
L = list(reversed(L))
```

```
print(L)
# out: [0, 29, 11, 57, 84, 33]
```



# Better still...

- To avoid the explicit copy and assignment operations (potentially expensive) use *reverse()* instead of *reversed()*

- Unlike *reversed()*, *reverse()* is a member function of the list itself

```
L = [33, 84, 57, 11, 29, 0]
L.reverse()
print(L)
# out: [0, 29, 11, 57, 84, 33]
```

- No single way is right: coding is about making good choices



# Building on the above (c): lambda functions

- Lambdas (sometimes anonymous functions) are one-line functions.
- Useful when you **don't want to use a function twice**
- Blueprint:      *lambda arguments : expression*

The diagram illustrates the functional equivalence between a lambda expression and a standard Python function definition. On the left, a blue bracket groups the text "plus\_one = lambda x:" and "x + 1". An arrow points from this bracket to a blue cloud containing the text "Functionally equivalent to". Another arrow points from the cloud to the right side of the diagram, which shows the standard Python code "def plus\_one(x): return x + 1". Below these, the code "print(plus\_one(5)) # out: 6" is shown.

```
plus_one = lambda x: x + 1
def plus_one(x): return x + 1
print(plus_one(5)) # out: 6
```

- Lambdas can be used to **pass around functionality** as we will see next...

# Lambda functions (continued)

- Map applies a function to all the items in a *list\_of\_inputs*.
  - **map(function\_to\_apply, list\_of\_inputs)**

- Where previously we would write:

```
items = [1, 2, 3, 4, 5]
squared = []

for i in items:
    squared.append(i ** 2)
print(squared) # out: [1, 4, 9, 16, 25]
```

- Now this can be simplified to:

```
squared = list(map(lambda x: x ** 2, items))
print(squared) # out: [1, 4, 9, 16, 25]
```



# Lambda functions (continued)

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

```
number_list = range(-5, 5)
less_than_zero = list(filter(lambda x: x < 0, number_list))
print(less_than_zero)
# out: [-5, -4, -3, -2, -1]
```

- Equiv. non-lambda expression:

```
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) # out: [-5, -4, -3, -2, -1]
```



# Mastering strings (a)

- Adjusting case
- Formatting strings
- None of these functions modify the original string. Instead, they return a **copy**. Modification requires assignment.

```
arc_update = "ThE HAmILton suPercompUTER is beiNg UPGraded"
print(arc_update.upper())
# out: THE HAMILTON SUPERCOMPUTER IS BEING UPGRADED
print(arc_update.title())
# out: The Hamilton Supercomputer Is Being Upgraded
print(arc_update.capitalize())
# out: The hamilton supercomputer is being upgraded

print(arc_update)
# out: ThE HAmILton suPercompUTER is beiNg UPGraded
```

```
arc_update = "      RSEs      "
print(arc_update.strip())
# out: 'RSEs'
print(arc_update.rstrip())
# out: '      RSEs'
print(arc_update.lstrip())
# out: 'RSEs      '
```



# Mastering strings (b)

- *find()*: return index of a substring
  - Returns -1 if substring not found
- Querying the existence of
- Replacing, splitting

```
line = 'the quick brown fox jumped over a lazy dog'  
print(line.find('fox'))  
# out: 16  
print(line.find("nonexistent string"))  
# out: -1  
  
print(line.startswith("the"))  
# out: true  
print(line.endswith("fox"))  
# out: false  
  
print(line.replace("brown", "red"))  
# out: the quick red fox jumped over a lazy dog  
  
print(line.split())  
# out: ['the', 'quick', 'brown', 'fox', 'jumped',  
#       'over', 'a', 'lazy', 'dog']
```



# Mastering strings (c)

- Index() is similar to find()
  - Returns index of substring
  - However, unlike find(), index() raises a ValueError **exception** when substring not found
  - Used alongside **exception handling**

```
line = 'the quick brown fox jumped over a lazy dog'
```

```
try:  
    index = line.index('bear')  
    print(index)  
except ValueError:  
    print("A bear is not mentioned in text")
```

```
# out: A bear is not mentioned in text
```



# An aside:

- 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")

# out: A fox has been seen
```



# Mastering strings (d)

- F-strings

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

```
interests = ["football", "zoom"]

print(f"Bob enjoys {interests[0]} and {interests[1]}")
# out: Bob enjoys football and zoom
```

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

# out: Today is Mon
#       Today is Tue
#       Today is Wed
#       ...
```

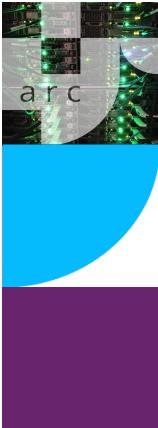
```
age = 70
print(f"Soon I'll be {age+1}!")

# out: Soon I'll be 71
```

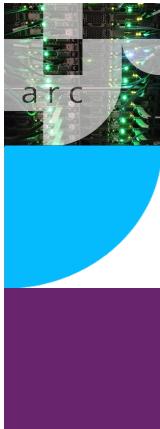


# Exercises

**Ask us questions!  
We're very happy to setup breakout  
rooms upon request**



# Coffee break



# Introduction to modules and packages



# Modules and packages

Namespaces

- Loading modules: the *import* statement
  - Explicit module import
  - Explicit module import by alias
  - Explicit import of module content

```
import math  
math.cos(math.pi)
```

```
import numpy as np  
np.cos(np.pi)
```

```
from math import cos, pi  
cos(pi)
```



# Other useful modules in the standard library

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

```
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)
```

Facilitates portability

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

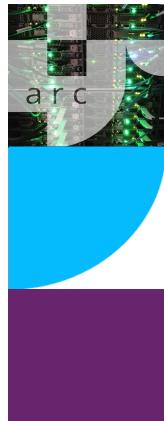
```
import csv

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

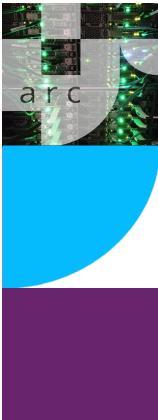
# out: 0.5403023058681398
```



# Third-Party Modules

- Especially for data science coding, third party modules have a lot to offer
- Can be imported just as the built-in modules, but first the modules must be installed on your system.
- Python comes with a program called **pip** which will automatically fetch packages released and listed on PyPI
  - Example: `pip install <some-module>`
- If you don't have root permissions use **--user** option

```
[kqkc25@hamilton2 ~]$ module load python/3.6.8  
[kqkc25@hamilton2 ~]$ pip3 install --user GitPython
```



# Data structures



# Data structures: dictionaries

- Dictionaries are flexible mappings of keys to values

- can be created via a comma-separated list of key:value pairs within curly braces:

```
numbers = {'one': 1, 'two': 2, 'three': 3}
```

- Items are accessed and set via the indexing syntax used for lists and tuples, except here the index is not a zero-based order but valid key in the dictionary:

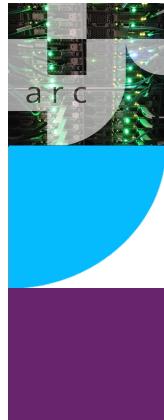
```
print(numbers['two']) # out: 2
```

- New items can be added to the dictionary using indexing:

```
numbers['ninety'] = 90
```

```
print(numbers)
```

```
# out: {'one': 1, 'two': 2, 'three': 3, 'ninety': 90}
```



# Data structures cont.: immutability

- All the data structures we have looked at are **mutable**
- Tuples exemplify **immutability**
- Typically, we have:
  - Lists for homogeneous data sequences (e.g., numbers, ingredients, names)
  - But tuples are ideal for heterogeneous data structures (where entries have different meanings - for example, coordinates)

```
location = (13, 88)  
x_coordinate = location[0]  
y_coordinate = location[1]
```

```
print(x_coordinate) # out: 13  
print(y_coordinate)  
  
# location[0] = 4 # ERROR!
```

```
locations = [  
    location,  
    (14, 86),  
    (15, 80)  
]
```

```
print(locations)
```

```
# out: [(13, 88), (14, 86), (15, 80)]
```

Note: List's tuples are immutable, but the list itself is mutable

# Data structures cont.

- Namedtuple is handy, but also **immutable**
- Namedtuple is a factory function for making a tuple class
  - In the example, *NINumber* 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'
```



**This forces us to think about a  
core programming concept:  
classes...**



# Very brief introduction to classes

- Class = code template (like previously seen factory function)

```
class FootballTeam:  
    players = ['Kane', 'Sterling', 'Pickford']  
  
    def get_players(self):  
        return self.players  
  
england_team = FootballTeam()  
print(england_team.get_players())  
# out: ['Kane', 'Sterling', 'Pickford']
```



**Ok... but how is this more interesting than a list?**



# Very brief introduction to classes

- We can **generalise** the template



```
class FootballTeam:  
    def __init__(self, players):  
        self.players = players  
  
    def get_players(self):  
        return self.players  
  
england_team = FootballTeam(["Kane", "Sterling", "Pickford"])  
print(england_team.get_players())  
# out: ['Kane', 'Sterling', 'Pickford']  
spanish_team = FootballTeam(["Moreno", "Llorente"])  
print(spanish_team.get_players())  
# out: ['Moreno', 'Llorente']
```



**Fine... but doesn't this lack  
flexibility?**



# Very brief introduction to classes

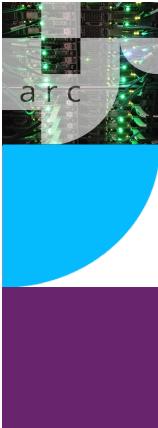
- We can **encapsulate** complexity

```
class FootballTeam:  
    def __init__(self, players):  
        self.players = players  
  
    def make_substitution(self, player_off, player_on):  
        self.players = [player if player != player_off else player_on  
                       for player in self.players]  
  
    def get_players(self):  
        return self.players  
  
england_team = FootballTeam(["Kane", "Sterling", "Pickford"])  
print(england_team.get_players())  
# out: ['Kane', 'Sterling', 'Pickford']  
england_team.make_substitution("Kane", "Grealish")  
print(england_team.get_players())  
# out: ['Grealish', 'Sterling', 'Pickford']
```



# Exercises

**Ask us questions!  
We're very happy to setup breakout  
rooms upon request**



## Thank you!

- Feedback would really be appreciated:  
**[https://bit.ly/arc\\_trainingfeedback](https://bit.ly/arc_trainingfeedback)**
- Other training courses at ARC
- RSE support

Solutions to the exercises can be found here:

[https://colab.research.google.com/github/DurhamARC/Intermediate-Python/blob/main/exercises/intermediate\\_python\\_exercises\\_solutions.ipynb](https://colab.research.google.com/github/DurhamARC/Intermediate-Python/blob/main/exercises/intermediate_python_exercises_solutions.ipynb)

# Data structures cont.: mutable alternatives

- Same API as namedtuple, but mutable

```
from dataclasses import dataclass

@dataclass(unsafe_hash=True)
class WeatherSystem:
    """Class for keeping track of local weather systems"""
    day_of_week: str
    temperature: float
    wind_speed: int
    rain: bool = False # default value must come at end
```

```
w = WeatherSystem('Monday', 35.0, 1)
print(w.day_of_week) # out: Monday

w.day_of_week = 'Tuesday'
w.temperature = 13.5
print(w.temperature) # out: 13.5
```

