# Programming for ML and Data Science

A review of basic programming concepts

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# Objects

- Everything in Python is an object (`object`)
- Typically an object
  - Has some state/data
  - Provides methods for functionality
  - Provides interfaces so you can interact with it
- Consider a `list`
  - Has data
  - `lst.append(...)` and other methods
  - Can iterate over it using `for`: programmable behavior

# Mutable and immutable

- Two broad categories for all objects
  - Immutable: cannot be changed
  - Mutable: can be changed
- Immutable: numbers, strings, tuples
- Mutable: list, dict, set

# Some builtin data types

- Numerical types:
  - Integers: `int`, these are arbitrary precision!
  - Floats: `float`, double precision 64 bits
  - Complex: `1 + 2j`, `complex(1, 2)`

```
# Example of large int.
2**(2**8)
```

```
115792089237316195423570985008687907853269984665640564039457584007913129639936
```

```
# Complex numbers.
x = complex(2.2, 1.5)
print(abs(x), x.conjugate())
```

```
2.662705391138869 (2.2-1.5j)
```

- Booleans: `True`/`False`

# Some builtin data types ...

- Sequence types:
  - Lists: `list`, `[]`: mutable
  - Tuples: `tuple`, `()`: immutable
  - Strings: `str`: `'hello'`, `"hello"`, `'''hello'''`, `"""hello"""`: immutable
  - Sets: `set`: behaves like a mathematical set: mutable
  - range: `range`: immutable
- Dictionaries: `dict`, `{key: value}`, a mapping (more later)
- Others: `bytes`, `bytearray`, `memoryview` (advanced)

# Tuples

- Immutable: `x = (1, 21.2, 'hello')`
  - Cannot change, no append
  - If it contains a list, the list can change

```
1 x = (1, 2, [21, 22])
2 x[-1] = [20, 21]  # TypeError!
3 x[-1].append(23)  # This will work
```

- Used when returning multiple values from a list.
- Tuple expansion

```
1 x, y, z = range(3)
2 x, *y = range(10)  # y is a list of remaining elements
3 x, *y, last = range(10)
4 x, y, z = range(10)  # ValueError!
```

# Operators

- Arithmetic but not always (lists)
- Arithmetic `+, -, *, /, **, //, %` etc.
- `@` is matrix multiplication
- Logical: `not, or, and`
- Comparison: `<, >, <=, !=`
- Identity: `is, is not`
- Containership: `in, not in`
- Assignment: `x = 1.0`
  - Augmented assignments: `x += 1.0`
- Bitwise operators: `&, |, ^, ~, <<, >>` (and, or, xor, not, left/right shift)
- Don’t remember operator precedence, use brackets!!

# Floor division

- Produces a float always

```
1 23/2
```

```
11.5
```

- Floor division: `//`, same output as left operand

```
1 23//2
```

```
11
```

```
1 23.0//2
```

```
11.0
```

# Identity

```
1 x = 2
2 y = 1 + 1
3 x is y
```

```
True
```

# Containership

```
1 x = ['hello', 'world']
2 'hello' in x
```

```
True
```

```
1 x = ('hello', 'world')
2 'hello' in x
```

```
True
```

```
1 x = 'hello world'
2 'ello w' in x
```

```
True
```

# Indexing/Slicing

- Use square brackets: `x[0]`
- Indices start at `0` to `len(x) - 1`
- Slice produces same kind of container: `x[start:stop:step]`
  - `stop` is not included
  - When not specified `start` is 0
  - When not specified `stop` is `len(x)`
  - When not specified `step` is `1`
- Dictionaries support non-integer "indices" called **keys**

# Looping

- Loops with `for`
- Loops with `while`
- Use `break` to exit the current loop
- Use `continue` to skip execution until end of block

```
1 for i in range(3):
2     print(i)
```

- While loops look like this:

```
while <conditional>:
    <block>
```

# While example

- Trivial infinite loop:

```
while True:
    pass
```

- `pass` a syntactic filler to do nothing
- Let us go over this example:

```
1  k = 23
2  while k != 1:
3      print(k, end=' ')
4      if k % 2 == 0:
5          k //= 2
6      else:
7          k = k*3 + 1
```

```
23 70 35 106 53 160 80 40 20 10 5 16 8 4 2
```

# Break/continue

- `break` example:

```
1 i = 0
2 while True:
3     if i > 5:
4         break
5     print(i, end=' ')
6     i += 1
```

```
0 1 2 3 4 5
```

- `continue` example:

```
1 for i in range(10):
2     if i % 2 == 1:
3         continue
4     print(i, end=' ')
```

```
0 2 4 6 8
```

# Variables in Python

- Names bound to objects: namespace
- Assignment performs this binding: `x = 1`
- The easy cases (immutable object):

```
1 x = 1
2 y = x
3 del x
4 print(y)
```

```
1
```

```
1 x = 1
2 y = x
3 x += 1
4 print(y)
```

```
1
```

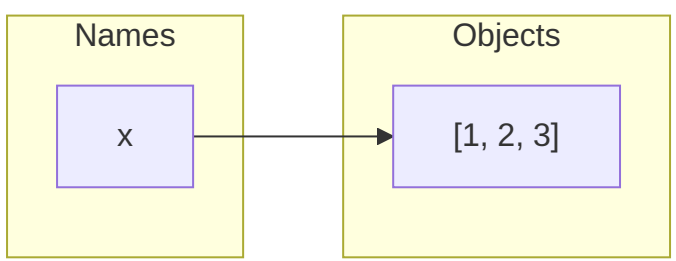
# Understanding name binding

- The case of mutable objects

```
1 x = [1, 2, 3]
2 y = x
3 x.append(4)
4 print(y)
```

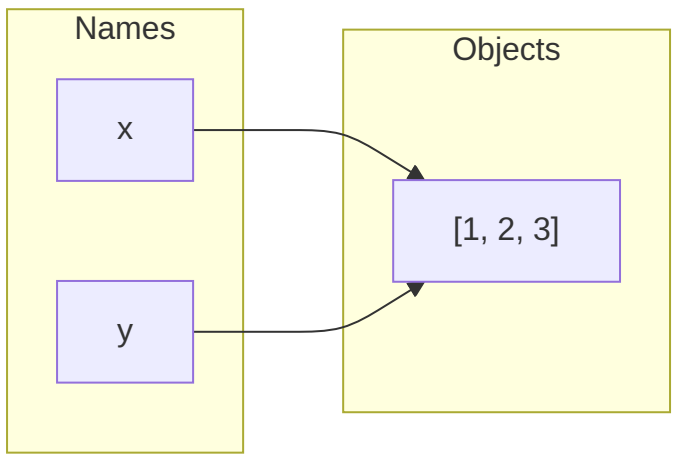
- Let us walk through this:

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

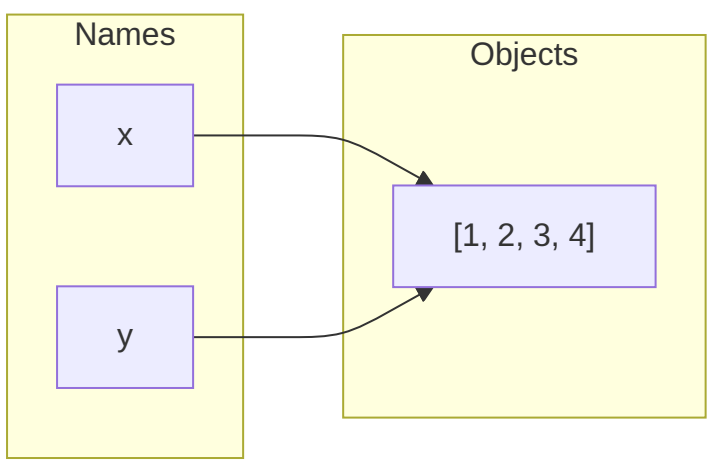


# Understanding name binding ...

```
1 y = x
```




```
1 x.append(4)
```



# Abstraction with functions

- Functions facilitate reuse
- Functions with no `return` implicitly return `None`

```
def func(x, y):
    """docstring"""
    # ...
    return x*y  # Optional
```

- Lambda (anonymous) functions are possible

```
func = lambda x, y: x*y
```

# Default and keyword arguments

- Note that defaults are evaluated only once

```
1 def greet(name, hi='Hello', repeat=1):
2     for i in range(repeat):
3         print(hi, name)
4 
5 greet("Vinay", "Namaste")
6 greet(hi="Namaste", name='X!')
```

# Special parameters

- Positional only and keyword only arguments

```
def f(pos1, pos2, /, pos_or_kwd, *, kwd1, kwd2):
    # ...
```

- Examples:

```
def normal_arg(arg):
    print(arg)

def pos_only_arg(arg, /):
    print(arg)

def kwd_only_arg(*, arg):
    print(arg)

def combined(pos_only, /, standard, *, kwd_only):
    print(pos_only, standard, kwd_only)
```

# Some patterns

- Use `None` as a default argument with mutable defaults
- Also to detect if someone passed an argument or not

```
1 def f(x, y=None):
2     if y is None:
3         y = []
4     # ...
```

# Functions are “first class” objects

- They can be treated like any other value
- Can be bound to a name
- Can be passed to functions

```
 1 import numpy as np
 2
 3 def improve(update, close, guess=1):
 4     while not close(guess):
 5         guess = update(guess)
 6     return guess
 7
 8 def update(guess):
 9     return 1/guess + 1
10
11 improve(update, close=lambda g: np.allclose(g*g, g+1))
```

```
1.6180257510729614
```

# Variable scope

- Functions introduce a new namespace
  - Function arguments and variables inside function
- Arguments passed by reference

```
x, y = [1, 2], 1

def f(x):
    z = 10
    x.append(3)
    print(x, y)  # Private x, global y

f(x)
print(x, y)  # z is not available here
```

```
[1, 2, 3] 1
[1, 2, 3] 1
```

# Variable scope ...

```
1 x, y = [1, 2], 1
2
3 def f(x):
4     y = 10
5     x.append(3)
6     print(x, y)  # Private x, local y
7
8 f(x)
9 print(x, y)
```

```
[1, 2, 3] 10
[1, 2, 3] 1
```

# Some builtin functions

- Available in `builtins` module
- `abs, all, any, ascii, bin, breakpoint`
- `callable, chr, compile, delattr, dir, divmod`
- `eval, exec, format, getattr, globals,`
- `hasattr, hash, hex, id, input, isinstance, issubclass, iter`
- `len, locals, max, min, next, oct, open, ord, pow, print`
- `repr, round, setattr, sorted, sum, vars`

- Homework: read the docs for each of these!

# Modules and imports

- Modules introduce a namespace
- Module/file name should be a valid variable
- Simple modules are just Python source files
- Python extension modules which are compiled native code

```
import module
import module as M
from module import name1
from module import name1, name2
from module import *  # Avoid using this!
```

# Writing scripts

- Scripts are Python files
- Can use the magic `__name__` variable to guard
  - `__name__` is `'__main__'` when executed as a script
  - `__name__` is the module name when imported

```
if __name__ == '__main__':
    main()
```

# Summary

- Introduced very basic Python syntax
- Will learn a little more later
- Learn language syntax from the Python tutorial
- See the documentation on the standard library