Introduction to (Python) programming

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What is programming / coding?

- Literally: Creating a set of instructions for a computer to execute
- First we construct a sequence of abstract operations, sometimes called an *algorithm* or *workplan*, that performs the desired task; this is problem-solving and done prior to coding
- Then we translate these abstract operations to concrete and precise instructions

Say hello ☞ `print("hello")`

- These instructions must follow the grammatical structure of a programming language, such as Python
- Each instruction typically solves a tiny piece of the problem
- The emergent behavior of the program solves our task

What's the hard part?

- Programming is mostly about converting "word problems" (project descriptions) to algorithms or work plans
- We immediately think about programming languages because we express ourselves using specific language syntax but…
- Programming is more about *what* to say, and in what order, rather than *how* to say it
  - You'll eventually get fast at Python coding and using libraries
  - It'll always be harder to design a sequence of steps that solves a data science problem (or other) than it is to code
  - I remember being confronted with my first programming task (using BASIC in 1979!) and drawing a complete blank even though I knew BASIC syntax
- Don't worry: we will study lots of patterns and strategies as aids

Learning to be a programmer

- While programming is more about problem-solving and design, rather than coding details, it's much easier to learn programming by actually speaking some Python (e.g., we learn a foreign language by memorizing a few key phrases like "*May I have a beer?*")
- Once we're conversant in basic Python, it's time to study some common programming patterns, such as "search a list"
- The final and most important skill is being able to translate real-world problems into appropriate sequences of operations (which are then straightforward to convert to Python)
- We'll learn problem-solving techniques and apply them to lots of sample problems

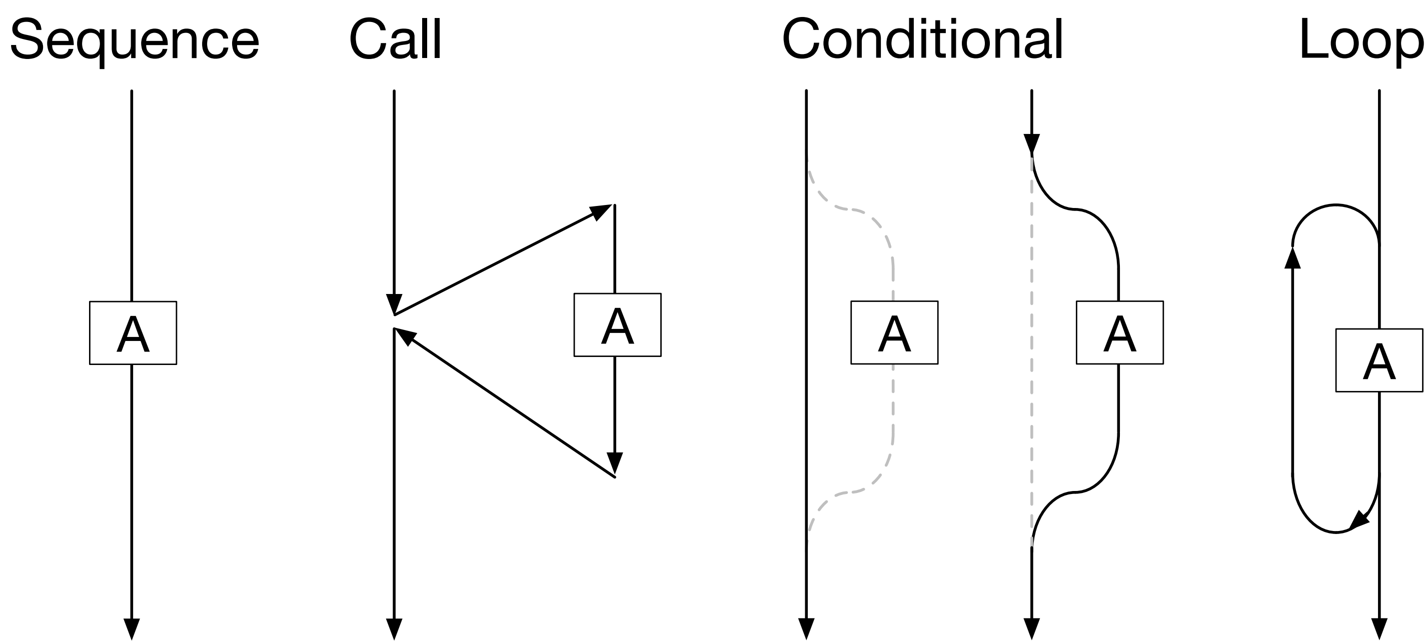
Most important programming concepts

- Batch execution vs interactive execution
- Order of operations (*control-flow*)
- Representing data in memory
- Aggregating instructions into reusable functions
- Aggregating instructions and functions into modules (.py files)
- Object-oriented (OO) programming (aggregating data, methods)

Key concept: order of operations

- Order is critical
  Example: get license, buy car, drive car

Big Bang theory's friendship algorithm



Anecdote: graphics designer confused by loops

Key language constructs

```
42 3.14
"string" 'string'
[ expr , expr ,… ]
{ expr : expr ,… }

var = expr

func ( expr , expr ,… )
expr . func ( expr , expr ,… )

[ expr for var(s) in elements ]
[ expr for var(s) in elements if condition ]
```

```
if condition :
    statement(s)
else:
    statement(s)
```

```
while condition :
    statement(s)

for var(s) in elements :
    statement(s)

import package
import package as alias
```

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Interactive demos via pythontutor.com

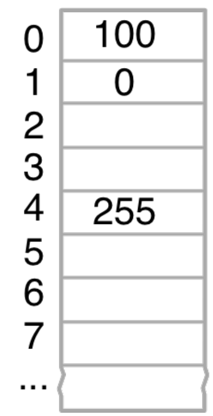
- Let's observe the control-flow using our key syntax constructs:
  - generate some output
  - assignment creates and alters variables
  - types matter, operators are overloaded
  - simple conditional execution
  - else-clause
  - simple loop that updates variable
  - demo loop for powers of two

Programmer's view of memory

Code operates on data, which is stored in memory, so we have to learn about how Python represents data elements in memory

Representing data in memory

- RAM is a sequence of discrete slots where we can stick values 0..255 called *bytes*; made up of 8 bits as 2^8=256
- Numbers, music, videos, text are all decomposed into one or more of these discrete bytes
- Data elements in memory have *values* and *types*
  - integer 32
  - string "hello"
  - floating point real number 3.14159
  - boolean values **True** and **False**
- A special element called a *pointer* or *reference* refers to another element; like a phone number "points at" a person but isn't a person
- We build data structures by combining and organizing data elements with references



Key size metrics

- Know these units; as data scientists, you need to know whether a data set fits in memory or whether it fits on the disk or even how long it will take to transfer across the network
  - Kilo. 10^3 = 1,000 or often 2^{10} = 1024
  - Mega. 10^6 = 1,000,000
  - Giga. 10^9 = 1,000,000,000
  - Tera. 10^{12} = 1,000,000,000,000

Let the units be your guide

- On an 80 megabits/second network you can transfer 10 megabytes/second because there are 8 bits/byte

$$\frac{80,000,000\frac{bits}{sec}}{8\frac{bits}{byte}} = 10,000,000\frac{bytes}{sec} = 10\frac{megabytes}{sec}$$

- So, a 100Mbyte file transmits in 10 seconds

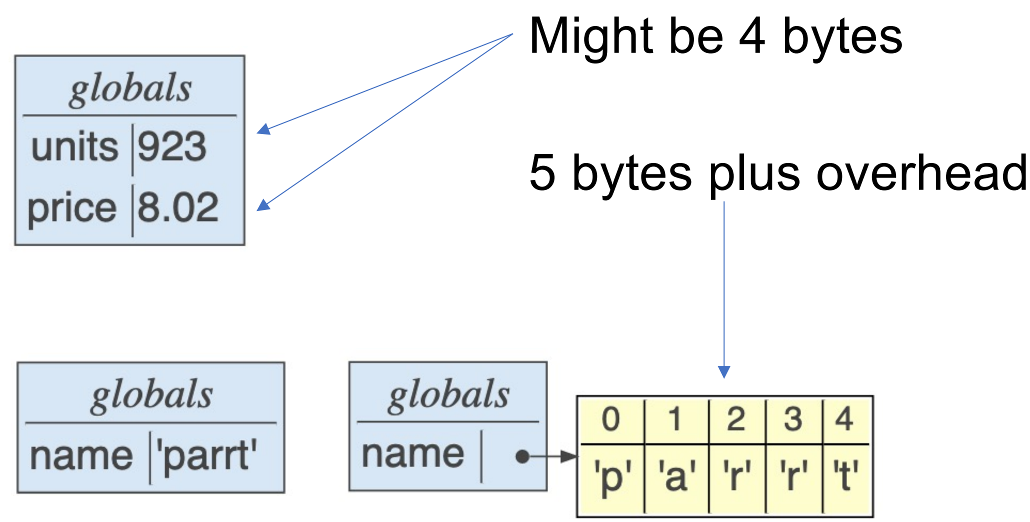
$$\frac{100megabytes}{10\frac{megabytes}{sec}} = 10sec$$

Programming language view of memory

- Dealing with untyped bytes is tedious; we prefer to group bytes into higher-level values, such as numbers and strings

```
units = 923
price = 8.02
```

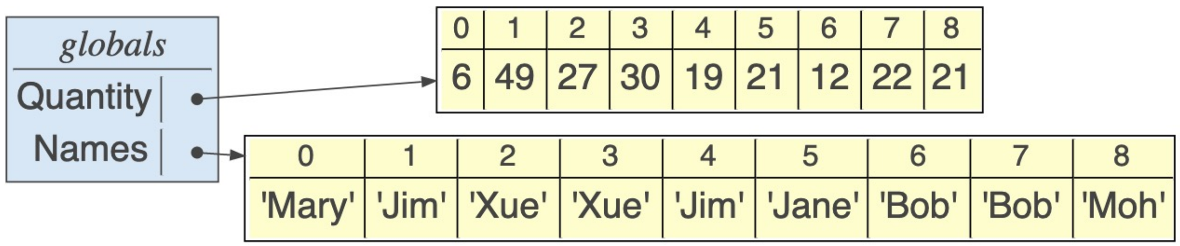
```
name = "parrt"
```



Lists of data elements

- Most common *data structure* is the **list**, which is just a sequence of data elements or other data structures

```
Quantity = [6, 49, 27, 30, 19, 21, 12, 22, 21]
Names = ['Mary', 'Jim', 'Xue', 'Xue', 'Jim', 'Jane', 'Bob', 'Bob', 'Moh']
```



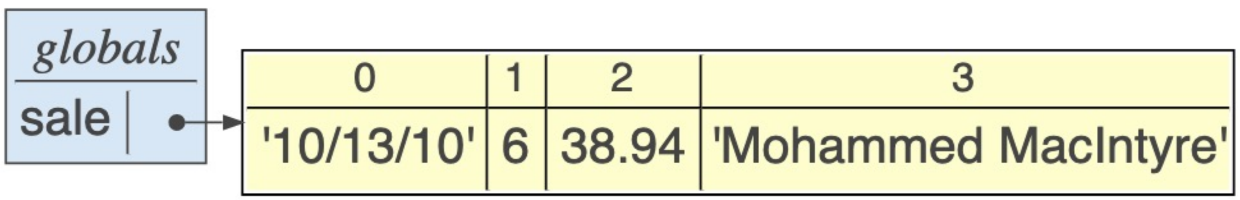
Quantity
6
49
27
30
19
21
12
22
21

- Indexed from 0 not 1 and list vars point at a chunk of memory holding the list elements contiguously (preserving the sequence order)
- Access elements with index operator; e.g., **Names[0]** is '**Mary**' and **Quantity[4]** is 19

Heterogeneous lists

- Elements can have different types:

```python
sale = ['10/13/10', 6, 38.94, 'Mohammed MacIntyre']
```

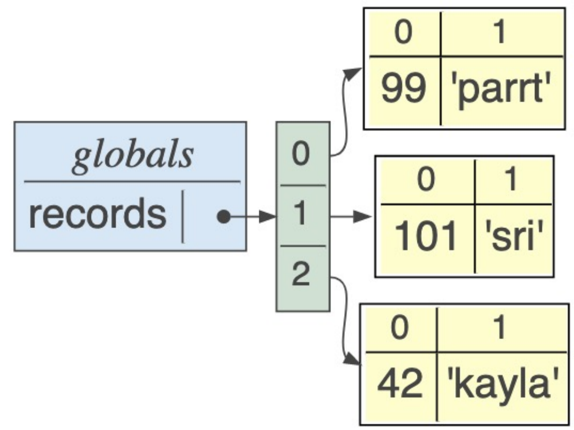


- Heterogeneous lists can be used to group bits of information about a particular entity or observation

List of lists

- In this case, the outer list is a list of elements that happen to be lists also; each of the inner lists has two elements representing a record of information
- [experiment via pythontutor]

```python
records = [[99, 'parrt'],
           [101, 'sri'],
           [42, 'kayla']]
```

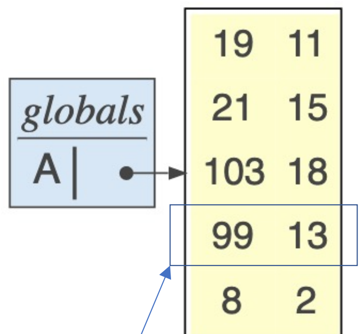


[Experiment via pythontutor]()

Matrices as lists of lists

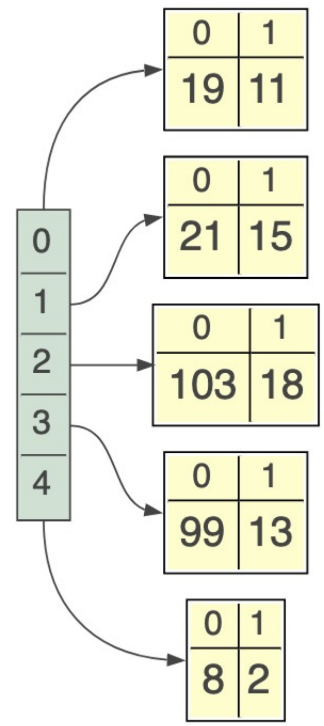
- A matrix is a list of rows; a row is a list of numbers
- We think of it like this:

```python
A = [[19,11],
     [21,15],
     [103,18],
     [99,13],
     [8,2]]
```



Row 4 is A[3]

But, it's actually represented like:



Sets

- A set is just an unordered, unique collection of elements; here is an example using integers:
  `ids = {100, 103, 121, 102, 113, 113, 113, 113}`
- We can do lots of fun set arithmetic:

```
{100,102}.union({109})
```

```
{100, 102, 109}
```

```
{100,102}.intersection({100,119})
```

```
{100}
```

Tuples

- A tuple is an *immutable* list and uses parentheses rather than square brackets for notation
- Tuples are often used to group related elements:

```
me = ('parrt',607)
userid,office = me
print(userid)
print(office)
print(me[0], me[1])
```

```
parrt
607
parrt 607
```

Experiment in pythontutor

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Dictionaries

- If we arrange two lists side-by-side and kind of glue them together, we get a **dictionary**
- Dictionaries map one value to another, just like a dictionary in the real world maps a word to a definition
- Here are two sample dictionaries:

```
movies = {'Amadeus':1984, 'Witness':1985}
```

'Amadeus' → 1984
'Witness' → 1985

- Index by key to get the value; e.g., `movies['Amadeus']`

title	year
A Soldier's Story	1984
Places in the Heart	1984
The Killing Fields	1984
A Passage to India	1984
Amadeus	1984
Prizzi's Honor	1985
Kiss of the Spider Woman	1985
Witness	1985

[Experiment in pythontutor]

Dictionary keys and values

- We can split a dictionary apart to get the keys and values:

```
print(movies.keys())
print(movies.values())
```

```
dict_keys(['Amadeus', 'Witness'])
dict_values([1984, 1985])
```

- Note: this uses the notation *object.function()*, which you can think of as *function(object)*; we'll learn more about this later

Iterating through a dictionary

- We can walk the keys/values of a dictionary with a *for-each* loop

```
movies = {'Amadeus':1984, 'Witness':1985}
for m in movies: # walk keys
    print(m)
```

```
Amadeus
Witness
```

```
for m in movies.values(): # walk values
    print(m)
```

```
1984
1985
```

```
for (key,value) in movies.items():
    print(f"{key} -> {value}")
```

```
Amadeus -> 1984
Witness -> 1985
```

More on looping next!

More on looping

For-loops

`for` $\boxed{\text{var(s)}}$ `in` $\boxed{\text{elements}}$ `:`

$\boxed{\text{statement(s)}}$

- [range loops]
- [for-each loops]
- [loop with enumerate()]
- [watch row var iterate through list-of-list rows]
- [indexed loop using range]
- [zip'd loop]

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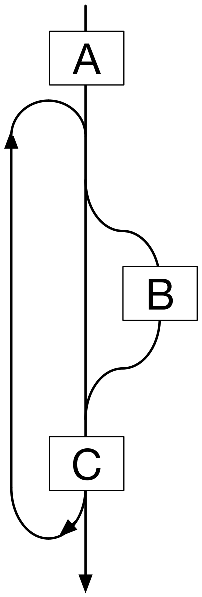
Combined conditional / loop

- Now that we have some basic Python skills, let's look at more complicated loop-related constructions starting with a combination:




```
i = 1
while i <= 6:
    if i==3:
        print("Halfway!")
    i = i + 1
```

[Step through code at pythontutor.com](https://pythontutor.com)

Translating formulas

- Sigmas become accumulator range-loops (recall indexed from 0)

$$\sum_{i=1}^{N} x_i$$

```
sum = 0
for i in range(0,N):
    sum = sum + x[i]
```

$$\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})$$

```
sum = 0
for i in range(0,N):
    sum = sum + (x[i] -xbar)  * (y[i] -ybar)
```

List comprehensions

- Making new lists from (optionally filtered) sequences, elements

`[` expr `for` var(s) `in` elements `]`

`[` expr `for` var(s) `in` elements `if` condition `]`

- [comprehensions on lists of strings]()
- [comprehensions on lists of numbers]()