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Python for AI Engineer

Oran Shemesh

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About me

- More than 10 years of experience in Programing in professional roles in multinational organizations and start-ups
- Big-data expert, with expertise in Data Scientist, Data Engineer, Spark Developer and Dev-ops
- Currently working as a CTO at ANS Tech

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TODAY

- Course info
- Material learned at home:
  - Python basics
  - Conditions, Loops, Functions
  - Object Oriented Programming
- Investigate and present data:
  - Numpy
  - MatplotLib

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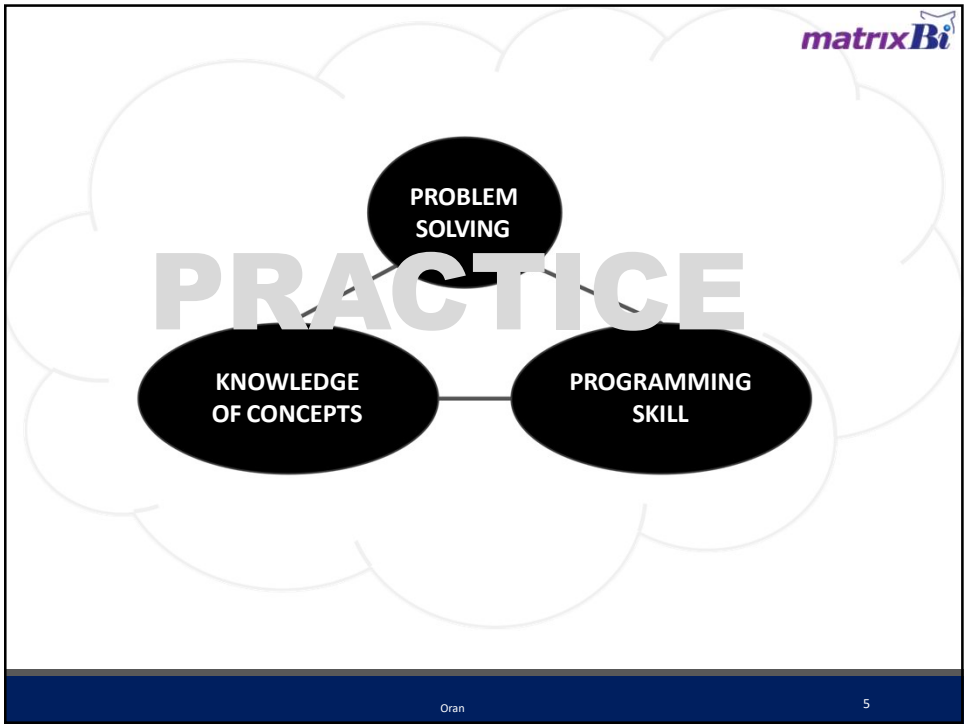
FAST PACED COURSE

- Position yourself to succeed!
  - It's is not about the number of hours you practice, it's about the number of hours your mind is present during the practice." – Kobe Bryant.
  - **write notes** and come back to them later
- **PRACTICE. PRACTICE? PRACTICE!**
  - can't passively absorb programming as a skill
  - download code before lecture and follow along
  - do exercises
  - **don't be afraid to try out Python commands!**



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COURSE POLICIES

- Collaboration
  - must collaborate with anyone
  - required to write code independently and write names of all collaborators on submission
  - I will be running the code solution with you
- Unlike what we were taught in school
  - learning is the acquisition of the ability to apply things
- An unfamiliar word
  - "עם רדת נשף, הילדים היו עצובים יותר ובהעדרו, הם היו שמחים הרבה יותר"

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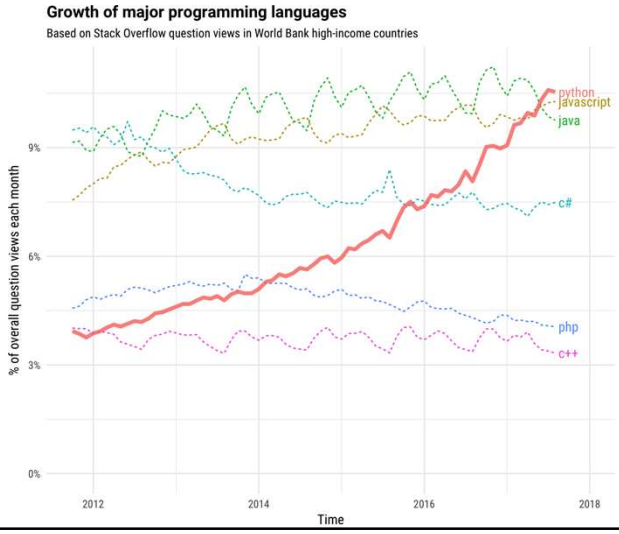
Growth major languages

link



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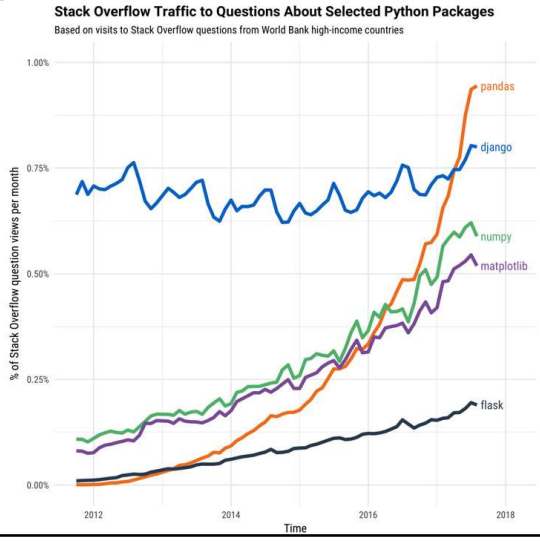
Stack overflow traffic to questions about selected python packages

link



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SCALAR OBJECTS

- `int` – represent **integers**, ex. `5`
- `float` – represent **real numbers**, ex. `3.27`
- `bool` – represent **Boolean** values `True` and `False`
- `NoneType` – **special** and has one value, `None`
- can use `type()` to see the type of an object

```
>>> type(5)
int
>>> type(3.0)
float
```

what you write into the Python shell

what shows after hitting enter

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TYPE CONVERSIONS (CAST)

- can **convert object of one type to another**
- `float(3)` converts integer `3` to float `3.0`
- `int(3.9)` truncates float `3.9` to integer `3`

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PRINTING TO CONSOLE

- to show output from code to a user, use `print` command

```
In [11]: 3+2
Out[11]: 5

In [12]: print(3+2)
5
```

"Out" tells you it's an interaction within the shell only

No "Out" means it is actually shown to a user, apparent when you edit/run files

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STRINGS

- letters, special characters, spaces, digits
- enclose in **quotation marks or single quotes**

```
hi = "hello there"
```

- **concatenate** strings

```
name = "Oran"

greet = hi + name

greeting = hi + " " + name
```

- do some **operations** on a string as defined in Python docs

```
silly = hi + " " + name * 3
```

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INPUT/OUTPUT: `print`

- used to **output** stuff to console
- keyword is `print`

```
x = 1
print(x)
x_str = str(x)
print("my fav num is", x, ".", "x =", x)
print("my fav num is " + x_str + ". " + "x = " + x_str)
print("my fav num is {}. {}".format(x_str, x))
print(f"my fav num is {x_str}. {x=}")
```

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INPUT/OUTPUT: `input("")`

- prints whatever is in the quotes
- user types in something and hits enter
- binds that value to a variable

```
text = input("Type anything... ")
print(5*text)
```

- `input` **gives you a string** so must cast if working with numbers

```
num = int(input("Type a number... "))
print(5*num)
```

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COMPARISON OPERATORS ON `int, float, string`

- `i` and `j` are variable names
- comparisons below evaluate to a Boolean

`i > j`

`i >= j`

`i < j`

`i <= j`

`i == j` → **equality** test, `True` if `i` is the same as `j`

`i != j` → **inequality** test, `True` if `i` not the same as `j`

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LOGIC OPERATORS ON bools

- `a` and `b` are variable names (with Boolean values)

`not a` → `True` if `a` is `False`
`False` if `a` is `True`

`a and b` → `True` if both are `True`

`a or b` → `True` if either or both are `True`

A	B	A and B	A or B
True	True	True	True
True	False	False	True
False	True	False	True
False	False	False	False

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CONTROL FLOW - BRANCHING

```
if <condition>:
    <expression>
    <expression>
    ...
```

```
if <condition>:
    <expression>
    <expression>
    ...
else:
    <expression>
    <expression>
    ...
```

```
if <condition>:
    <expression>
    <expression>
    ...
elif <condition>:
    <expression>
    <expression>
    ...
else:
    <expression>
    <expression>
    ...
```

- `<condition>` has a value `True` or `False`
- evaluate expressions in that block if `<condition>` is `True`

CONTROL FLOW: `while` LOOPS

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```
while <condition>:
    <expression>
    <expression>
    ...
```

- `<condition>` evaluates to a Boolean
- if `<condition>` is `True`, do all the steps inside the while code block
- check `<condition>` again
- repeat until `<condition>` is `False`

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`while` LOOP EXAMPLE

```
You are in the Lost Forest.
************
************
  ☺
************
************
Go left or right?
```

PROGRAM:

```
n = input("You're in the Lost Forest. Go left or right? ")
while n == "right":
    n = input("You're in the Lost Forest. Go left or right? ")
print("You got out of the Lost Forest!")
```

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CONTROL FLOW: `while` and `for` LOOPS

- iterate through numbers in a sequence

```
# more complicated with while loop
n = 0
while n < 5:
    print(n)
    n = n+1


# shortcut with for loop
for n in range(5):
    print(n)
```

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CONTROL FLOW: `for` LOOPS

```
for <variable> in range(<some_num>):
    <expression>
    <expression>
    ...
```

- each time through the loop, `<variable>` takes a value
- first time, `<variable>` starts at the smallest value
- next time, `<variable>` gets the prev value + 1
- etc.

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`range(start,stop,step)`

- default values are `start = 0` and `step = 1` and optional
- loop until value is `stop - 1`

```
mysum = 0
for i in range(7, 10):
    mysum += i
print(mysum)
```

```
mysum = 0
for i in range(5, 11, 2):
    mysum += i
print(mysum)
```

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`break` STATEMENT

- immediately exits whatever loop it is in
- skips remaining expressions in code block
- exits only innermost loop!

```
while <condition_1>:
    while <condition_2>:
        <expression_a>
        break
        <expression_b>
    <expression_c>
```

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`break` STATEMENT

```
mysum = 0
for i in range(5, 11, 2):
    if mysum == 5:
        break
    mysum += 1
print(mysum)
```

- what happens in this program?

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`for` VS `while` LOOPS

`for` loops

- **know** number of iterations
- can **end early** via `break`
- uses a **counter**
- **can rewrite** a `for` loop using a `while` loop

`while` loops

- **unbounded** number of iterations
- can **end early** via `break`
- can use a **counter but must initialize** before loop and increment it inside loop
- **may not be able to rewrite** a `while` loop using a `for` loop

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STRINGS

- think of as a **sequence** of case sensitive characters
- can compare strings with ==, >, < etc.
- `len()` is a function used to retrieve the **length** of the string in the parentheses

```
s = "abc"
len(s)
```
→ evaluates to 3

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STRINGS

- square brackets used to perform **indexing** into a string to get the value at a certain index/position

```
s = "abc"
```

index: 0 1 2 ← indexing always starts at 0

index: -3 -2 -1 ← last element always at index -1

```
s[0]   →
s[1]   →
s[2]   →
s[3]   →
s[-1]  →
s[-2]  →
s[-3]  →
```

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STRINGS

- can **slice** strings using `[start:stop:step]`
- if give two numbers, `[start:stop]`, `step=1` by default
- you can also omit numbers and leave just colons

If unsure what some command does, try it out in your console!

```
s = "abcdefgh"
s[3:6]   →
s[3:6:2] →
s[::]    →
s[::-1]  →
s[4:1:-2]→
```

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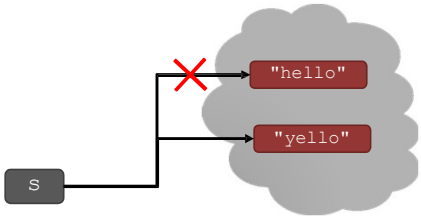
STRINGS

- strings are "**immutable**" – cannot be modified

```
s = "hello"
```

```
s[0] = 'y'
```
→ gives an error

```
s = 'y'+s[1:len(s)]
```
→ is allowed, s bound to new object



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STRINGS AND LOOPS

- these two code snippets do the same thing
- bottom one is more "pythonic"

```
s = "abcdefgh"
for index in range(len(s)):
    if s[index] == 'i' or s[index] == 'u':
        print("There is an i or u")

for char in s:
    if char == 'i' or char == 'u':
        print("There is an i or u")
```

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TUPLES

- an ordered sequence of elements, can mix element types
- cannot change element values, **immutable**
- represented with parentheses

remember strings?

```
te = ()
t = (2,"mit",3)
t[0]                    → evaluates to 2
(2,"mit",3) + (5,6)     → evaluates to (2,"mit",3,5,6)
t[1:2]                  → slice tuple, evaluates to ("mit",)
t[1:3]                  → slice tuple, evaluates to ("mit",3)
len(t)                  → evaluates to 3
t[1] = 4                → gives error, can't modify object
```

empty tuple

extra comma means a tuple with one element

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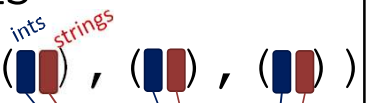
MANIPULATING TUPLES



- can **iterate** over tuples

```
def get_data(aTuple):
    nums = ()
    words = ()
    for t in aTuple:
        nums = nums + (t[0],)
        if t[1] not in words:
            words = words + (t[1],)
    min_n = min(nums)
    max_n = max(nums)
    unique_words = len(words)
    return (min_n, max_n, unique_words)
```

empty tuple

singleton tuple

nums( )

words(? ? ?)

if not already in words
i.e. unique strings from aTuple

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LISTS

- **ordered sequence** of information, accessible by index
- a list is denoted by **square brackets**, `[]`
- a list contains **elements**
  - usually homogeneous (ie, all integers)
  - can contain mixed types (not common)
- list elements can be changed so a list is **mutable**

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INDICES AND ORDERING

```
a_list = []
```
empty list

```
L = [2, 'a', 4, [1,2]]
len(L)  →
L[0]    →
L[2]+1  →
L[3]    →
L[4]    →
i = 2
L[i-1]  →
```

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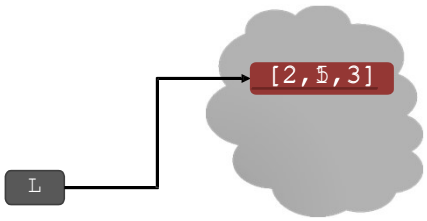
CHANGING ELEMENTS

- lists are **mutable**!
- assigning to an element at an index changes the value

```
L = [2, 1, 3]
L[1] = 5
```

- `L` is now `[2, 5, 3]`, note this is the **same object** `L`



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ITERATING OVER A LIST

- compute the **sum of elements** of a list
- common pattern, iterate over list elements

like strings, can iterate over list elements directly

```
total = 0
for i in range(len(L)):
    total += L[i]
print total
```

```
total = 0
for i in L:
    total += i
print total
```

- notice
  - list elements are indexed `0` to `len(L)-1`
  - `range(n)` goes from `0` to `n-1`

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CONVERT LISTS TO STRINGS AND BACK

- convert **string to list** with `list(s)`, returns a list with every character from `s` an element in `L`
- can use `s.split()`, to **split a string on a character** parameter, splits on spaces if called without a parameter

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MUTATION, ALIASING, CLONING

Again, Python Tutor is your best friend to help sort this out!

http://www.pythontutor.com/

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LISTS IN MEMORY

- lists are **mutable**
- behave differently than immutable types
- is an object in memory
- variable name points to object
- any variable pointing to that object is affected
- key phrase to keep in mind when working with lists is **side effects**

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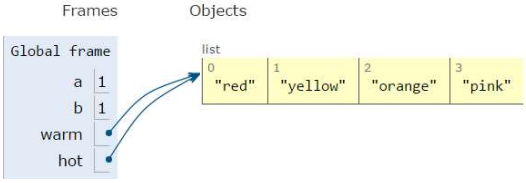
ALIASES

- `hot` is an **alias** for `warm` – changing one changes the other!
- `append()` has a side effect

```
1  a = 1
2  b = a
3  print(a)
4  print(b)
5
6  warm = ['red', 'yellow', 'orange']
7  hot = warm
8  hot.append('pink')
9  print(hot)
10 print(warm)
```

```
1
1
['red', 'yellow', 'orange', 'pink']
['red', 'yellow', 'orange', 'pink']
```



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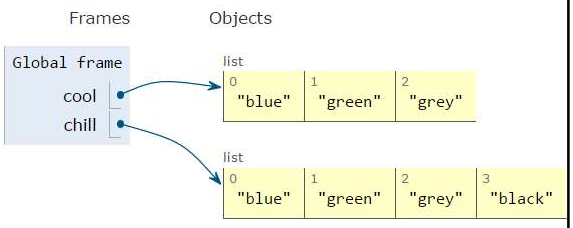
CLONING A LIST

- create a new list and **copy every element** using `chill = cool[:]`

```
1 cool = ['blue', 'green', 'grey']
2 chill = cool[:]
3 chill.append('black')
4 print(chill)
5 print(cool)
```

```
['blue', 'green', 'grey', 'black']
['blue', 'green', 'grey']
```



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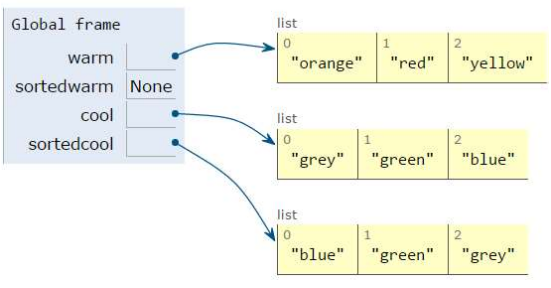
SORTING LISTS

- calling `sort()` **mutates** the list, returns nothing
- calling `sorted()` **does not mutate** list, must assign result to a variable

```
1 warm = ['red', 'yellow', 'orange']
2 sortedwarm = warm.sort()
3 print(warm)
4 print(sortedwarm)
5
6 cool = ['grey', 'green', 'blue']
7 sortedcool = sorted(cool)
8 print(cool)
9 print(sortedcool)
```

```
['orange', 'red', 'yellow']
None
['grey', 'green', 'blue']
['blue', 'green', 'grey']
```



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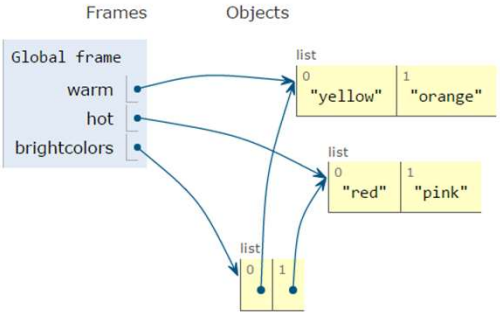
LISTS OF LISTS OF LISTS OF….

- can have **nested** lists
- side effects still possible after mutation

```
[['yellow', 'orange'], ['red']]
['red', 'pink']
[['yellow', 'orange'], ['red', 'pink']]
```

```
1 warm = ['yellow', 'orange']
2 hot = ['red']
3 brightcolors = [warm]
4 brightcolors.append(hot)
5 print(brightcolors)
6 hot.append('pink')
7 print(hot)
8 print(brightcolors)
```



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MUTATION AND ITERATION
Try this in Python Tutor!

- **avoid** mutating a list as you are iterating over it

```
def remove_dups(L1, L2):
    for e in L1:
        if e in L2:
            L1.remove(e)
```

✖

```
def remove_dups(L1, L2):
    L1_copy = L1[:]
    for e in L1_copy:
        if e in L2:
            L1.remove(e)
```

✓

```
L1 = [1, 2, 3, 4]
L2 = [1, 2, 5, 6]
remove_dups(L1, L2)
```

clone list first, note that `L1_copy = L1` does NOT clone

- `L1` is `[2,3,4]` not `[3,4]` Why?
  - Python uses an internal counter to keep track of index it is in the loop
  - mutating changes the list length but Python doesn't update the counter
  - loop never sees element 2

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HOW DO WE WRITE CODE?

- so far…
  - covered language mechanisms
  - know how to write different files for each computation
  - each file is some piece of code
  - each code is a sequence of instructions
- problems with this approach
  - easy for small-scale problems
  - messy for larger problems
  - hard to keep track of details
  - how do you know the right info is supplied to the right part of code

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GOOD PROGRAMMING

- more code not necessarily a good thing
- measure good programmers by the amount of functionality
- introduce **functions**
- mechanism to achieve **decomposition** and **abstraction**

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EXAMPLE – PROJECTOR

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EXAMPLE – PROJECTOR

- a projector is a black box
- don't know how it works
- know the interface: input/output
- connect any electronic to it that can communicate with that input
- black box somehow converts image from input source to a wall, magnifying it
- **ABSTRACTION IDEA**: do not need to know how projector works to use it

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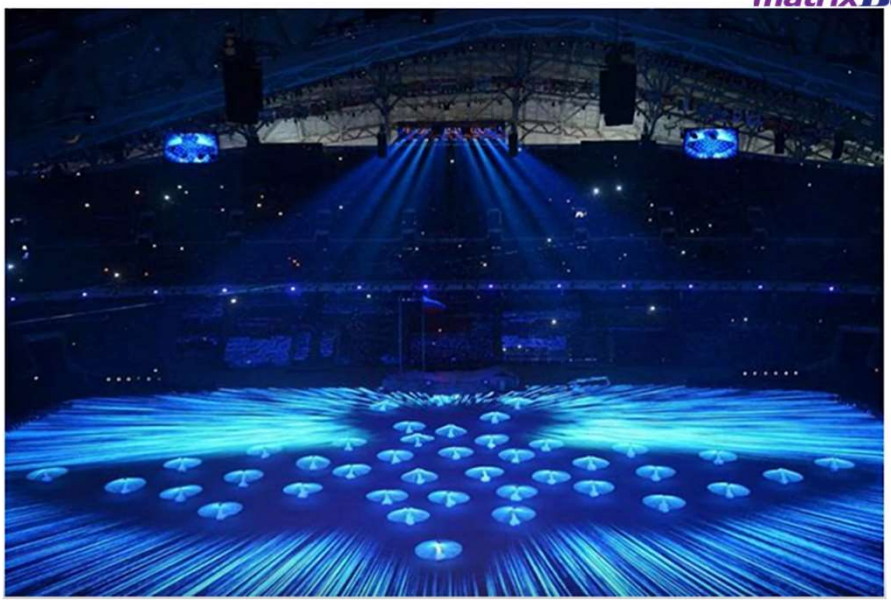

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EXAMPLE – PROJECTOR

- projecting large image for Olympics decomposed into separate tasks for separate projectors
- each projector takes input and produces separate output
- all projectors work together to produce larger image
- **DECOMPOSITION IDEA**: different devices work together to achieve an end goal

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CREATE STRUCTURE with DECOMPOSITION

- in projector example, separate devices
- in programming, divide code into **modules**
  - are **self-contained**
  - used to **break up** code
  - intended to be **reusable**
  - keep code **organized**
  - **keep code coherent**
- this lecture, achieve decomposition with **functions**
- in a few weeks, achieve decomposition with **classes**

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SUPRESS DETAILS with ABSTRACTION

- in projector example, instructions for how to use it are sufficient, no need to know how to build one
- in programming, think of a piece of code as a **black box**
  - cannot see details
  - do not need to see details
  - do not want to see details
  - hide tedious coding details
- achieve abstraction with **function specifications** or **docstrings**

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FUNCTIONS

- write reusable pieces/chunks of code, called **functions**
- functions are not run in a program until they are "**called**" or "**invoked**" in a program
- function characteristics:
  - has a **name**
  - has **parameters** (0 or more)
  - has a **docstring** (optional but recommended)
  - has a **body**
  - **returns** something

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HOW TO WRITE and CALL/INVOKE A FUNCTION

keyword

name

parameters or arguments

specification, docstring

```
def is_even( i ):
    """
    Input: i, a positive int
    Returns True if i is even, otherwise False
    """
    print("inside is_even")
    return i%2 == 0
```

body

later in the code, you call the function using its name and values for parameters

```
is_even(3)
```

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IN THE FUNCTION BODY

```
def is_even( i ):
    """
    Input: i, a positive int
    Returns True if i is even, otherwise False
    """
    print("inside is_even")
    return i%2 == 0
```

run some commands

keyword

expression to evaluate and return

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VARIABLE SCOPE

- **formal parameter** gets bound to the value of **actual parameter** when function is called
- new **scope/frame/environment** created when enter a function
- **scope** is mapping of names to objects

```
def f( x ):
    x = x + 1
    print('in f(x): x =', x)
    return x
```

formal parameter

Function definition

```
x = 3
z = f( x )
```

actual parameter

Main program code
* initializes a variable x
* makes a function call f(x)
* assigns return of function to variable z

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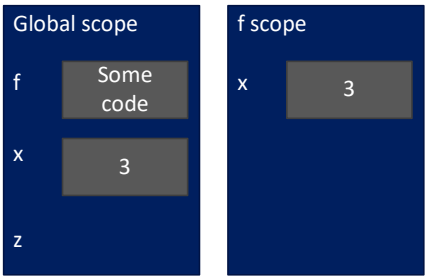
VARIABLE SCOPE

```
def f( x ):
    x = x + 1
    print('in f(x): x =', x)
    return x

x = 3
z = f( x )
```



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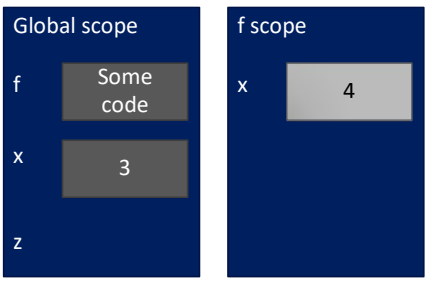
VARIABLE SCOPE

```
def f( x ):
    x = x + 1
    print('in f(x): x =', x)
    return x

x = 3
z = f( x )
```



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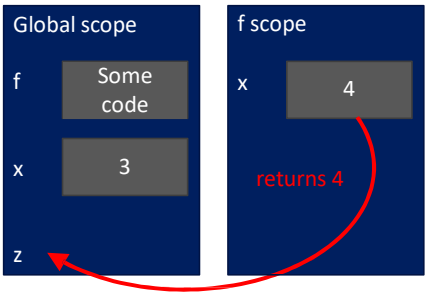
VARIABLE SCOPE

```
def f( x ):
    x = x + 1
    print('in f(x): x =', x)
    return x

x = 3
z = f( x )
```



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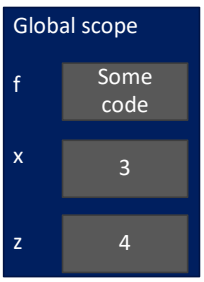
VARIABLE SCOPE

```
def f( x ):
    x = x + 1
    print('in f(x): x =', x)
    return x

x = 3
z = f( x )
```



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ONE WARNING IF NO `return` STATEMENT

```
def is_even( i ):
    """
    Input: i, a positive int
    Does not return anything
    """
    i%2 == 0
```

without a return statement

- Python returns the value **None, if no `return` given**
- represents the absence of a value

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ONE WARNING IF NO `return` STATEMENT

```
def is_even( i ):
    """
    Input: i, a positive int
    Does not return anything
    """
    remainder = i % 2
is_even( 3 )
print(is_even( 3 ))
```

None

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FUNCTIONS AS ARGUMENTS

- arguments can take on any type, even functions

```
def func_a():
    print 'inside func_a'
def func_b(y):
    print 'inside func_b'
    return y
def func_c(z):
    print 'inside func_c'
    return z()
print func_a()
print 5 + func_b(2)
print func_c(func_a)
```

call `func_a`, takes no parameters
call `func_b`, takes one parameter
call `func_c`, takes one parameter, another function

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FUNCTIONS AS ARGUMENTS

```
def func_a():
    print 'inside func_a'
def func_b(y):
    print 'inside func_b'
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    print 'inside func_c'
    return z()
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```

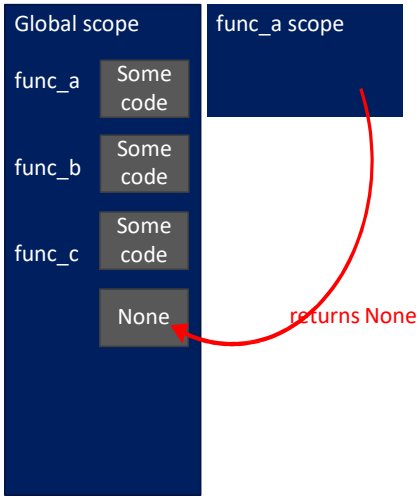

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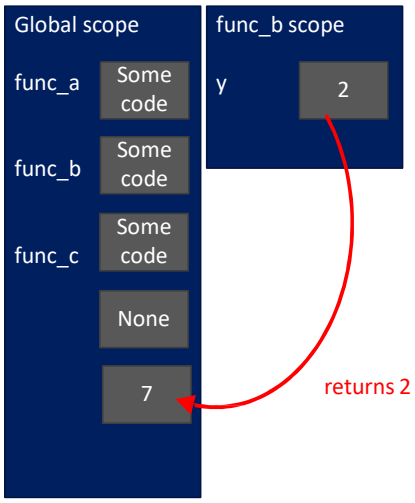
FUNCTIONS AS ARGUMENTS

```
def func_a():
    print 'inside func_a'
def func_b(y):
    print 'inside func_b'
    return y
def func_c(z):
    print 'inside func_c'
    return z()
print func_a()
print 5 + func_b(2)
print func_c(func_a)
```



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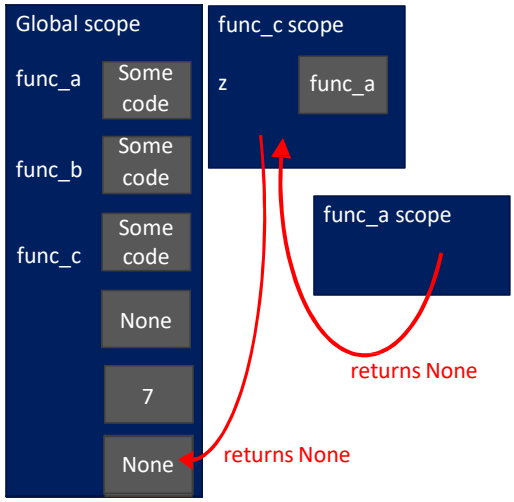
FUNCTIONS AS ARGUMENTS

```
def func_a():
    print 'inside func_a'
def func_b(y):
    print 'inside func_b'
    return y
def func_c(z):
    print 'inside func_c'
    return z()
print func_a()
print 5 + func_b(2)
print func_c(func_a)
```



SCOPE EXAMPLE

- inside a function, **can access** a variable defined outside
- inside a function, **cannot modify** a variable defined outside -- can using **global variables**, but frowned upon

```
def f(y):
    x = 1
    x += 1
    print(x)

x = 5
f(x)
print(x)
```

x is re-defined in scope of f

different x objects

```
def g(y):
    print(x)
    print(x + 1)

x = 5
g(x)
print(x)
```

x from outside g

x inside g is picked up from scope that called function g

```
def h(y):
    x += 1

x = 5
h(x)
print(x)
```

UnboundLocalError: local variable 'x' referenced before assignment

SCOPE EXAMPLE

- inside a function, **can access** a variable defined outside
- inside a function, **cannot modify** a variable defined outside -- can using **global variables**, but frowned upon

```
def f(y):
    x = 1
    x += 1
    print(x)

x = 5
f(x)
print(x)
```

```
def g(y):
    print(x)


x = 5
g(x)
print(x)
```

```
def h(y):
    x += 1

x = 5
h(x)
print(x)
```

x from global/main program scope

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HARDER SCOPE EXAMPLE

IMPORTANT and TRICKY!

Python Tutor is your best friend to help sort this out!

http://www.pythontutor.com/

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LEGB Rule:

- L: Local — Names assigned in any way within a function (def or lambda), and not declared global in that function.
- E: Enclosing function locals — Names in the local scope of any and all enclosing functions (def or lambda), from inner to outer.
- G: Global (module) — Names assigned at the top-level of a module file, or declared global in a def within the file.
- B: Built-in (Python) — Names preassigned in the built-in names module : open, range, SyntaxError,...

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```
# GLOBAL
name = 'THIS IS A GLOBAL STRING'

def greet():

    # ENCLOSING
    name = 'Sammy'

    def hello():
        #LOCAL
        name = 'IM A LOCAL'
        print('Hello '+name)

    hello()
```

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FUNCTIONS AS ARGUMENTS

- arguments can take on any type, even functions

```
def func_a():
    print 'inside func_a'
def func_b(y):
    print 'inside func_b'
    return y
def func_c(z):
    print 'inside func_c'
    return z()
print func_a()
print 5 + func_b(2)
print func_c(func_a)
```

call `func_a`, takes no parameters
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call `func_c`, takes one parameter, another function

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FUNCTIONS AS ARGUMENTS

```
def func_a():
    print 'inside func_a'
def func_b(y):
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    return z()
print func_a()
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```

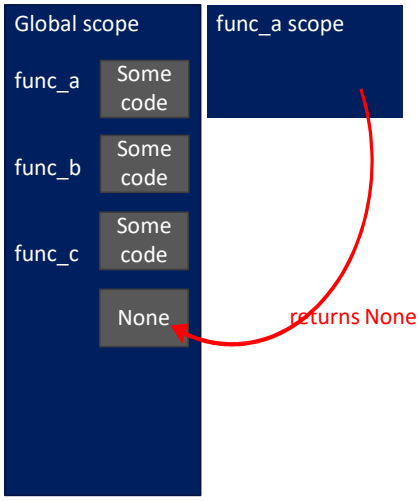

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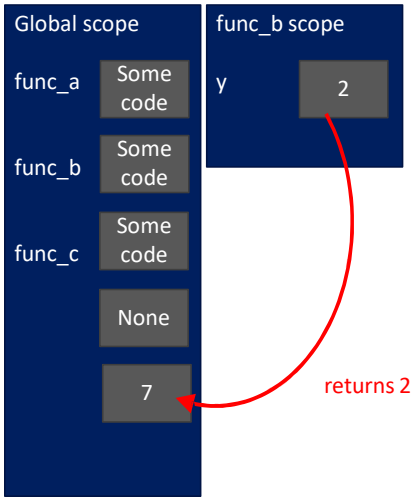
FUNCTIONS AS ARGUMENTS

```
def func_a():
    print 'inside func_a'
def func_b(y):
    print 'inside func_b'
    return y
def func_c(z):
    print 'inside func_c'
    return z()
print func_a()
print 5 + func_b(2)
print func_c(func_a)
```



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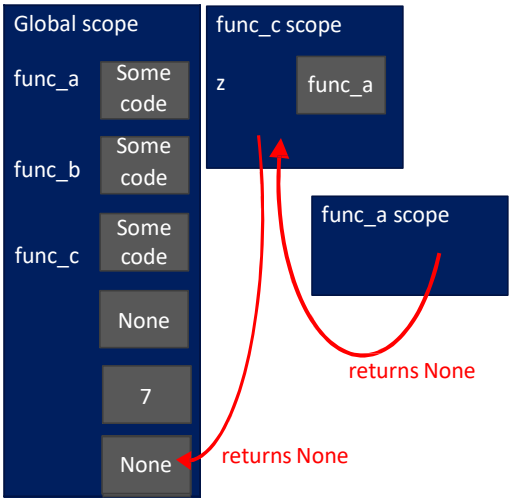
FUNCTIONS AS ARGUMENTS

```
def func_a():
    print 'inside func_a'
def func_b(y):
    print 'inside func_b'
    return y
def func_c(z):
    print 'inside func_c'
    return z()
print func_a()
print 5 + func_b(2)
print func_c(func_a)
```



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HOW TO STORE STUDENT INFO

- so far, can store using separate lists for every info

```
names = ['Ana', 'John', 'Denise', 'Katy']
grade = ['B', 'A+', 'A', 'A']
course = [2.00, 6.0001, 20.002, 9.01]
```

- a **separate list** for each item
- each list must have the **same length**
- info stored across lists at **same index**, each index refers to info for a different person

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HOW TO UPDATE/RETRIEVE STUDENT INFO

```
def get_grade(student, name_list, grade_list, course_list):
    i = name_list.index(student)
    grade = grade_list[i]
    course = course_list[i]
    return (course, grade)
```

- **messy** if have a lot of different info to keep track of
- must maintain **many lists** and pass them as arguments
- must **always index** using integers
- must remember to change multiple lists

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A BETTER AND CLEANER WAY – A DICTIONARY

- nice to **index item of interest directly** (not always int)
- nice to use **one data structure**, no separate lists

A list

0	Elem 1
1	Elem 2
2	Elem 3
3	Elem 4
…	…

index element

A dictionary

Key 1	Val 1
Key 2	Val 2
Key 3	Val 3
Key 4	Val 4
…	…

custom index by label element

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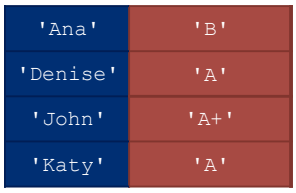
A PYTHON DICTIONARY

- store pairs of data
  - key
  - value



empty dictionary

```
my_dict = {}
grades = {'Ana':'B', 'John':'A+', 'Denise':'A', 'Katy':'A'}
```

key1 val1 key2 val2 key3 val3 key4 val4

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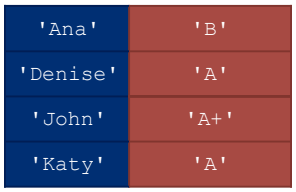
DICTIONARY LOOKUP

- similar to indexing into a list
- **looks up** the **key**
- **returns** the **value** associated with the key
- if key isn't found, get an error




```
grades = {'Ana':'B', 'John':'A+', 'Denise':'A', 'Katy':'A'}
grades['John']      → evaluates to 'A+'
grades['Sylvan']    → gives a KeyError
```

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DICTIONARY OPERATIONS

'Ana'	'B'
'Denise'	'A'
'John'	'A+'
'Katy'	'A'
'Sylvan'	'A'

```
grades = {'Ana':'B', 'John':'A+', 'Denise':'A', 'Katy':'A'}
```

- **add** an entry

```
grades['Sylvan'] = 'A'
```

- **test** if key in dictionary

```
'John' in grades          → returns True
'Daniel' in grades        → returns False
```

- **delete** entry

```
del(grades['Ana'])
```

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DICTIONARY OPERATIONS

'Ana'	'B'
'Denise'	'A'
'John'	'A+'
'Katy'	'A'

```
grades = {'Ana':'B', 'John':'A+', 'Denise':'A', 'Katy':'A'}
```

- get an **iterable that acts like a tuple of all keys** (no guaranteed order)

```
grades.keys()   → returns ['Denise','Katy','John','Ana']
```

- get an **iterable that acts like a tuple of all values**

```
grades.values() → returns ['A', 'A', 'A+', 'B']
```

(no guaranteed order)

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DICTIONARY KEYS and VALUES

- values
  - any type (**immutable and mutable**)
  - can be **duplicates**
  - dictionary values can be lists, even other dictionaries!
- keys
  - must be **unique**
  - **immutable** type (`int`, `float`, `string`, `tuple`, `bool`)
    - actually need an object that is **hashable,** but think of as immutable as all immutable types are hashable
  - careful with `float` type as a key
- **no order** to keys or values!

```
d = {4:{1:0}, (1,3):"twelve",
'const':[3.14,2.7,8.44]}
```

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List vs dict

- **ordered** sequence of elements
- look up elements by an integer index
- indices have an **order**
- index is an **integer**

- **matches** "keys" to "values"
- look up one item by another item
- **no order** is guaranteed
- key can be any **immutable** type

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OBJECTS

- Python supports many different kinds of data

```
1234      3.14159     "Hello"     [1, 5, 7, 11, 13]
{"CA": "California", "MA": "Massachusetts"}
```

- each is an **object**, and every object has:
  - a **type**
  - an internal **data representation** (primitive or composite)
  - a set of procedures for **interaction** with the object
- an object is an **instance** of a type
  - `1234` is an instance of an `int`
  - `"hello"` is an instance of a string

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OBJECT ORIENTED PROGRAMMING (OOP)

- **EVERYTHING IN PYTHON IS AN OBJECT** (and has a type)
- can **create new objects** of some type
- can **manipulate objects**
- can **destroy objects**
  - explicitly using `del` or just "forget" about them
  - python system will reclaim destroyed or inaccessible objects – called "garbage collection"

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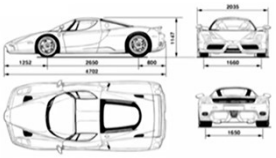
WHAT ARE OBJECTS?

- objects are **a data abstraction** that captures…

(1) an **internal representation**
- through data attributes

(2) an **interface** for interacting with object
- through methods (aka procedures/functions)
- defines behaviors but hides implementation



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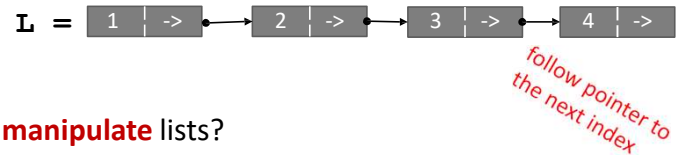
EXAMPLE: [1,2,3,4] has type list

- how are lists **represented internally**? linked list of cells



- how to **manipulate** lists?
  - `L[i], L[i:j], +`
  - `len(), min(), max(), del(L[i])`
  - `L.append(),L.extend(),L.count(),L.index(), L.insert(),L.pop(),L.remove(),L.reverse(), L.sort()`
- internal representation should be private
- correct behavior may be compromised if you manipulate internal representation directly

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ADVANTAGES OF OOP

- **bundle data into packages** together with procedures that work on them through well-defined interfaces
- **divide-and-conquer** development
  - implement and test behavior of each class separately
  - increased modularity reduces complexity
- classes make it easy to **reuse** code
  - many Python modules define new classes
  - each class has a separate environment (no collision on function names)
  - inheritance allows subclasses to redefine or extend a selected subset of a superclass' behavior

Implementing the class | Using the class

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CREATING AND USING YOUR OWN TYPES WITH CLASSES

- make a distinction between **creating a class** and **using an instance** of the class
- **creating** the class involves
  - defining the class name
  - defining class attributes
  - *for example, someone wrote code to implement a list class*
- **using** the class involves
  - creating new **instances** of objects
  - doing operations on the instances
  - *for example,* `L=[1,2]` *and* `len(L)`

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DEFINE YOUR OWN TYPES

- use the `class` keyword to define a new type

name/type

class parent

```
class Coordinate(object):
    #define attributes here
```

class definition

- similar to `def`, indent code to indicate which statements are part of the **class definition**
- the word `object` means that `Coordinate` is a Python object and **inherits** all its attributes (inheritance next lecture)
  - `Coordinate` is a subclass of `object`
  - `object` is a superclass of `Coordinate`

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WHAT ARE ATTRIBUTES?

- data and procedures that "**belong**" to the class
- **data attributes**
  - think of data as other objects that make up the class
  - *for example, a coordinate is made up of two numbers*
- **methods** (procedural attributes)
  - think of methods as functions that only work with this class
  - how to interact with the object
  - *for example you can define a distance between two coordinate objects but there is no meaning to a distance between two list objects*

Implementing the class | Using the class

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DEFINING HOW TO CREATE AN INSTANCE OF A CLASS

- first have to define **how to create an instance** of object
- use a **special method called `__init__`** to initialize some data attributes

```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y
```

special method to create an instance — is double underscore

parameter to refer to an instance of the class

what data initializes a Coordinate object

two data attributes for every Coordinate

Implementing the class | Using the class

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ACTUALLY CREATING AN INSTANCE OF A CLASS

```
c = Coordinate(3,4)
origin = Coordinate(0,0)
print(c.x)
print(origin.x)
```

create a new object of type Coordinate and pass in 3 and 4 to the __init__

use the dot to access an attribute of instance c

- data attributes of an instance are called **instance variables**

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WHAT IS A METHOD?

- procedural attribute, like a **function that works only with this class**
- Python sometime passes the object as the first argument
  - convention is to use **`self`** as the name of the first argument of all methods
- the "**.**" **operator** is used to access any attribute
  - a data attribute of an object
  - a method of an object

Implementing the class | Using the class

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DEFINE A METHOD FOR THE `Coordinate` CLASS

```
class Coordinate(object):
    def __init_(self, x, y):
        self.x = x
        self.y = y
    def distance(self, other):
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
```

another parameter to method

use it to refer to any instance

dot notation to access data

- other than `self` and dot notation, methods behave just like functions (take params, do operations, return)

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HOW TO USE A METHOD

```
def distance(self, other):
    # code here
```

method def

Using the class:

- conventional way

```
c = Coordinate(3,4)
zero = Coordinate(0,0)
print(c.distance(zero))
```

object to call method on; name of method; parameters not including self (self is implied to be c)

- equivalent to

```
c = Coordinate(3,4)
zero = Coordinate(0,0)
print(Coordinate.distance(c, zero))
```

name of class; name of method; parameters, including an object to call the method on, representing self

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PRINT REPRESENTATION OF AN OBJECT

```
>>> c = Coordinate(3,4)
>>> print(c)
<__main__.Coordinate object at 0x7fa918510488>
```

- **uninformative** print representation by default
- define a **__str__ method** for a class
- Python calls the `__str__` method when used with `print` on your class object
- you choose what it does! Say that when we print a `Coordinate` object, want to show

```
>>> print(c)
<3,4>
```

Implementing the class | Using the class

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DEFINING YOUR OWN PRINT METHOD

```
class Coordinate(object):
    def __init_(self, x, y):
        self.x = x
        self.y = y
    def distance(self, other):
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
    def __str__(self):
        return "<"+str(self.x)+","+str(self.y)+">"
```

name of special method

must return a string

Implementing the class | Using the class

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WRAPPING YOUR HEAD AROUND TYPES AND CLASSES

- can ask for the type of an object instance

```
>>> c = Coordinate(3,4)
>>> print(c)
<3,4>
>>> print(type(c))
<class __main_.Coordinate>
```

return of the __str__ method

the type of object c is a class Coordinate

- this makes sense since

```
>>> print(Coordinate)
<class __main__.Coordinate>
>>> print(type(Coordinate))
<type 'type'>
```

a Coordinate is a class

a Coordinate class is a type of object

- use `isinstance()` to check if an object is a `Coordinate`

```
>>> print(isinstance(c, Coordinate))
True
```

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SPECIAL OPERATORS

- +, -, ==, <, >, len(), print, and many others

https://docs.python.org/3/reference/datamodel.html#basic-customization

- like `print`, can override these to work with your class
- define them with double underscores before/after

```
__add__(self, other)     →    self + other
__sub__(self, other)     →    self - other
__eq__(self, other)      →    self == other
__lt__(self, other)      →    self < other
__len__(self)            →    len(self)
__str__(self)            →    print self
```

... and others

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EXAMPLE: FRACTIONS

- create a **new type** to represent a number as a fraction
- **internal representation** is two integers
  - numerator
  - denominator
- **interface** a.k.a. **methods** a.k.a **how to interact** with `Fraction` objects
  - add, subtract
  - print representation, convert to a float
  - invert the fraction
- the code for this is in the handout, check it out!

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CLASS EXERCISE

```
a = Fraction(1,4)
b = Fraction(3,4)
c = a + b # c is a Fraction object
print(c) # 16/16
print(float(c)) # 1.0
print(Fraction.__float__(c))  # 1.0
print(float(b.inverse())) # 1.3333333

##c = Fraction(3.14, 2.7) # assertion error
##print a*b # error, did not define how to multiply two Fraction objects
```

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THE POWER OF OOP

- **bundle together objects** that share
  - common attributes
  - procedures that operate on those attributes
- use **abstraction** to make a distinction between how to implement an object vs how to use the object
- build **layers** of object abstractions that inherit behaviors from other classes of objects
- create our **own classes of objects** on top of Python's basic classes

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IMPLEMENTING THE CLASS vs USING THE CLASS

- write code from two different perspectives

implementing a new object type with a class
- **define** the class
- define **data attributes** (WHAT IS the object)
- define **methods** (HOW TO use the object)

using the new object type in code
- create **instances** of the object type
- do **operations** with them

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CLASS DEFINITION OF AN OBJECT TYPE vs INSTANCE OF A CLASS

- class name is the **type**
  - `class Coordinate(object)`
- class is defined generically
  - use `self` to refer to some instance while defining the class
  - `(self.x - self.y)**2`
  - `self` is a parameter to methods in class definition
- class defines data and methods **common across all instances**

- instance is **one specific** object
  `coord = Coordinate(1,2)`
- data attribute values vary between instances
  `c1 = Coordinate(1,2)`
  `c2 = Coordinate(3,4)`
  - `c1` and `c2` have different data attribute values `c1.x` and `c2.x` because they are different objects
- instance has the **structure of the class**

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WHY USE OOP AND CLASSES OF OBJECTS?

- mimic real life
- group different objects part of the same type


Jelly
1 year old
brown


5 years old
brown


Tiger
2 years old
brown


Bean
0 years old
black


2 years old
white


1 year old
b/w

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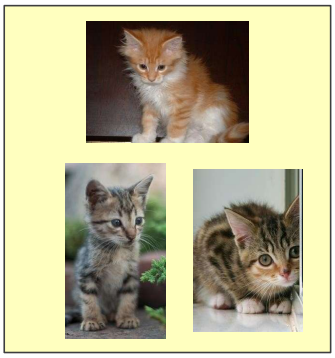
WHY USE OOP AND CLASSES OF OBJECTS?

- mimic real life
- group different objects part of the same type



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GROUPS OF OBJECTS HAVE ATTRIBUTES (RECAP)

- **data attributes**
  - how can you represent your object with data?
  - **what it is**
  - *for a coordinate: x and y values*
  - *for an animal: age, name*
- **procedural attributes** (behavior/operations/**methods**)
  - how can someone interact with the object?
  - **what it does**
  - *for a coordinate: find distance between two*
  - *for an animal: make a sound*

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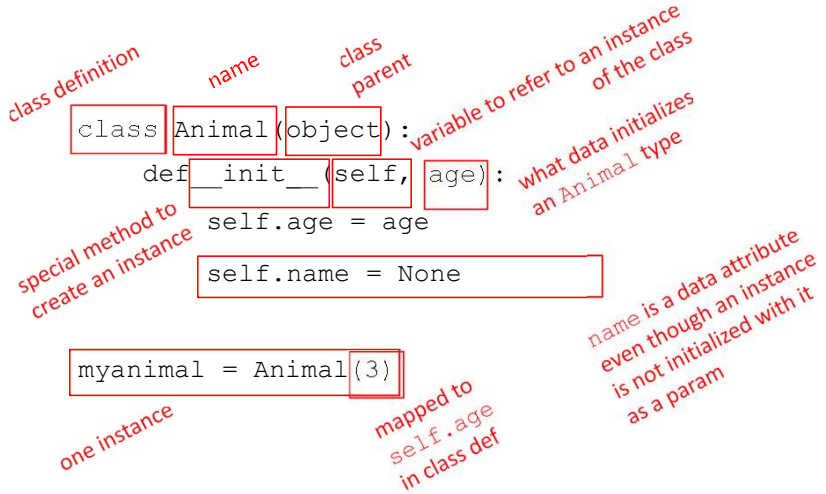
HOW TO DEFINE A CLASS (RECAP)



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GETTER AND SETTER METHODS

```
class Animal(object):
    def_init_(self, age):
        self.age = age
        self.name = None
    def get_age(self):
        return self.age
    def get_name(self):
        return self.name
    def set_age(self, newage):
        self.age = newage
    def set_name(self, newname=""):
        self.name = newname
    def_str__(self):
        return "animal:"+str(self.name)+":"+str(self.age)
```

getter

setter

- **getters and setters** should be used outside of class to access data attributes

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AN INSTANCE and DOT NOTATION (RECAP)

- instantiation creates an **instance of an object**

```
a = Animal(3)
```

- **dot notation** used to access attributes (data and methods) though it is better to use getters and setters to access data attributes

```
a.age
```

- access data attribute
- allowed, but not recommended

```
a.get_age()
```

- access method
- best to use getters and setters

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INFORMATION HIDING

- author of class definition may **change data attribute** variable names

replaced age data attribute by years

```
class Animal(object):
    def __init__(self, age):
        self.years = age
    def get_age(self):
        return self.years
```

- if you are **accessing data attributes** outside the class and class **definition changes**, may get errors
- outside of class, use getters and setters instead
  use `a.get_age()` NOT `a.age`
  - good style
  - easy to maintain code
  - prevents bugs

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PYTHON NOT GREAT AT INFORMATION HIDING

- allows you to **access data** from outside class definition

```
print(a.age)
```

- allows you to **write to data** from outside class definition

```
a.age = 'infinite'
```

- allows you to **create data attributes** for an instance from outside class definition

```
a.size = "tiny"
```

- it's **not good style** to do any of these!

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DEFAULT ARGUMENTS

- **default arguments** for formal parameters are used if no actual argument is given

```
def set_name(self, newname=""):
    self.name = newname
```

- default argument used here

```
a = Animal(3)
a.set_name()
print(a.get_name())
```

prints ""

- argument passed in is used here

```
a = Animal(3)
a.set_name("fluffy")
print(a.get_name())
```

prints "fluffy"

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HIERARCHIES

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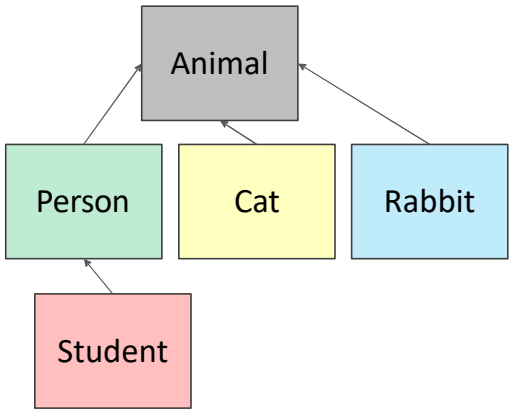
HIERARCHIES

- **parent class** (superclass)
- **child class** (subclass)
  - **inherits** all data and behaviors of parent class
  - **add** more **info**
  - **add** more **behavior**
  - **override** behavior



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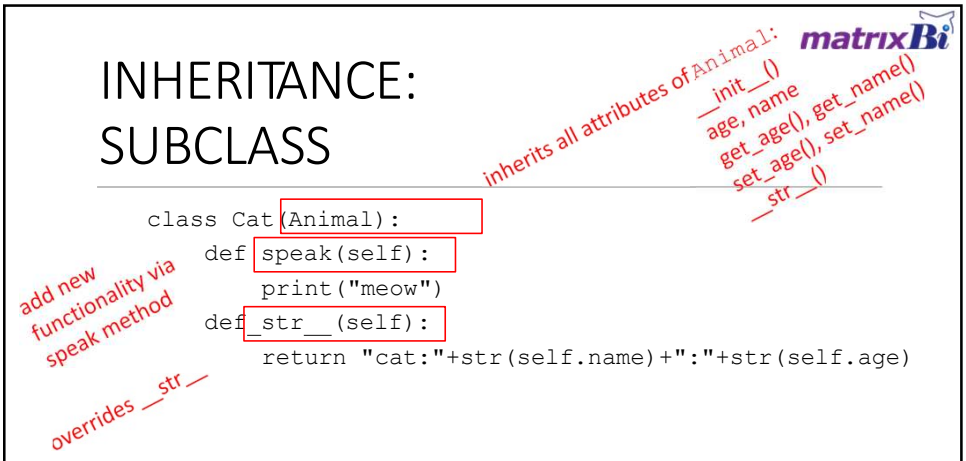
INHERITANCE: PARENT CLASS

```
class Animal(object):
    def __init__(self, age):
        self.age = age
        self.name = None
    def get_age(self):
        return self.age
    def get_name(self):
        return self.name
    def set_age(self, newage):
        self.age = newage
    def set_name(self, newname=""):
        self.name = newname
    def __str__(self):
        return "animal:"+str(self.name)+":"+str(self.age)
```

- everything is an object
- class object implements basic operations in Python, like binding variables, etc

INHERITANCE: SUBCLASS



- add new functionality with `speak()`
  - instance of type `Cat` can be called with new methods
  - instance of type `Animal` throws error if called with `Cat`'s new method
- `__init__`is not missing, uses the `Animal` version

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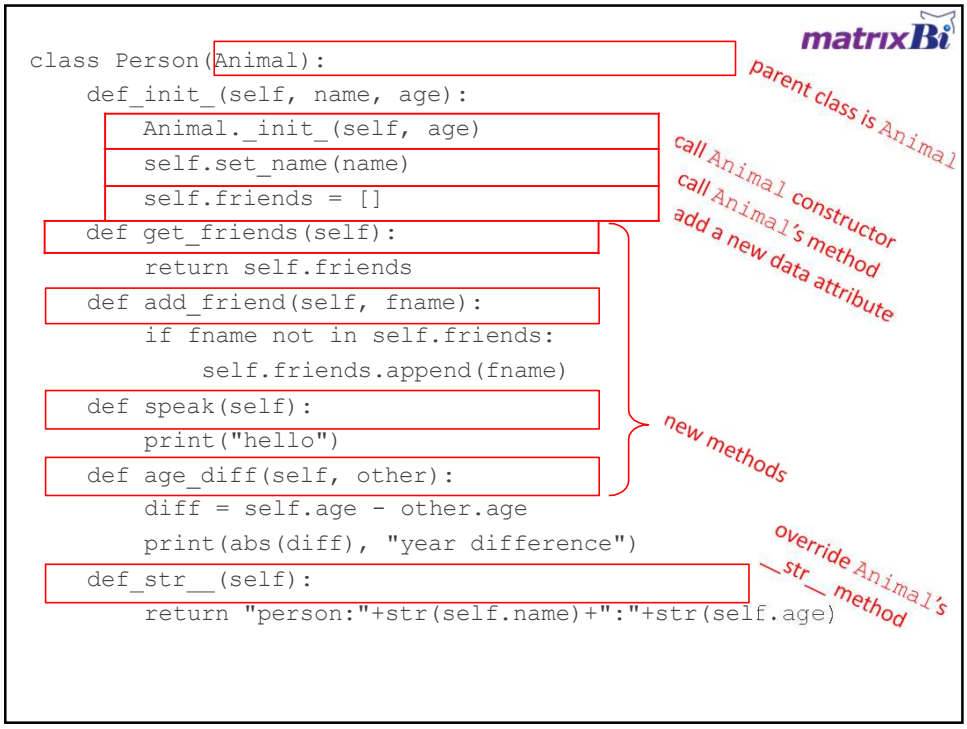
WHICH METHOD TO USE?

- subclass can have **methods with same name** as superclass
- for an instance of a class, look for a method name in **current class definition**
- if not found, look for method name **up the hierarchy** (in parent, then grandparent, and so on)
- use first method up the hierarchy that you found with that method name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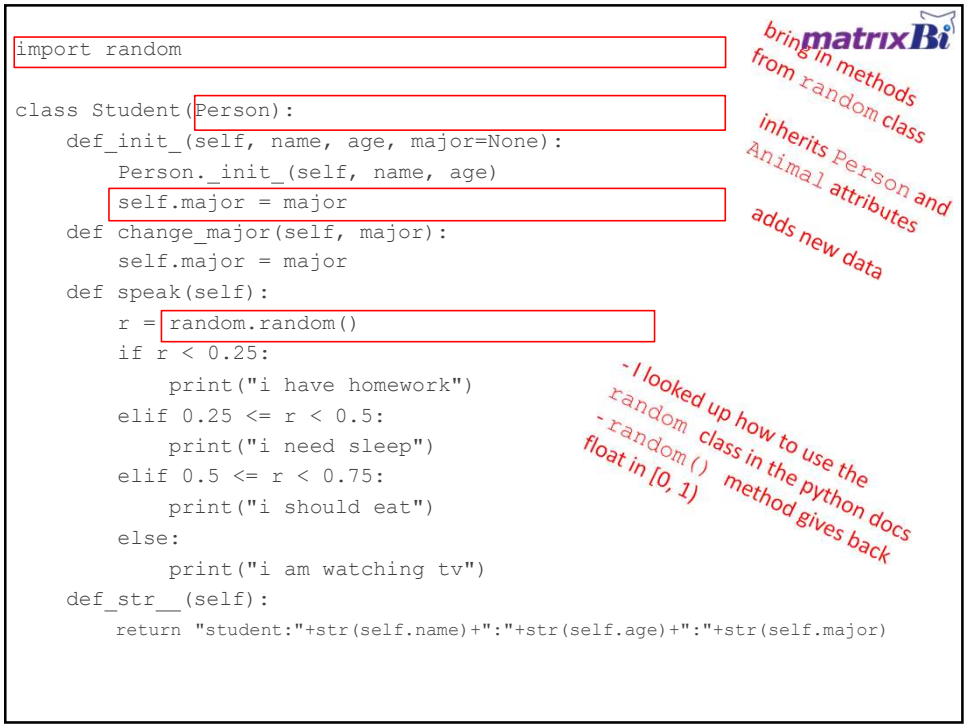
class Person(Animal):
def __init__(self, name, age):
Animal.__init__(self, age)
self.set_name(name)
self.friends = []
def get_friends(self):
return self.friends
def add_friend(self, fname):
if fname not in self.friends:
self.friends.append(fname)
def speak(self):
print("hello")
def age_diff(self, other):
diff = self.age - other.age
print(abs(diff), "year difference")
def __str__(self):
return "person:"+str(self.name)+":"+str(self.age)
parent class is Animal
call Animal constructor
call Animal's method
add a new data attribute
new methods
override Animal's __str__ method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import random
class Student(Person):
def __init__(self, name, age, major=None):
Person.__init__(self, name, age)
self.major = major
def change_major(self, major):
self.major = major
def speak(self):
r = random.random()
if r < 0.25:
print("i have homework")
elif 0.25 <= r < 0.5:
print("i need sleep")
elif 0.5 <= r < 0.75:
print("i should eat")
else:
print("i am watching tv")
def __str__(self):
return "student:"+str(self.name)+":"+str(self.age)+":"+str(self.major)
bring in methods from random class
inherits Person and Animal attributes
adds new data
- I looked up how to use the random class in the python docs
- random() method gives back float in [0, 1)

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CLASS VARIABLES AND THE `Rabbit` SUBCLASS

- **class variables** and their values are shared between all instances of a class

```
class Rabbit(Animal):
    tag = 1
    def __init__(self, age, parent1=None, parent2=None):
        Animal.__init__(self, age)
        self.parent1 = parent1
        self.parent2 = parent2
        self.rid = Rabbit.tag
        Rabbit.tag += 1
```

parent class

class variable

access class variable

instance variable

incrementing class variable changes it for all instances that may reference it

- `tag` used to give **unique id** to each new rabbit instance

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`Rabbit` GETTER METHODS

```
class Rabbit(Animal):
    tag = 1
    def __init__(self, age, parent1=None, parent2=None):
        Animal.__init__(self, age)
        self.parent1 = parent1
        self.parent2 = parent2
        self.rid = Rabbit.tag
        Rabbit.tag += 1
    def get_rid(self):
        return str(self.rid).zfill(3)
    def get_parent1(self):
        return self.parent1
    def get_parent2(self):
        return self.parent2
```

method on a string to pad the beginning with zeros for example, 001 not 1

- getter methods specific for a `Rabbit` class
- there are also getters `get_name` and `get_age` inherited from `Animal`

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WORKING WITH YOUR OWN TYPES

```
def __add__(self, other):
        # returning object of same type as this class
        return Rabbit(0, self, other)
```

recall Rabbit's `__init__(self, age, parent1=None, parent2=None)`

- define **+ operator** between two `Rabbit` instances
  - define what something like this does: `r4 = r1 + r2` where `r1` and `r2` are `Rabbit` instances
  - `r4` is a new `Rabbit` instance with age 0
  - `r4` has `self` as one parent and `other` as the other parent
  - in `__init__`, **`parent1` and `parent2` are of type `Rabbit`**

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SPECIAL METHOD TO COMPARE TWO `Rabbits`

- decide that two rabbits are equal if they have the **same two parents**

```
def __eq__(self, other):
    parents_same = self.parent1.rid == other.parent1.rid \  and
self.parent2.rid == other.parent2.rid
    parents_opposite = self.parent2.rid == other.parent1.rid \ and
    self.parent1.rid == other.parent2.rid  return parents_same or
    parents_opposite
```

booleans

- compare ids of parents since **ids are unique** (due to class var)
- note you can't compare objects directly
  - for ex. with `self.parent1 == other.parent1`
  - this calls the `__eq__` method over and over until call it on `None` and gives an `AttributeError` when it tries to do `None.parent1`

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OBJECT ORIENTED PROGRAMMING

- create your own **collections of data**
- **organize** information
- **division** of work
- access information in a **consistent** manner
- add **layers** of complexity
- like functions, classes are a mechanism for **decomposition** and **abstraction** in programming

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Python naming convention

Type	Public	Internal
Packages	`lower_with_under`	
Modules	`lower_with_under`	`_lower_with_under`
Classes	`CapWords`	`_CapWords`
Exceptions	`CapWords`	
Functions	`lower_with_under()`	`_lower_with_under()`
Global/Class Constants	`CAPS_WITH_UNDER`	`_CAPS_WITH_UNDER`
Global/Class Variables	`lower_with_under`	`_lower_with_under`
Instance Variables	`lower_with_under`	`_lower_with_under`
Method Names	`lower_with_under()`	`_lower_with_under()`
Function/Method Parameters	`lower_with_under`	
Local Variables	`lower_with_under`	

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WHAT IS RECURSION?

- Algorithmically: a way to design solutions to problems by **divide-and-conquer** or **decrease-and-conquer**
  - reduce a problem to simpler versions of the same problem
- Semantically: a programming technique where a **function calls itself**
  - in programming, goal is to NOT have infinite recursion
    - must have **1 or more base cases** that are easy to solve
    - must solve the same problem on **some other input** with the goal of simplifying the larger problem input

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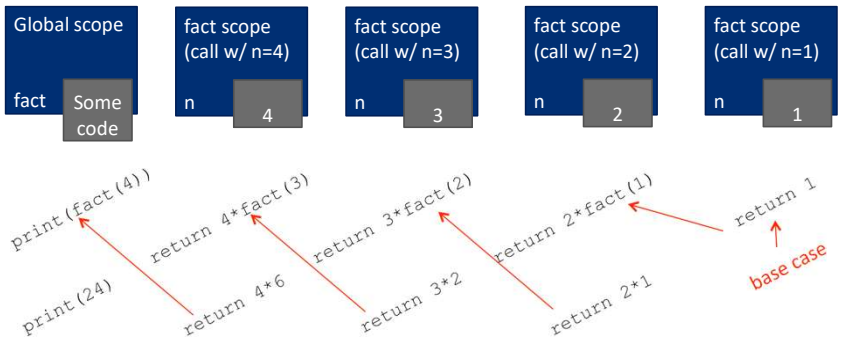
RECURSIVE FUNCTION SCOPE EXAMPLE

```
def fact(n):
    if n == 1:
        return 1
    else:
        return n*fact(n-1)

print(fact(4))
```



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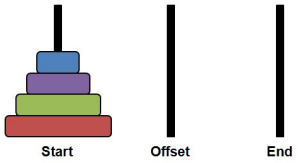
TOWERS OF HANOI

- The story:
  - 3 tall spikes
  - Stack of 64 different sized discs – start on one spike
  - Need to move stack to second spike (at which point universe ends)
  - Can only move one disc at a time, and a larger disc can never cover up a small disc



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TOWERS OF HANOI

- Having seen a set of examples of different sized stacks, how would you write a program to print out the right set of moves?
- **Think recursively!**
  - Solve a smaller problem
  - Solve a basic problem
  - Solve a smaller problem

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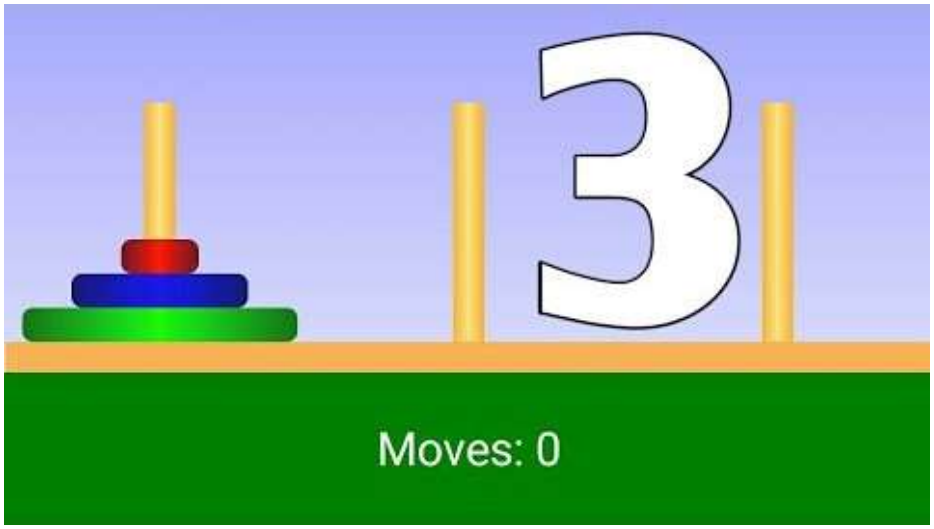

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```
def printMove(fr, to):
    print('move from ' + str(fr) + ' to ' +
    str(to))

def Towers(n, fr, to, spare):
    if n == 1:
        printMove(fr, to)
    else:
        Towers(n-1, fr, spare, to)
        Towers(1, fr, to, spare)
        Towers(n-1, spare, to, fr)
```

PRACTICE

- תרגילים בסיסיים בתכנות