http://www.cs.cornell.edu/courses/cs1110/2021sp

Lecture 17:
Classes
(Chapters 15 & 17.1-17.5)

CS 1110

Introduction to Computing Using Python

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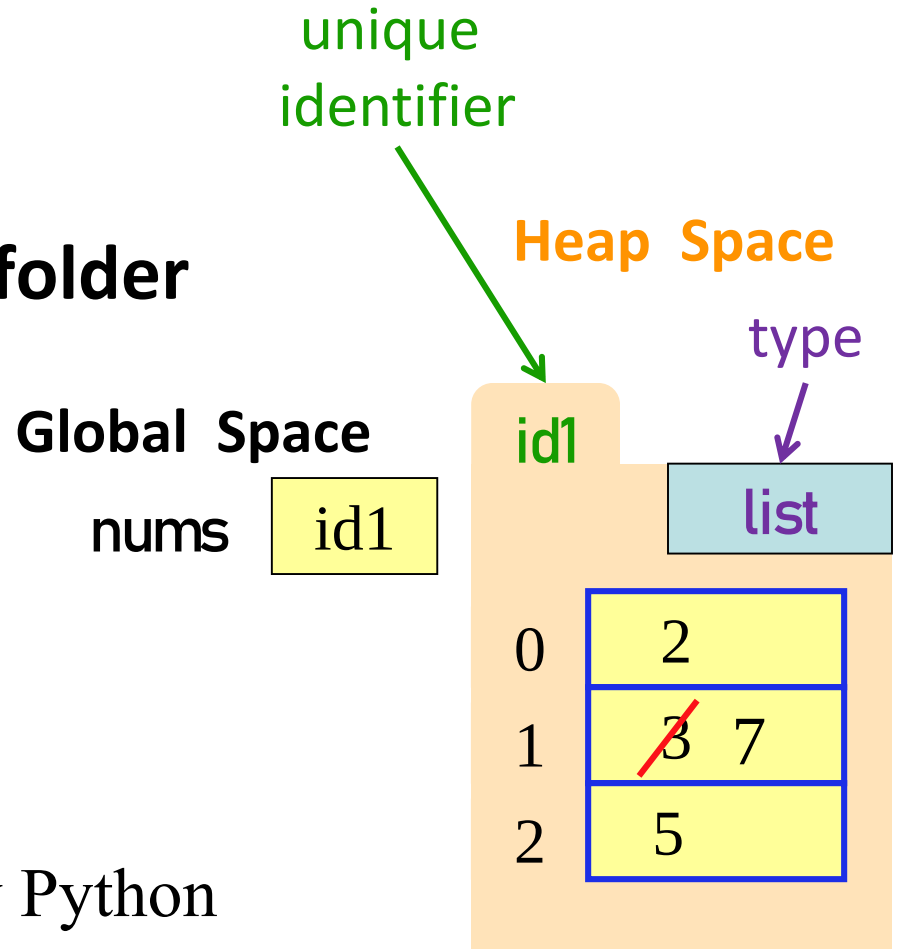
Announcements

- A4 due Tues Apr 13
- Prelim 2 on Apr 22 (Thurs)
- Prelim 2 seat or online session will be assigned by tomorrow via CMS. You have until Wedn Apr 14 to request a change in CMS *with justification*
- ACSU annual Research Night, Apr 8 5:30-7:30pm
  - Interested in undergraduate research in CS?
  - https://discord.com/invite/cCM3QuGY3B

Recall: Objects as Data in Folders

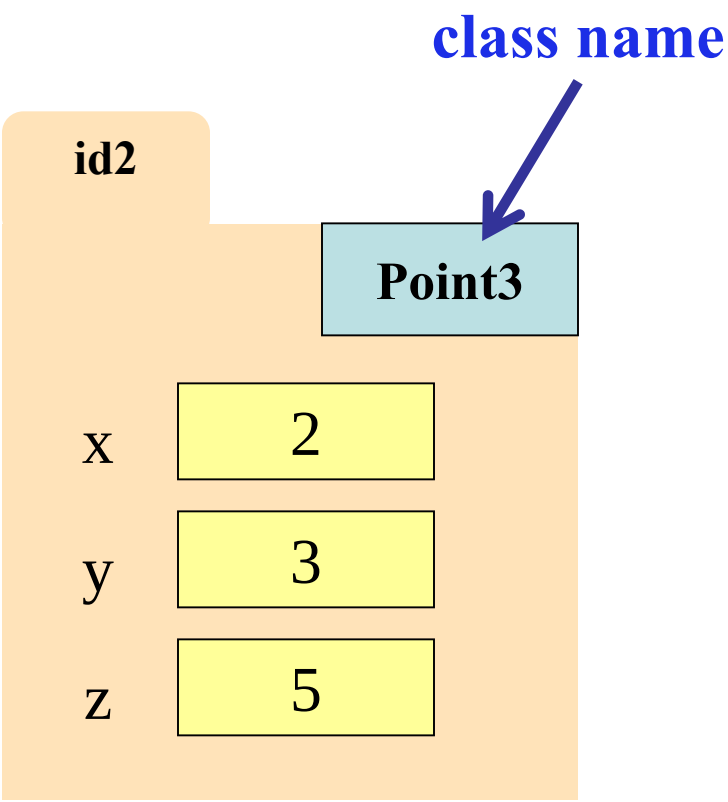
```
nums = [2,3,5]
nums[1] = 7
```

- An object is like a **manila folder**
- Contains variables
  - called **attributes**
  - Can change attribute values (w/ assignment statements)
- **Tab** identifies it
  - Unique number assigned by Python
  - Fixed for lifetime of the object
- **Type** shown in the corner



Classes are user-defined Types

Classes are how we add new types to Python



Example Classes

- Point3
- Rect
- Person
- Book
- Reader

Simple Class Definition

```
class <class-name>:
    """Class specification"""
    <method definitions>
```

Just like function definitions, but placed inside a class definition, i.e., indented relative to the class header

The Class Specification

```
class Student:
    """An instance is a Cornell student

    Instance Attributes:
    netID:      student's netID [str], 2-3 letters + 1-4 digits
    courses:    nested list [ [name0, n0], [name1, n1], ... ]
        name is course name [str], n is number of credits [int]
    major:      declared major [str]
    """
```

Short summary

Attribute list

Description and *invariant*

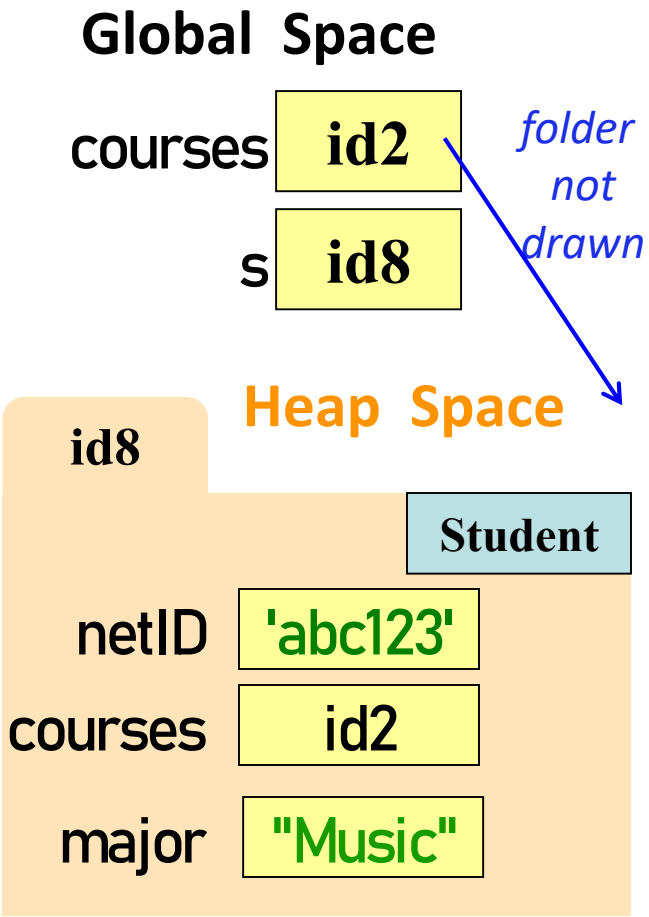
Attribute name

Convention: capitalize first letter of class name

Constructor

- Function to create new instances
  - function name is the class name
  - Created for you automatically
- Calling the constructor:
  - Makes a new object folder
  - Initializes attributes (see next slide)
  - Returns the id of the folder

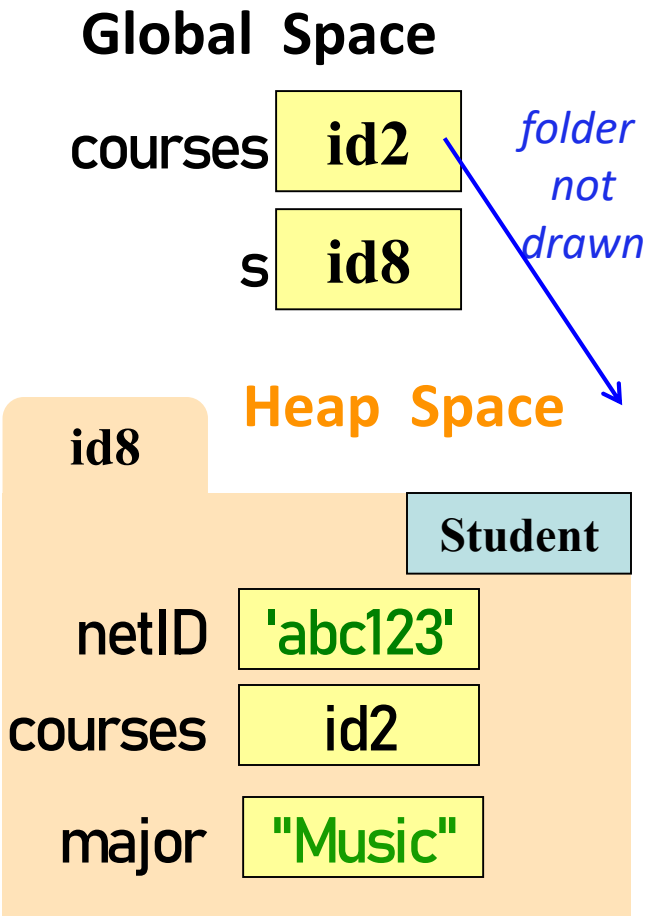
```
courses = [ ["CS 1110", 4], ["MATH 1920", 3] ]
s = Student("abc123", courses, "Music")
```



What happens when constructor is called?

s = Student("abc123", courses, "Music")

- Creates a new object (folder) of the class Student on the heap
  - Folder is initially empty
- Executes the method __init__
  - if __init__ exists
  - Puts attributes in the folder
  - Note: constructor calls __init__ automatically if it exists
- Returns folder name, the identifier



two underscores

Special Method: __init__

```
def __init__(self, netID, courses, major):
    """Initializer: creates a Student

    Has netID, courses and a major

    netID: [str], 2-3 letters + 1-4 digits
    courses:   nested list [ [name0, n0], [name1, n1], ... ]
        name is course name [str],
        n is number of credits [int]
    major:   declared major [str] """
    self.netID  = netID
    self.courses = courses
    self.major = major
```

called by the **constructor**

Param self: id of instance being initialized. Use it to assign attributes

Global Space

courses	id2
s	id8

folder not drawn

Heap Space

id8

Student

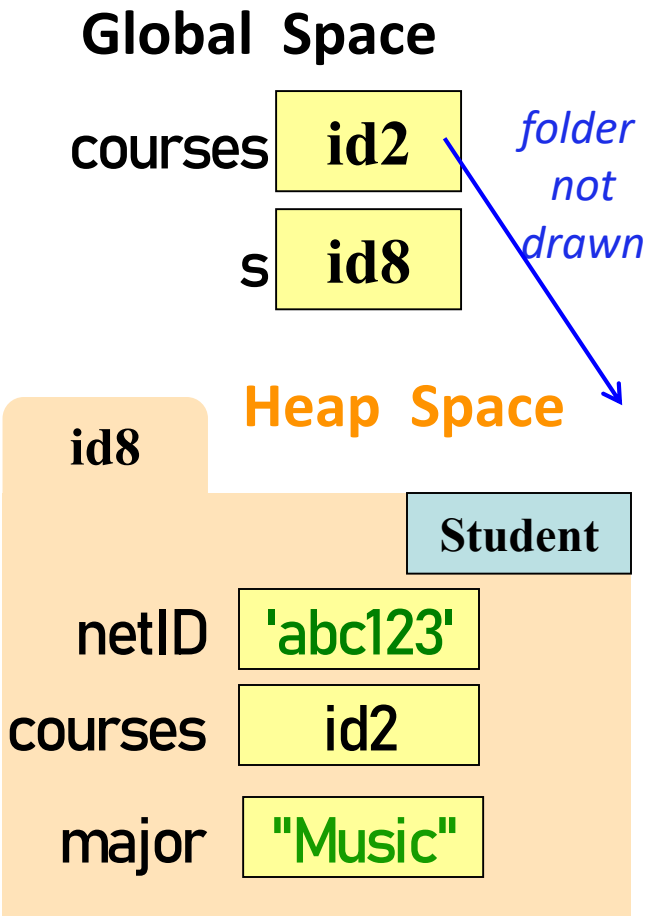
netID	'abc123'
courses	id2
major	"Music"

```
courses = [ ["CS 1110", 4], ["MATH 1920", 3] ]
s = Student("abc123", courses, "Music")
# this is the call to the constructor, which calls __init__
```

Evaluating a Constructor Expression

s = Student("abc123", courses, "Music")

- Creates a new object (folder) of the class Student on the heap
  - Folder is initially empty
- Executes the method __init__
  - self = folder name = identifier
  - Other arguments passed in order
  - Executes commands in initializer
  - Note: constructor calls __init__ automatically if it exists
- Returns folder name, the identifier



Truths about instantiating an object of a class

A) Instantiate an object by calling the constructor

B) The constructor creates the folder

C) A constructor calls the __init__ method

D) __init__ puts attributes in the folder

E) The constructor returns the id of the folder

Invariants

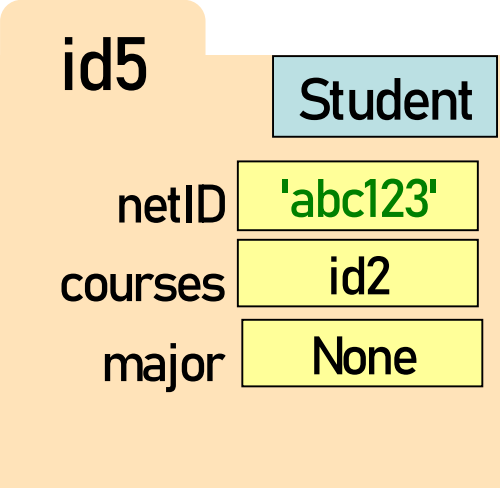
- Properties of an attribute that must be true
- Works like a precondition:
  - If invariant satisfied, object works properly
  - If not satisfied, object is "corrupted"
- **Example**:
  - `Student` class: attribute `courses` must be a list
- Purpose of the **class specification**

Checking Invariants with an Assert

```
class Student:
    """Instance is a Cornell student  """
    def __init__(self, netID, courses, major):
        """Initializer: instance with netID, and courses which defaults empty
        netID: [str], 2-3 letters + 1-4 digits
        courses:   nested list [ [name0, n0], [name1, n1], ... ]
                   name is course name [str], n is number of credits [int]
        major:     declared major [str]   """
        assert type(netID) == str, "netID should be type str"
        assert netID[0].isalpha(), "netID should begin with a letter"
        assert netID[-1].isdigit(), "netID should end with an int"
        assert type(courses) == list, "courses should be a list"
        assert major==None or type(major) == str, "major should be None or type str"
        self.netID = netID
        self.courses = couress
        self.major = major
```

Aside: The Value None

- The **major** attribute is a problem.
  - **major** is a declared major
  - Some students don't have one!



Solution: use value **None**

- **None**: Lack of str
- Will reassign the field later!

Making Arguments Optional

- We can assign default values to __init__ arguments
  - Write as assignments to parameters in definition
  - Parameters with default values are optional

Examples:

```
s1 = Student("xy1234", [ ], "History")   # all 3 arguments given

s1 = Student("xy1234", course_list)  # netID, courses given, major defaults to None

s1 = Student("xy1234", major="Art")  # netID, major given, courses defaults to [ ]
```

```
class Student:
    def __init__(self, netID, courses=[ ], major=None):
        self.netID = netID
        self.courses = courses
        self.major = major
        # < the rest of initializer goes here >
```

We know how to make:

- Class definitions
- Class specifications
- The `__init__` method
- Attributes (using `self`)

Continue developing our class Student …

What if we want to track and limit the number of credits a student is taking….

id5	Student
netID	'abc123'
courses	id2
major	"Music"
n_credit	15
max_credit	22

id6	Student
netID	'def456'
courses	id3
major	"History"
n_credit	14
max_credit	22

id7	Student
netID	'gh7890'
courses	id4
major	"CS"
n_credit	21
max_credit	22

Anything wrong with this?

Class Attributes

Class Attributes: Variables that belong to the Class

- One variable for the whole Class
- Shared by all object instances
- Access by <Class Name>.<attribute-name>

Why?

- Some variables are relevant to ***every*** object instance of a class
- Does not make sense to make them object attributes
- Doesn't make sense to make them global variables, either

Example: we want all students to have the same credit limit

Class Attributes – assign in class definition

```
class Student:
  """Instance is a Cornell student  """
  max_credit = 22
  def __init__(self, netID, courses, major):
      # < specs go here >
      # < assertions go here >
     self.netID = netID
     self.courses = courses
     self.major = major
     self.n_credit = 0
     for one_course in courses:
         self.n_credit = self.n_credit + one_course[1]     # add up all the credits

     assert self.n_credit <= Student.max_credit, "over credit limit"
```

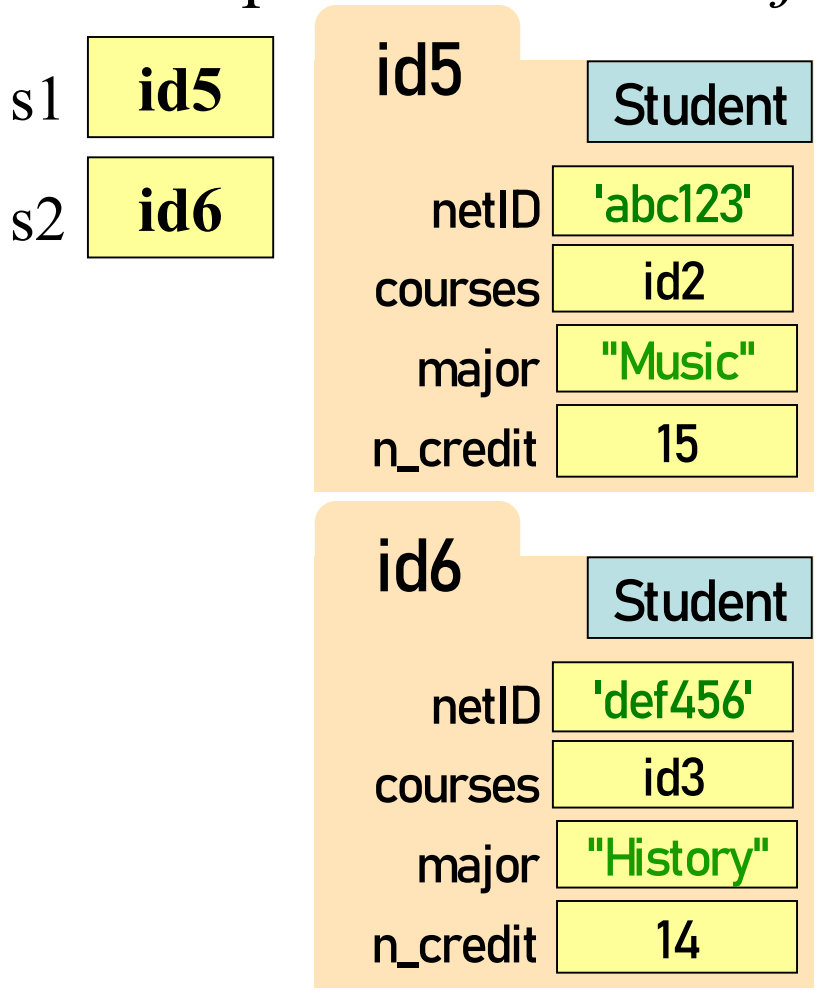
Where does **max_credit** live???

Refer to class attribute using class name

Classes Have Folders Too

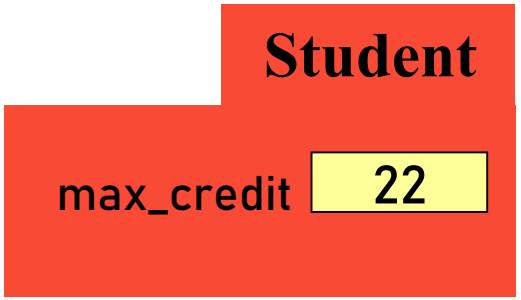
Object Folders

- Separate for each *instance*
- Example: *2* **Student** *objects*



Class Folders

- Data common to **all** instances



- Not just data!
- *Everything* common to all instances goes here!

Objects can have Methods

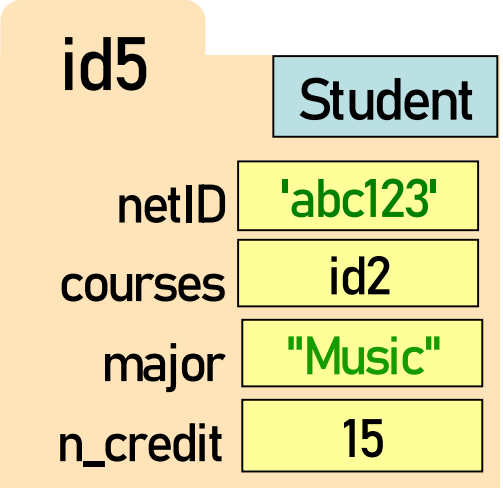
Function: call with object as argument

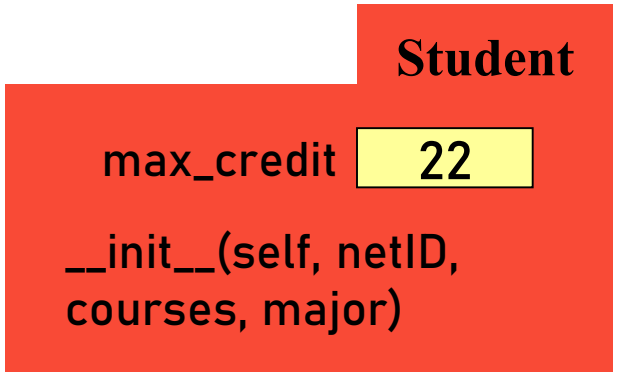
```
<function-name>(<arguments>)
len(my_list)
```

Method: function tied to the object

```
<object-variable>.<function-call>
my_list.count(7)
```

- **Attributes** live in **object** folder
- **Class Attributes** live in **class folder**
- **Methods** live in **class folder**





Complete Class Definition

keyword **class**
Beginning of a class definition

class *<class-name>*:

Specification (similar to one for a function)

"""Class specification"""

<assignment statements>

to define **class variables**

<method definitions>

to define **class methods**

```
class Student():
    """Specification goes here."""
    max_credit = 22
    def __init__(self, netID, courses, major):
        . . . <snip> . . .
```

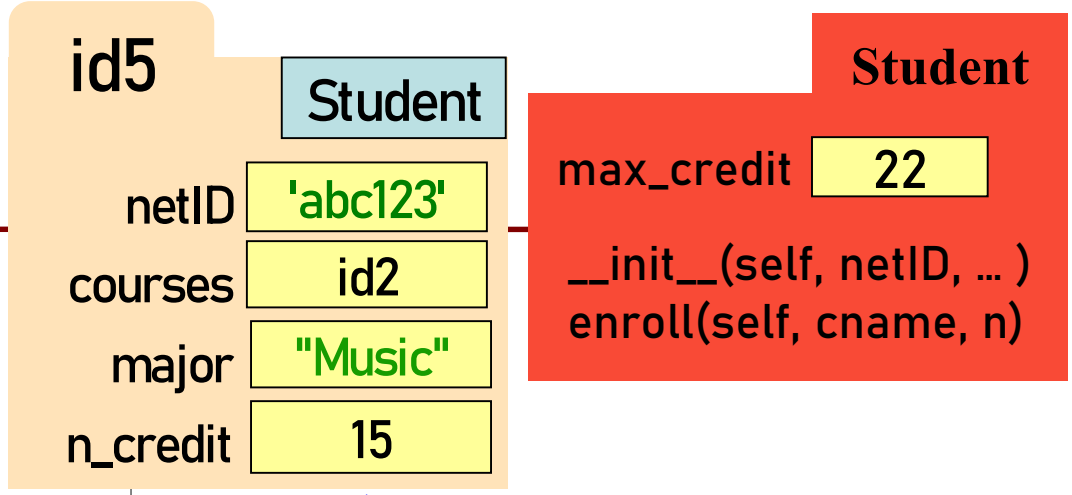
Student

max_credit 22

__init__(self, netID, courses, major)

Python creates after reading the class definition

Method Definitions



Looks like a function def

- But indented *inside* class
- 1st parameter always **self**

Example:

s1.enroll("AEM 2400", 4)

- Go to class folder for **s1** (*i.e.*, **Student**) that's where **enroll** is defined
- Now **enroll** is called with **s1** as its first argument
- Now **enroll** knows which instance of **Student** it is working with

```
def __init__(self, netID, courses=[], major=None):
    self.netID = netID
    self.courses = courses
    self.major = major
    # < rest of init fn goes here >

def enroll( self, cname, n):
    if self.n_credit + n > Student.max_credit:
        print("Sorry your schedule is full!")
    else:
        self.courses.append([cname, n])
        self.n_credit = self.n_credit + n
        print("Welcome to "+ cname)
```

More Method Definitions!

```
class Student:
    def __init__(self, netID, courses=[], major=None):
        # < init fn definition goes here >
    def enroll(self, name, n):
        # < enroll fn definition goes here >
    def drop( self, course_name):
        """removes course with name course_name from courses list
        updates n_credit accordingly
        course_name: name of course to drop [str] """
        for one_course  in self.courses:
            if one_course[0] == course_name:
                self.n_credit = self.n_credit – one_course[1]
                self.courses.remove(one_course)
                print("just dropped "+course_name)
        print("currently have "+str(self.n_credit)+" credits")
```

Recall from class invariant that attribute courses is a nested list, so one_course here is a list with 2 values: at index 0 is the course name; at index 1 is the number of credits of that course

Class Gotchas… and how to avoid them

Rules to live by:

1. Refer to Class Attributes using the Class Name

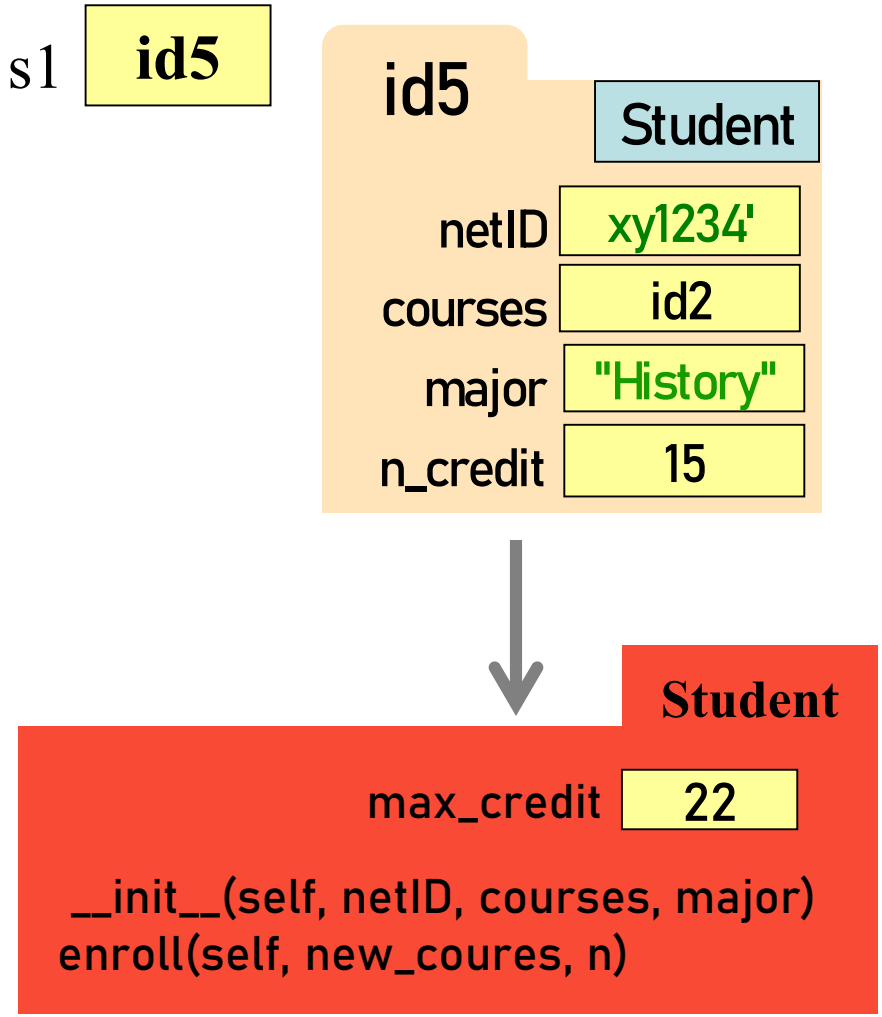
```
s1 = Student("xy1234", [ ], "History")
print("max credits = " + str(Student.max_credit))
```

2. Don't forget **self**
   - in parameter list of method (method header)
   - when defining method (method body)

Name Resolution for Objects

- ⟨*object*⟩.⟨*name*⟩ means
  - Go the folder for *object*
  - Find attribute/method *name*
  - If missing, check **class folder**
  - If not in either, raise error

```
s1 = Student("xy1234", [ ], "History")
# finds attribute in object folder
print(s1.netID)
# finds attribute in class folder
print(s1.max_credit) ← dangerous
```



Accessing vs. *Modifying* Class Variables

- **Recall:** you cannot assign to a global variable from inside a function call
- **Similarly:** you cannot assign to a class attribute from "inside" an object variable

```
s1 = Student("xy1234", [ ], "History")

Student.max_credit = 23  # updates class attribute

s1.max_credit = 24       # creates new object attribute
                         #   called max_credit
```

Better to refer to Class Variables using the Class Name

Don't forget self, Part 1

```
s1 = Student("xy1234", [ ], "History")
s2 = Student("ab132", [ ], "Math")
s1.enroll("AEM 2400", 4)
```

<var>.<method_name> **always** passes <var> as first argument

```
class Student:
    def __init__(self, netID, courses, major):
        self.netID = netID
        self.courses = courses
        self.major = major
        # < rest of constructor goes here >

    def enroll(self, name, n):  # if you forget self
        if self.n_credit + n > Student.max_credit:
            print("Sorry your schedule is full!")
        else:
            self.courses.append((name, n))
            self.n_credit = self.n_credit + n
            print("Welcome to "+ name)
```

TypeError: enroll() takes 2 positional arguments but 3 were given

Don't forget self, Part 2 (Q)

```
s1 = Student("xy1234", [ ], "History")
s2 = Student("ab132", [ ], "Math")
s1.enroll("AEM 2400", 4)
```

What happens?

A) Error
B) Nothing, self is not needed
C) creates new local variable n_credit
D) creates new instance variable n_credit
E) creates new Class attribute n_credit

```
class Student:
    def __init__(self, netID, courses, major):
        self.netID = netID
        self.courses = courses
        self.major = major
        # < rest of constructor goes here >

    def enroll(self, name, n):
        if ~~self~~.n_credit + n > Student.max_credit:
            print("Sorry your schedule is full!")
        else:
            self.courses.append((name, n))
            self.n_credit = self.n_credit + n
            print("Welcome to "+ name)
```

if you forget self

What gets Printed? (Q)

```
import college

s1 = college.Student("jl200", [], "Art")
print(s1.max_credit)
s2 = college.Student("jl202", [], "History")
print(s2.max_credit)
s2.max_credit = 23
print(s1.max_credit)
print(s2.max_credit)
print(college.Student.max_credit)
```

A:	B:
22	22
22	22
23	23
23	23
23	22

C:	D:
22	22
22	22
22	22
23	23
22	23