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

CS 1110

Introduction to Computing Using Python

Corrections made after lecture are shown in orange

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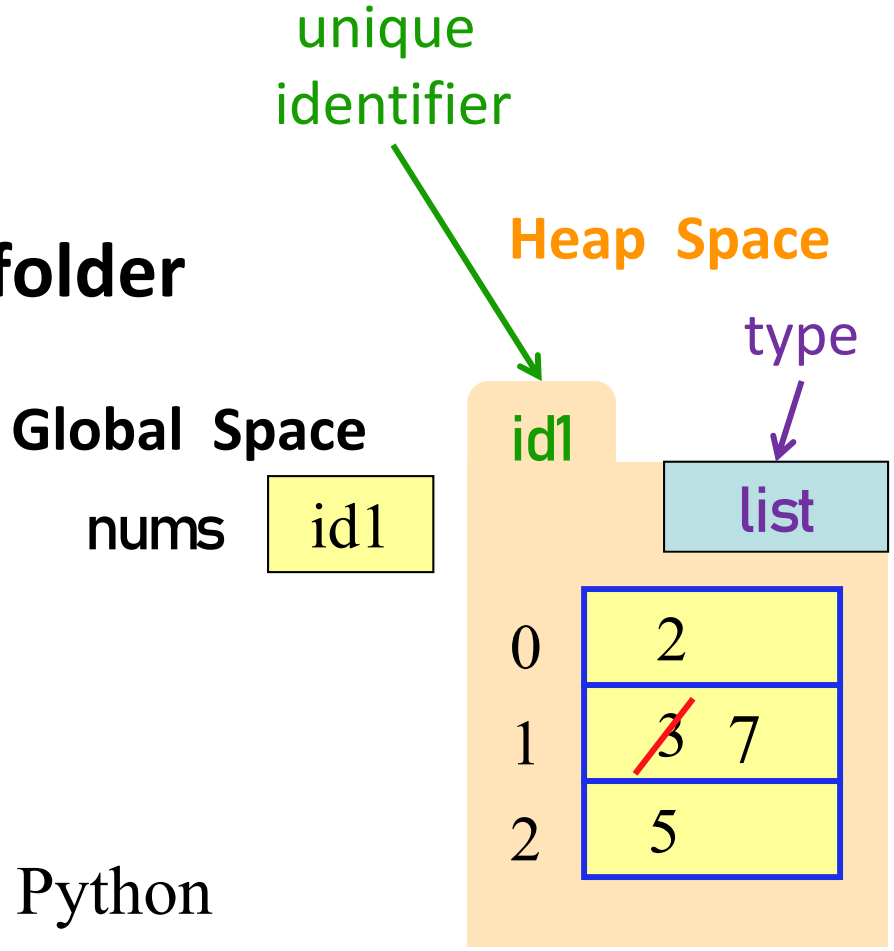
Recall: Objects as Data in Folders

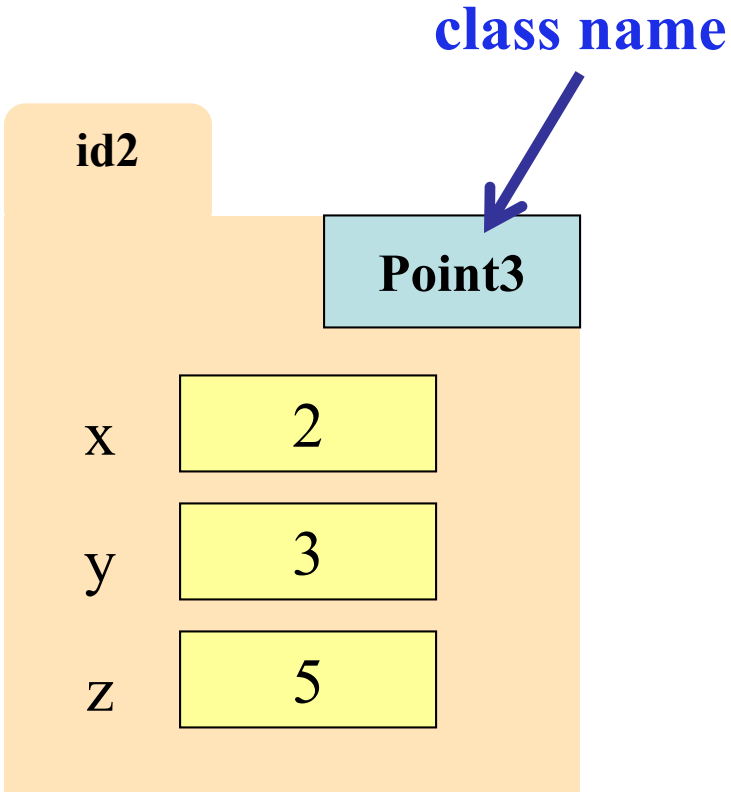
```
nums = [2,3,5]
nums[1] = 7
```

- 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** listed in the corner



Classes are user-defined Types

Classes are how we add new types to Python



Example Classes

- Point3
- Timer
- Rect
- Person

Simple Class Definition

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

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

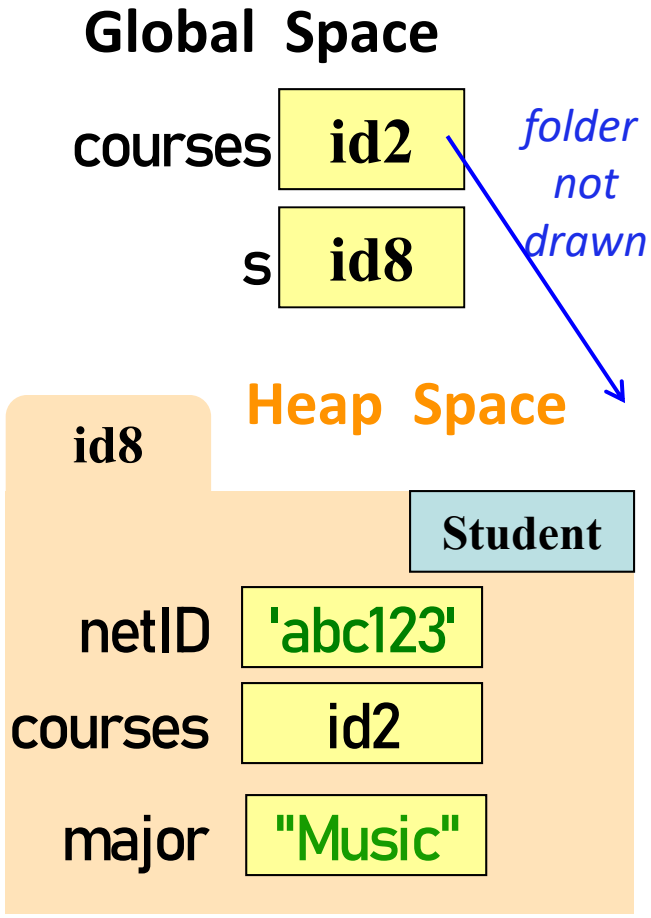
Description and *invariant*

Attribute Name

Constructors

- 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")
```



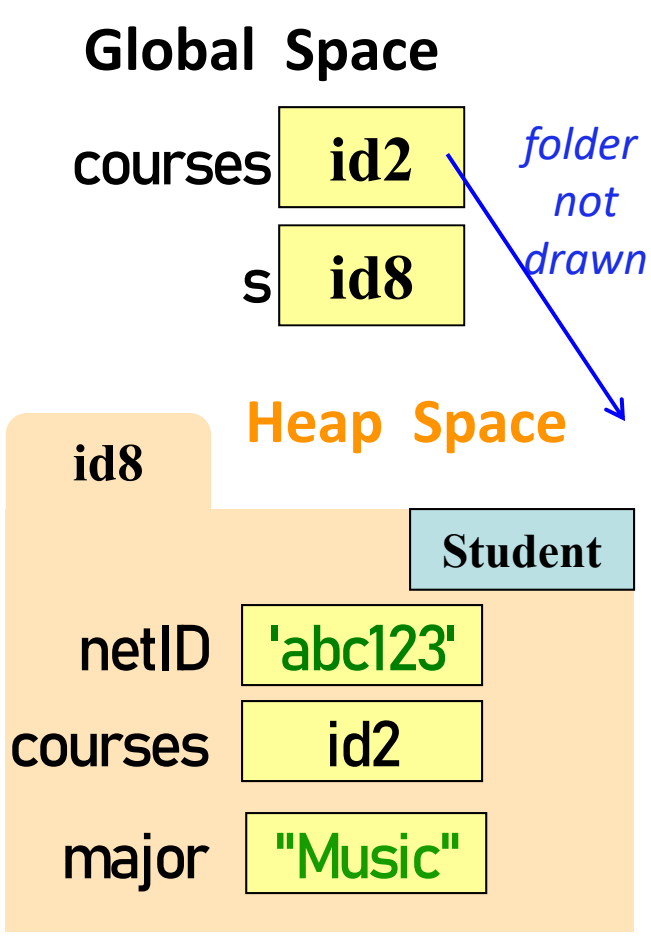
two underscores

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

use self to assign attributes

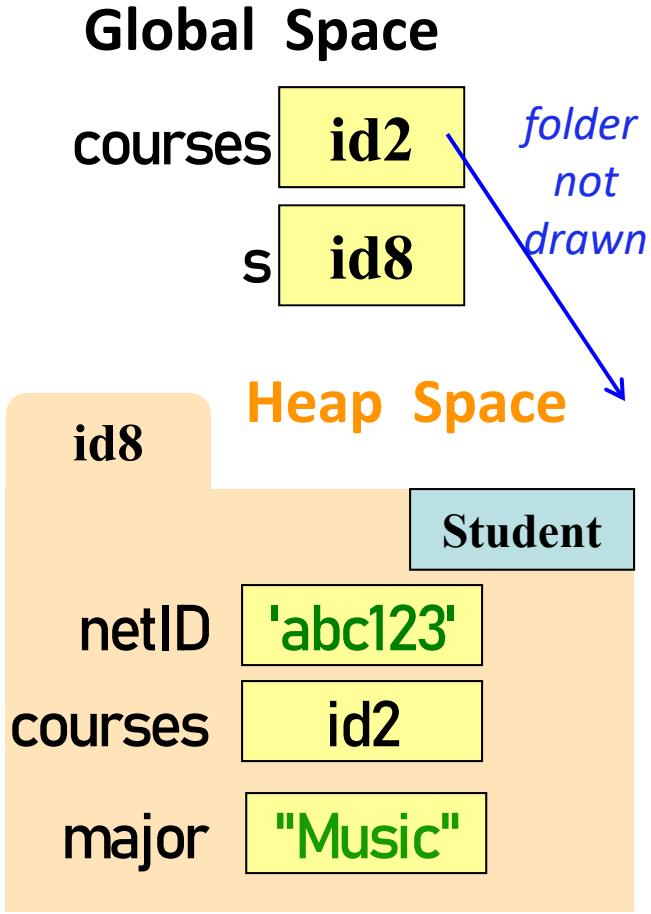



```
s = Student("abc123", courses, "Music")
# this is the call to the constructor, which calls __init__
```

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
- 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) The constructor returns the id of the folder

D) A constructor calls the __init__ method

E) __init__ puts attributes in the folder

Invariants

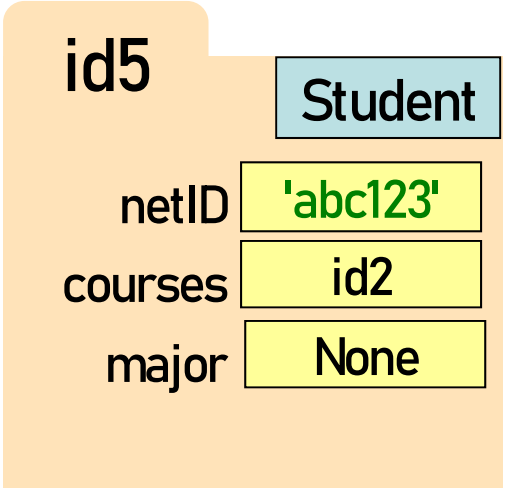
- Properties of an attribute that must be true
- Works like a precondition:
  - If invariant satisfied, object works properly
  - If not satisfied, object is "corrupted"
- **Example**:
  - Point3 class: all attributes must be ints
- Purpose of the **class specification**

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 parameters 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
        # < rest of constructor goes here >
```

We know how to make:

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

Start next video:

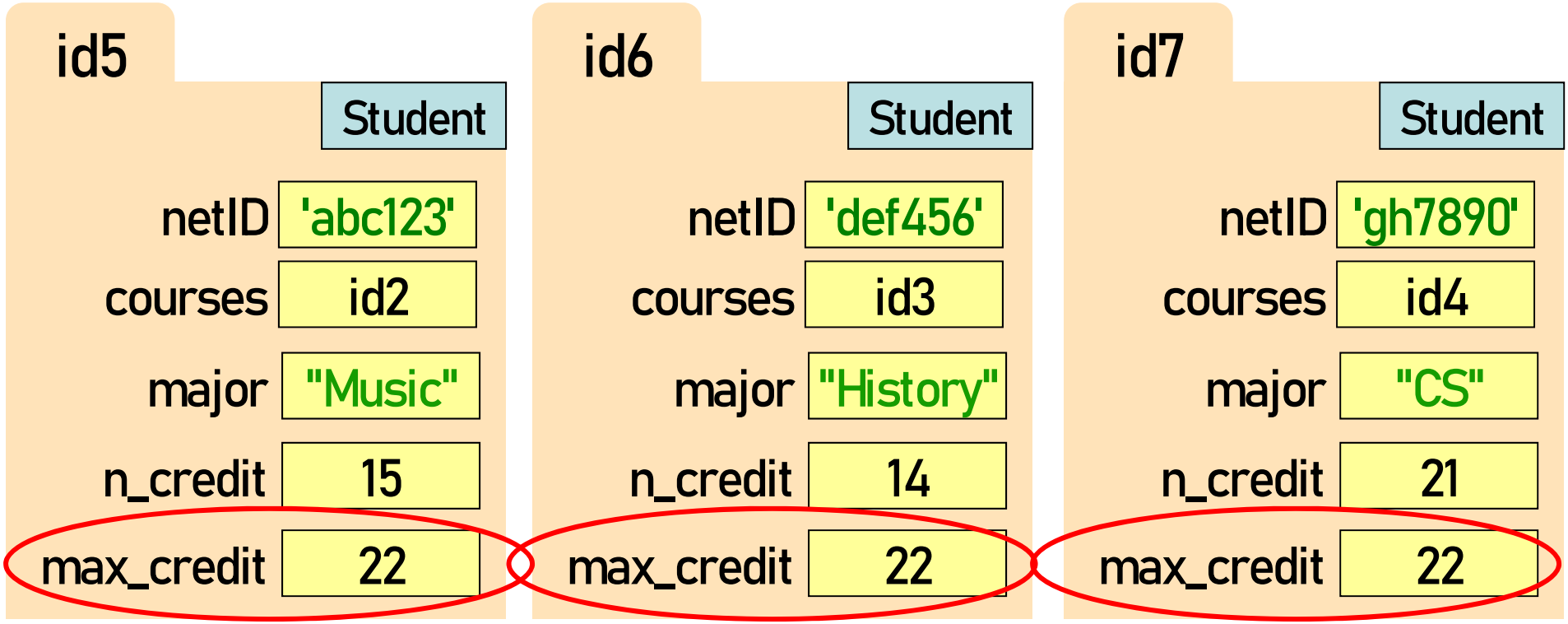
Class attributes and method definiations

We know how to make:

- Simple 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….



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 for CS1110

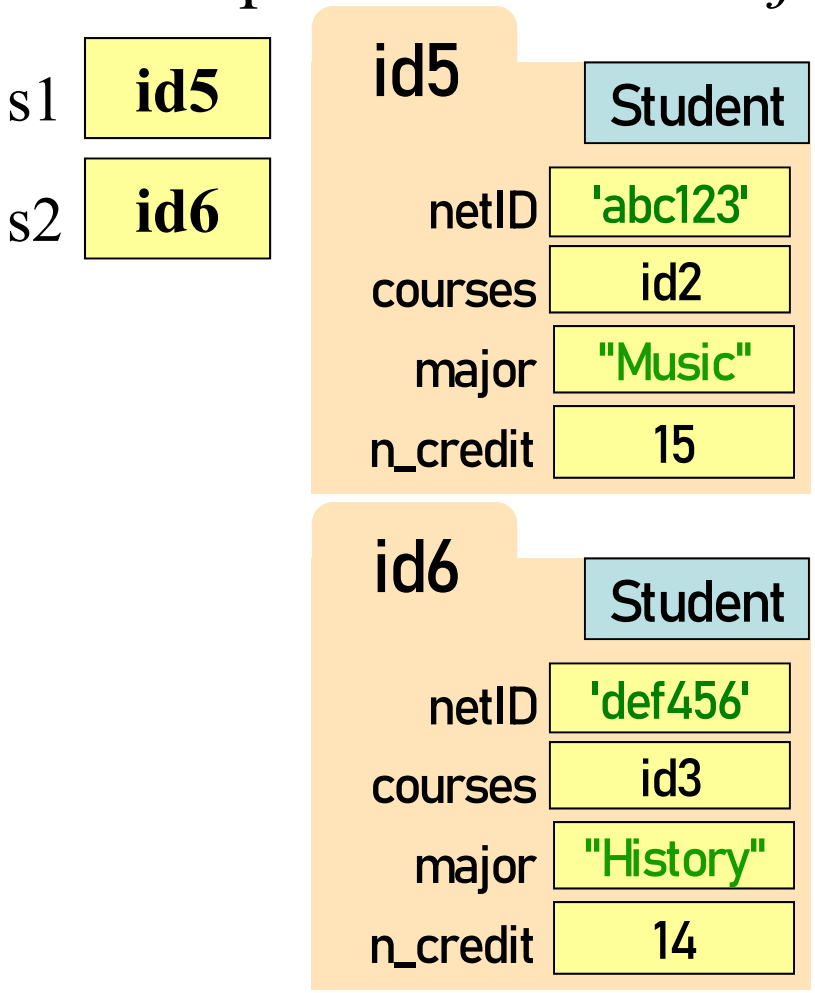
```
class Student():
    """Instance is a Cornell student  """
    max_credit = 22
    def __init__(self, netID, courses, major):
        # < specs go here >
        # < assertions go here >
        self.netID = netID
        self.courses = courses
        self.major = major
        self.n_credit = 0
        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???

Classes Have Folders Too

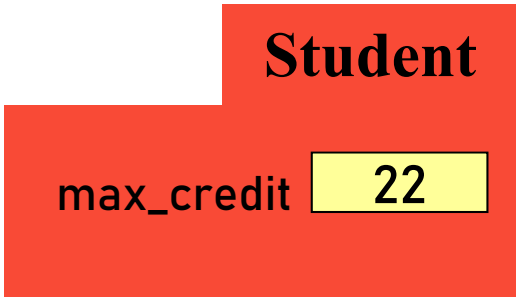
Object Folders

- 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

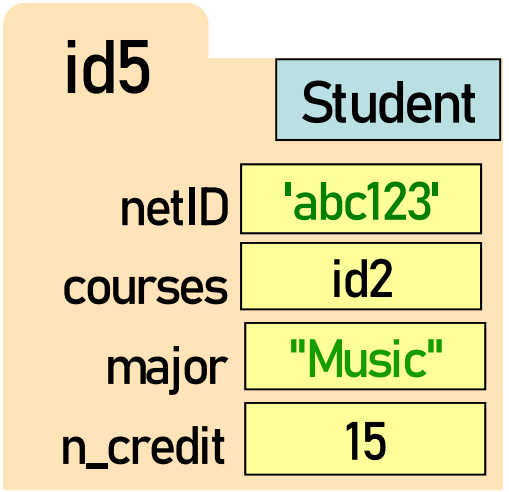
<function-name>(<arguments>)

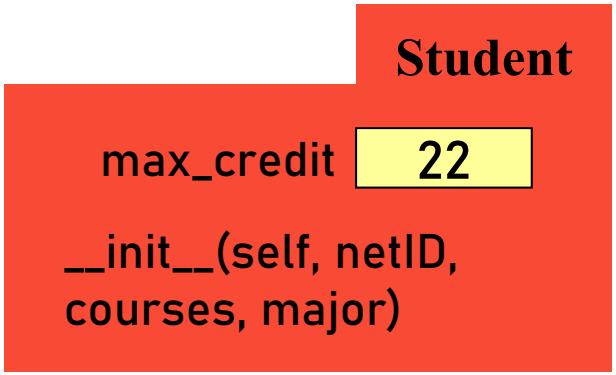
len(my_list)

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>():
    """Class specification"""
    <assignment statements>
    <method definitions>
```

Specification (similar to one for a function)

to define **class variables**

to define **class methods**

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

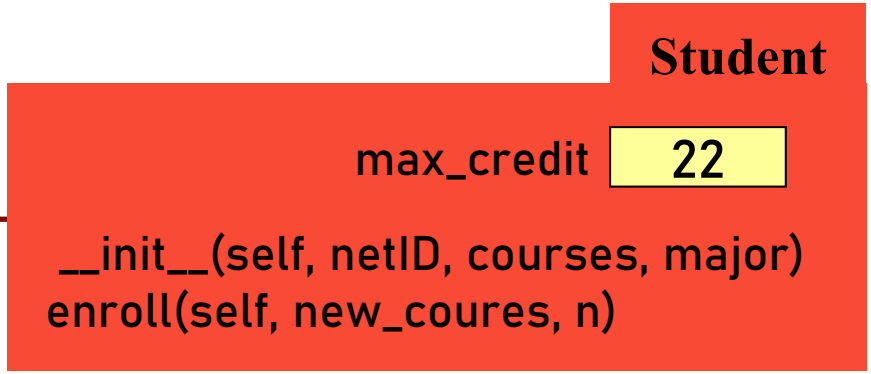
Student

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

```
class Student():
    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, 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)
```

We now know how to make:

- Class definitions
- Class specifications
- The __init__ function
- Attributes (using self)
- Class attributes
- Class methods

Class Gotchas… and how to avoid them

Rules to live by:

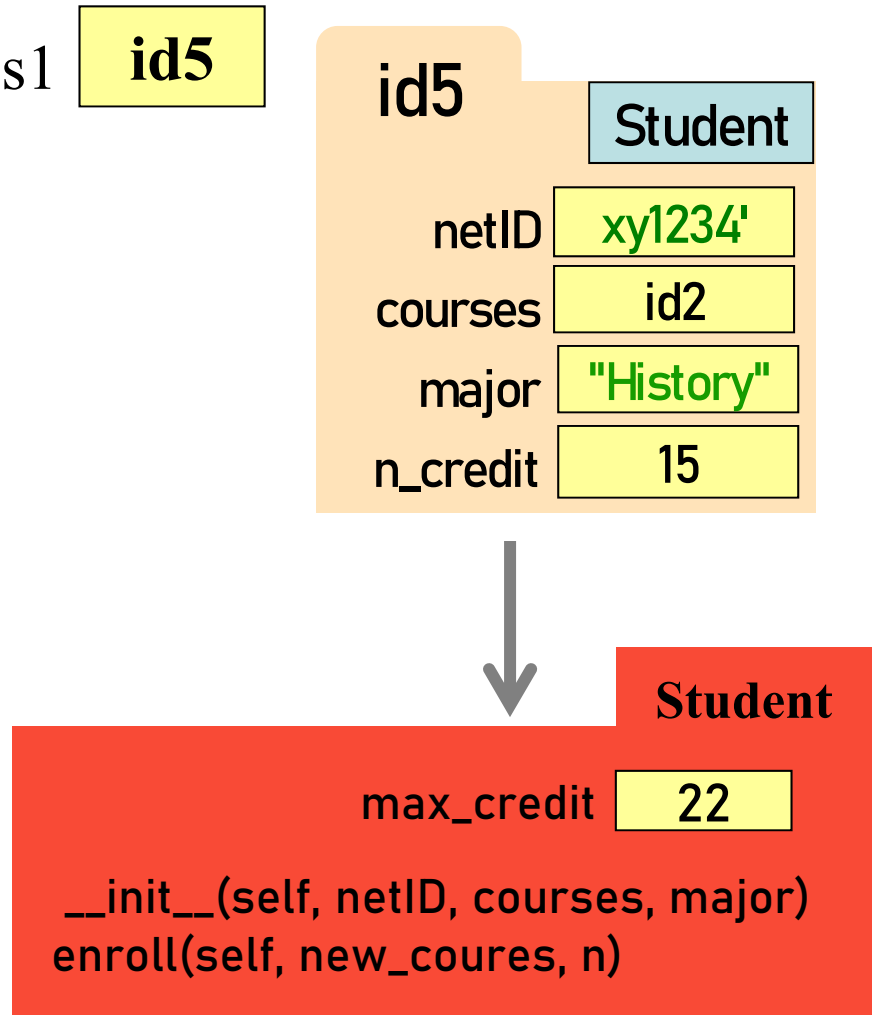
1. Refer to Class Attributes using the Class Name

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

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

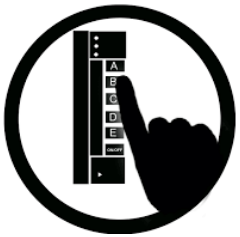
- **Recall:** you cannot assign to a global variable from inside a function call
- **Similarly:** you cannot assign to a class attribute from "inside" an object variable

```
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

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:
22
22
23
23
23

B:
22
22
23
23
22

C:
22
22
22
23
22

D:
22
22
22
23
23

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)

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

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

```
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)
```

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