Object-oriented programming (OOP) is a programming paradigm that allows us to treat data as objects, like we do in real life.

For example, consider the class `Student`. Each of you as individuals is an instance of this class.

Details that all CS 61A students have, such as `name`, are called instance variables. Every student has these variables, but their values differ from student to student. A variable that is shared among all instances of `Student` is known as a class variable. For example, the `extension_days` attribute is a class variable as it is a property of all students.

All students are able to do homework, attend lecture, and go to office hours. When functions belong to a specific object, they are called methods. In this case, these actions would be methods of `Student` objects.

Here is a recap of what we discussed above:

- **class**: a template for creating objects
- **instance**: a single object created from a class
- **instance variable**: a data attribute of an object, specific to an instance
- **class variable**: a data attribute of an object, shared by all instances of a class
- **method**: a bound function that may be called on all instances of a class

Instance variables, class variables, and methods are all considered attributes of an object.
Q1: WWPD: Student OOP

Below we have defined the classes `Professor` and `Student`, implementing some of what was described above. Remember that Python passes the `self` argument implicitly to methods when calling the method directly on an object.

class Student:

    extension_days = 3  # this is a class variable

    def __init__(self, name, staff):
        self.name = name  # this is an instance variable
        self.understanding = 0
        staff.add_student(self)
        print("Added", self.name)

    def visit_office_hours(self, staff):
        staff.assist(self)
        print("Thanks, " + staff.name)

class Professor:

    def __init__(self, name):
        self.name = name
        self.students = {}

    def add_student(self, self, student):
        self.students[student.name] = student

    def assist(self, self, student):
        student.understanding += 1

    def grant_more_extension_days(self, self, student, days):
        student.extension_days = days

What will the following lines output?

```python
>>> callahan = Professor("Callahan")
>>> elle = Student("Elle", callahan)

>>> elle.visit_office_hours(callahan)

>>> elle.visit_office_hours(Professor("Paulette"))
```
>>> elle.understanding

>>> [name for name in callahan.students]

>>> x = Student("Vivian", Professor("Stromwell")).name

>>> x

>>> [name for name in callahan.students]

>>> elle.extension_days

>>> callahan.grant_more_extension_days(elle, 7)
>>> elle.extension_days

>>> Student.extension_days

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
Q2: Email

We would like to write three different classes (Server, Client, and Email) to simulate a system for sending and receiving email.

To solve this problem, we’ll split the section into two halves (students on the left and students on the right): * Everyone will implement the Email class together * The first half (left) will implement the Server class * The other half (right) will implement the Client class

Fill in the definitions below to finish the implementation!

```python
class Email:
    """Every email object has 3 instance attributes: the message, the sender name, and the recipient name.
    >>> email = Email('hello', 'Alice', 'Bob')
    >>> email.msg
    'hello'
    >>> email.sender_name
    'Alice'
    >>> email.recipient_name
    'Bob'
    ""
    def __init__(self, msg, sender_name, recipient_name):
        """*** YOUR CODE HERE ***"
```

# You can use more space on the back if you want

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
class Server:
    """Each Server has an instance attribute clients, which
    is a dictionary that associates client names with
    client objects.
    """
    def __init__(self):
        self.clients = {}

    def send(self, email):
        """Take an email and put it in the inbox of the client
        it is addressed to.
        """
        "*** YOUR CODE HERE ***"

    def register_client(self, client, client_name):
        """Takes a client object and client_name and adds them
        to the clients instance attribute.
        """
        "*** YOUR CODE HERE ***"

# You can use more space on the back if you want
class Client:
    """Every Client has instance attributes name (which is used for addressing emails to the client), server (which is used to send emails out to other clients), and inbox (a list of all emails the client has received)."

    >>> s = Server()
    >>> a = Client(s, 'Alice')
    >>> b = Client(s, 'Bob')
    >>> a.compose('Hello, World!', 'Bob')
    """Hello, World!"
    >>> b.inbox[0].msg
    'Hello, World!'
    >>> a.compose('CS 61A Rocks!', 'Bob')
    >>> len(b.inbox)
    2
    >>> b.inbox[1].msg
    'CS 61A Rocks!'
    ""

    def __init__(self, server, name):
        self.inbox = []
        """*** YOUR CODE HERE ***"

    def compose(self, msg, recipient_name):
        """Send an email with the given message msg to the given recipient client.
        """
        """*** YOUR CODE HERE ***"

    def receive(self, email):
        """Take an email and add it to the inbox of this client.
        """
        """*** YOUR CODE HERE ***"

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
Inheritance

To avoid redefining attributes and methods for similar classes, we can write a single base class from which the similar classes inherit. For example, we can write a class called Pet and define Dog as a subclass of Pet:

```python
class Pet:
    def __init__(self, name, owner):
        self.is_alive = True  # It's alive!!!
        self.name = name
        self.owner = owner

    def eat(self, thing):
        print(f'{self.name} ate a {str(thing)}!!!')

    def talk(self):
        print(self.name)

class Dog(Pet):
    def talk(self):
        super().talk()
        print('This Dog says woof!')
```

Inheritance represents a hierarchical relationship between two or more classes where one class is a more specific version of the other: a dog is a pet (We use is a to describe this sort of relationship in OOP languages, and not to refer to the Python is operator).

Since Dog inherits from Pet, the Dog class will also inherit the Pet class’s methods, so we don’t have to redefine `__init__` or `eat`. We do want each Dog to talk in a Dog-specific way, so we can override the talk method.

We can use `super()` to refer to the superclass of self, and access any superclass methods as if we were an instance of the superclass. For example, `super().talk()` in the Dog class will call the talk() method from the Pet class, but passing the Dog instance as the self.

This is a little bit of a simplification, and if you’re interested you can read more in the Python documentation on super.

Q3: Cat

Below is a skeleton for the Cat class, which inherits from the Pet class. To complete the implementation, override the `__init__` and talk methods and add a new lose_life method.

Hint: You can call the `__init__` method of Pet (the superclass of Cat) to set a cat’s name and owner.
class Cat(Pet):
    def __init__(self, name, owner, lives=9):
        """ *** YOUR CODE HERE *** """

def talk(self):
    """Print out a cat's greeting."

>>> Cat('Thomas', 'Tammy').talk()
Thomas says meow!
""
""" *** YOUR CODE HERE *** """

def lose_life(self):
    """Decrements a cat's life by 1. When lives reaches zero, is_alive becomes False. If this is called after lives has reached zero, print 'This cat has no more lives to lose.'"

""
""" *** YOUR CODE HERE *** """

# You can use more space on the back if you want

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
Q4: NoisyCat

More cats! Fill in this implementation of a class called NoisyCat, which is just like a normal Cat. However, NoisyCat talks a lot: in fact, it talks twice as much as a regular Cat! If you’d like to test your code, feel free to copy over your solution to the Cat class above.

```python
class __________ # Fill me in!
   """A Cat that repeats things twice."""
   def __init__(self, name, owner, lives=9):
       # Is this method necessary? Why or why not?
       "*** YOUR CODE HERE ***"

   def talk(self):
       """Talks twice as much as a regular cat."
       >>> NoisyCat('Magic', 'James').talk()
       Magic says meow!
       Magic says meow!
       """
       "*** YOUR CODE HERE ***"

# You can use more space on the back if you want
```

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
Class Methods

Now we’ll try out another feature of Python classes: class methods. A method can be turned into a class method by adding the `classmethod` decorator. Then, instead of receiving the instance as the first argument (`self`), the method will receive the class itself (`cls`).

Class methods are commonly used to create “factory methods”: methods whose job is to construct and return a new instance of the class.

For example, we can add a `robo_factory` class method to our `Dog` class that makes robo-dogs:

```python
class Dog(Pet):
    # With the previously defined methods not written out
    @classmethod
    def robo_factory(cls, owner):
        return cls("RoboDog", owner)
```

Then a call to `Dog.robo_factory('Sally')` would return a new `Dog` instance with the name “RoboDog” and owner “Sally”.

*Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.*
Q5: Own A Cat

Now implement the `cat_creator` method below, which takes in a string `owner` and creates a `Cat` named “`[owner]`'s Cat”, where `[owner]` is replaced with the name in the `owner` string.

**Hint:** To place an apostrophe within a string, the entire string must be surrounded in double-quotes (i.e. "DeNero 's Dog")

```python
class Cat:
    def __init__(self, name, owner, lives=9):
        self.is_alive = True
        self.name = name
        self.owner = owner
        self.lives = lives

    def talk(self):
        return self.name + ' says meow!

@classmethod
def cat_creator(cls, owner):
    ""
    Returns a new instance of a Cat.
    This instance's name is "[owner]'s Cat", with
    [owner] being the name of its owner.
    ""

    name = __________
    return cls(________, ________)

>>> cat1 = Cat.cat_creator("Bryce")
>>> isinstance(cat1, Cat)
True
>>> cat1.owner
'Bryce'
>>> cat1.name
'Bryce's Cat'
>>> cat2 = Cat.cat_creator("Tyler")
>>> cat2.owner
'Tyler'
>>> cat2.name
'Tyler's Cat'

name = __________
return cls(________, ________)
```

*Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.*
**Representation: Repr, Str**

There are two main ways to produce the “string” of an object in Python: `str()` and `repr()`. While the two are similar, they are used for different purposes.

`str()` is used to describe the object to the end user in a “Human-readable” form, while `repr()` can be thought of as a “Computer-readable” form mainly used for debugging and development.

When we define a class in Python, `_str_` and `_repr_` are both built-in methods for the class.

We can call those methods using the global built-in functions `str(obj)` or `repr(obj)` instead of dot notation, `obj._repr_()` or `obj._str_()`.

In addition, the `print()` function calls the `_str_` method of the object, while simply calling the object in interactive mode calls the `_repr_` method.

Here’s an example:

```python
class Rational:

    def __init__(self, numerator, denominator):
        self.numerator = numerator
        self.denominator = denominator

    def __str__(self):
        return f'{self.numerator}/{self.denominator}'

    def __repr__(self):
        return f'Rational({self.numerator},{self.denominator})'

>>> a = Rational(1, 2)
>>> str(a)
'1/2'
>>> repr(a)
'Rational(1,2)'
>>> print(a)
1/2
>>> a
Rational(1,2)
```

*Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.*
Q6: WWPD: Representation

Note: This is not the typical way `repr` is used, nor is this way of writing `repr` recommended, this problem is mainly just to make sure you understand how `repr` and `str` work.

```python
class A:
    def __init__(self, x):
        self.x = x
    def __repr__(self):
        return self.x
    def __str__(self):
        return self.x * 2

class B:
    def __init__(self):
        print('boo!')
        self.a = []
    def add_a(self, a):
        self.a.append(a)
    def __repr__(self):
        print(len(self.a))
        ret = ''
        for a in self.a:
            ret += str(a)
        return ret
```

Given the above class definitions, what will the following lines output?

```python
>>> A('one')
```

```python
>>> print(A('one'))
```

```python
>>> repr(A('two'))
```

```python
>>> b = B()
```
>>> b.add_a(A('a'))
>>> b.add_a(A('b'))
>>> b

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.