香港中文大學(深圳)
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Introduction to Computer Science: Programming Methodology

Lecture 7 Object Oriented Programming II

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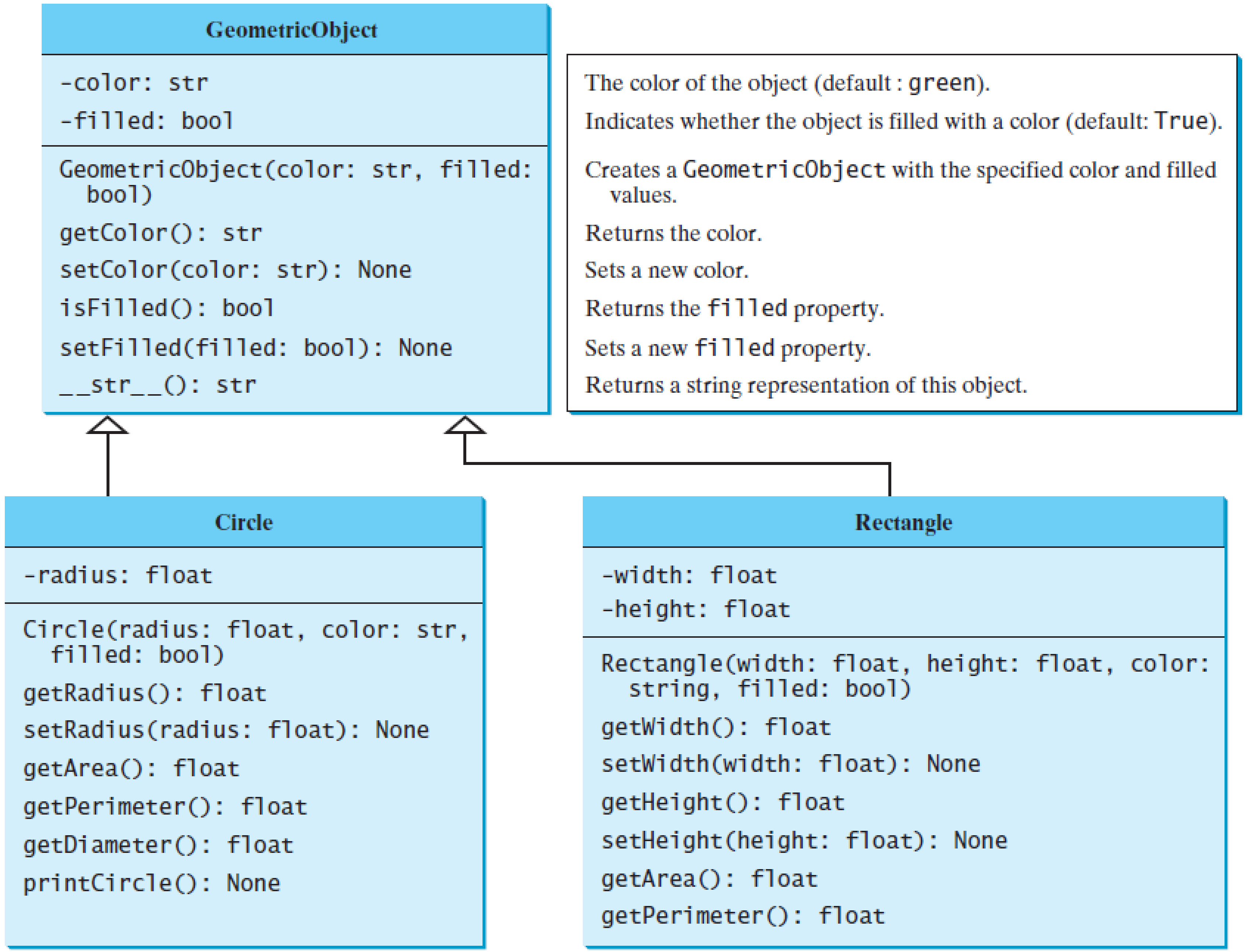
Inheritance

- The object-oriented programming couples data and methods together into objects
- The object oriented approach combines the power of the structural programming with an added dimension that integrates data with operations into objects
- Object-oriented programming (OOP) allows you to define new classes from existing classes. This is called inheritance
- Inheritance extends the power of the object-oriented paradigm by adding an important and powerful feature for reusing software

Superclass and subclass

- Inheritance enables you to define a general class (a superclass) and later extend it to more specialized classes (subclasses)
- You use a class to model objects of the same type. Different classes may have some common properties and behaviours that you can generalize in a class
- Inheritance enables you to define a general class and later extend it to define more specialized classes
- The specialized classes inherit the properties and methods from the general class.

Geometric Object and two of its subclasses

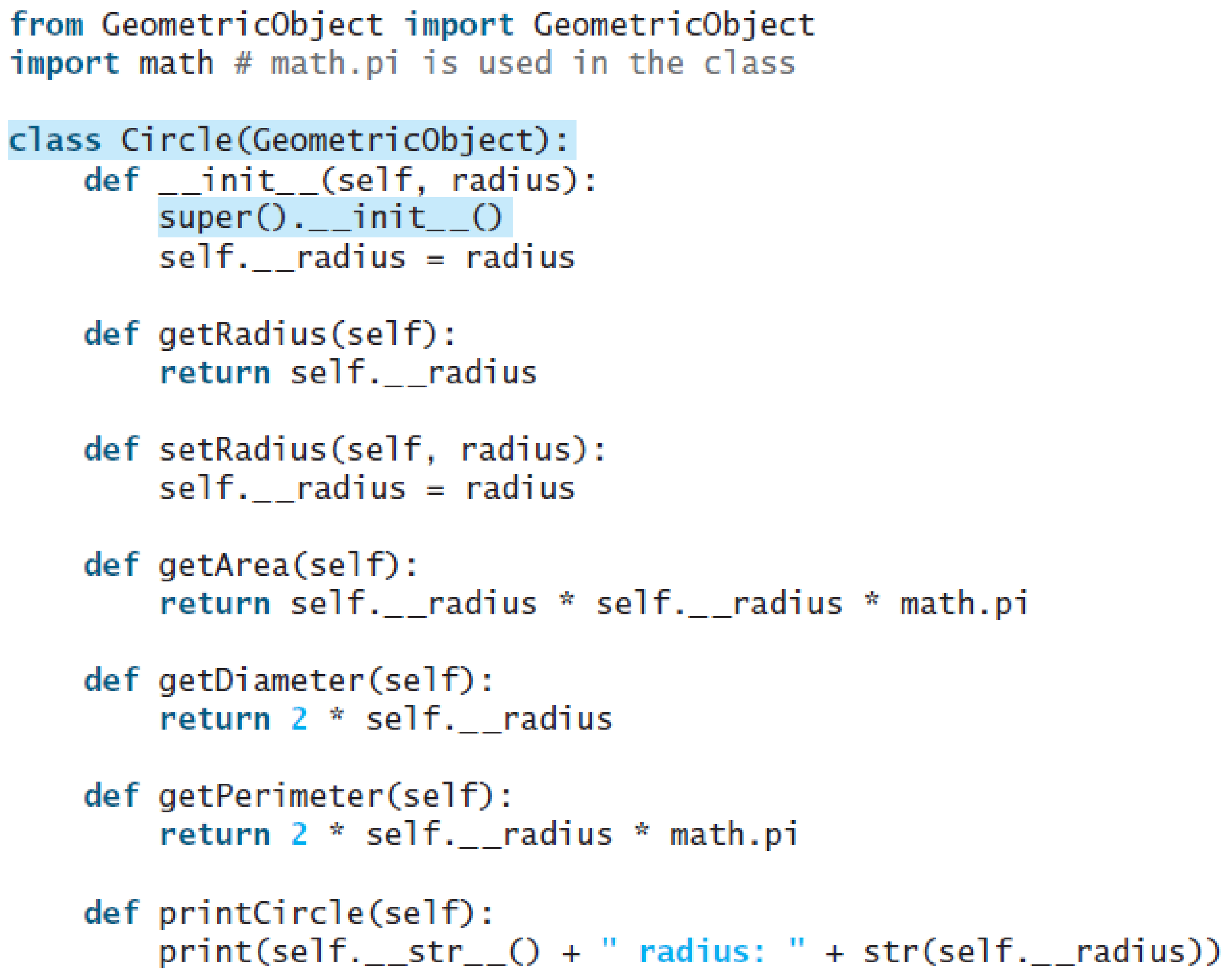

GeometricObject
-color: str
-filled: bool
GeometricObject(color: str, filled: bool)
getColor(): str
setColor(color: str): None
isFilled(): bool
setFilled(filled: bool): None
__str__(): str
The color of the object (default : green).
Indicates whether the object is filled with a color (default: True).
Creates a GeometricObject with the specified color and filled values.
Returns the color.
Sets a new color.
Returns the filled property.
Sets a new filled property.
Returns a string representation of this object.
Circle
-radius: float
Circle(radius: float, color: str, filled: bool)
getRadius(): float
setRadius(radius: float): None
getArea(): float
getPerimeter(): float
getDiameter(): float
printCircle(): None
Rectangle
-width: float
-height: float
Rectangle(width: float, height: float, color: string, filled: bool)
getWidth(): float
setWidth(width: float): None
getHeight(): float
setHeight(height: float): None
getArea(): float
getPerimeter(): float

The code for GeometricObject

```
class GeometricObject:                                          GeometricObject class
    def __init__(self, color = "green", filled = True):         initializer
        self.__color = color                                    data fields
        self.__filled = filled

    def getColor(self):                                         getColor
        return self.__color

    def setColor(self, color):                                  setColor
        self.__color = color

    def isFilled(self):                                         isFilled
        return self.__filled

    def setFilled(self, filled):
        self.__filled = filled

    def __str__(self):
        return "color: " + self.__color + \
            " and filled: " + str(self.__filled)
```

The code for Circle class

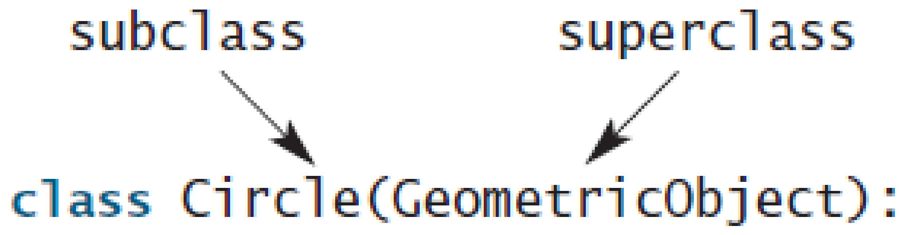
- A subclass inherits accessible data fields and methods from its superclass, but it can also have other data fields and methods



```
from GeometricObject import GeometricObject
import math # math.pi is used in the class

class Circle(GeometricObject):
    def __init__(self, radius):
        super().__init__()
        self.__radius = radius

    def getRadius(self):
        return self.__radius

    def setRadius(self, radius):
        self.__radius = radius

    def getArea(self):
        return self.__radius * self.__radius * math.pi

    def getDiameter(self):
        return 2 * self.__radius

    def getPerimeter(self):
        return 2 * self.__radius * math.pi

    def printCircle(self):
        print(self.__str__() + " radius: " + str(self.__radius))
```

Inheritance syntax

- The Circle class is derived from the GeometricObject class, based on the following syntax



```
class Circle(GeometricObject):
```

- Circle class inherits the GeometricObject class, thus inheriting the methods getColor, setColor, isFilled, setFilled, and __str__
- The printCircle method invokes the __str__() method defined to obtain properties defined in the superclass

The code for rectangle class

```
from GeometricObject import GeometricObject

class Rectangle(GeometricObject):                                   extend superclass
    def __init__(self, width = 1, height = 1):                      initializer
        super().__init__()                                          superclass initializer
        self.__width = width
        self.__height = height

    def getWidth(self):                                             methods
        return self.__width

    def setWidth(self, width):
        self.__width = width

    def getHeight(self):
        return self.__height

    def setHeight(self, height):
        self.__height = self.__height

    def getArea(self):
        return self.__width * self.__height

    def getPerimeter(self):
        return 2 * (self.__width + self.__height)
```

The code for testing Circle and Rectangle

```python
from CircleFromGeometricObject import Circle
from RectangleFromGeometricObject import Rectangle

def main():
    circle = Circle(1.5)
    print("A circle", circle)
    print("The radius is", circle.getRadius() )
    print("The area is", circle.getArea())
    print("The diameter is", circle.getDiameter())

    rectangle = Rectangle(2, 4)
    print("\nA rectangle", rectangle)
    print("The area is", rectangle.getArea())
    print("The perimeter is", rectangle.getPerimeter())

main() # Call the main function
```

```
A circle color: green and filled: True
The radius is 1.5
The area is 7.06858347058
The diameter is 3.0

A rectangle color: green and filled: True
The area is 8
The perimeter is 12
```

Some more information about super and sub-class

- A subclass is not a subset of its superclass; In fact, a subclass usually contains more information and methods than its superclass

- Inheritance models the is-a relationships, but not all is-a relationships should be modelled using inheritance

- Do not blindly extend a class just for the sake of reusing methods. For example, it makes no sense for a Tree class to extend a Person class, even though they share common properties such as height and weight. A subclass and its superclass must have the is-a relationship

Practice

```
class A:
    def __init__(self, i = 0):
        self.i = i

class B(A):
    def __init__(self, j = 0):
        self.j = j

def main():
    b = B()
    print(b.i)
    print(b.j)

main() # Call the main function
```

What is the problem with the above code?

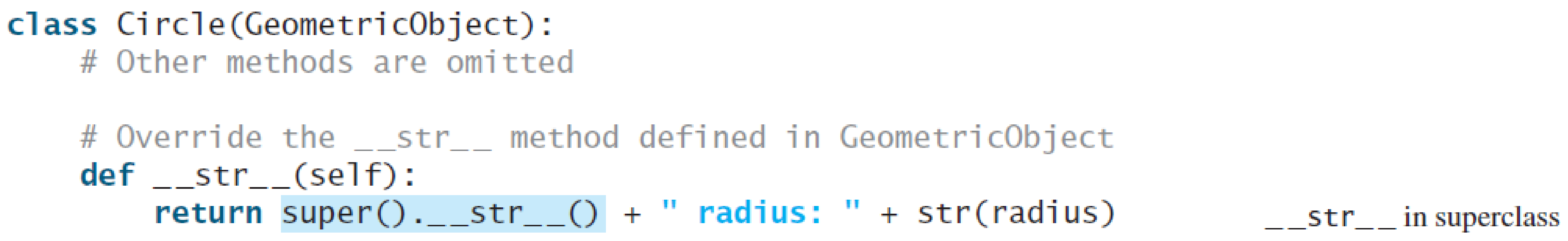
Overriding methods

- A subclass inherits methods from a superclass
- Sometimes it is necessary for the subclass to modify the implementation of a method defined in the superclass. This is referred to as method overriding

Example

- The __str__ method in the GeometricObject class returns the string describing a geometric object. This method can be overridden to return the string describing a circle

- The __str__() method is defined in the GeometricObject class and modified in the Circle class. Both methods can be used in the Circle class. To invoke the __str__ method defined in the GeometricObject class from the Circle class, use super().__str__()



```
class Circle(GeometricObject):
    # Other methods are omitted

    # Override the __str__ method defined in GeometricObject
    def __str__(self):
        return super().__str__() + " radius: " + str(radius)
```

Practice

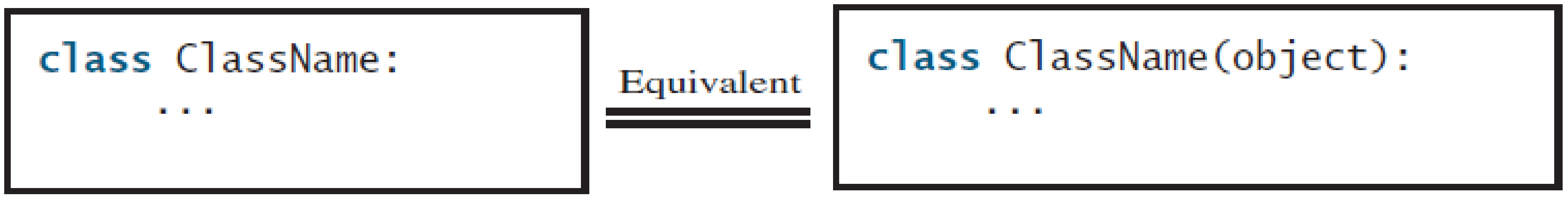
What would be the output of the following program?

```python
class A:
    def __init__(self, i = 0):
        self.i = i

    def m1(self):
        self.i += 1

class B(A):
    def __init__(self, j = 0):
        super().__init__(3)
        self.j = j

    def m1(self):
        self.i += 1

def main():
    b = B()
    b.m1()
    print(b.i)
    print(b.j)

main() # Call the main function
```

The object class

- Every class in Python is descended from the object class

- The object class is defined in the Python library. If no inheritance is specified when a class is defined, its superclass is object by default



```
class ClassName:
    ...
```

```
class ClassName(object):
    ...
```

Methods of the object class

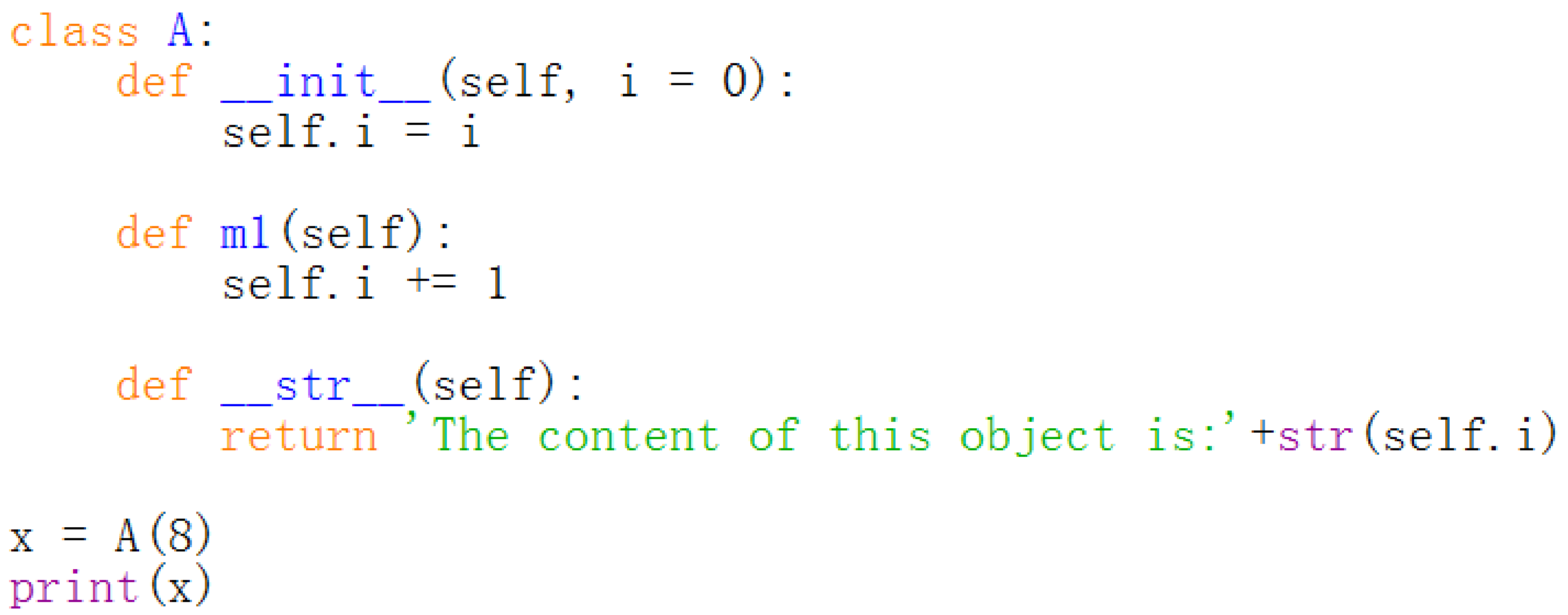
- The __new__() method is automatically invoked when an object is constructed. This method then invokes the __init__() method to initialize the object. Normally you should only override the __init__() method to initialize the data fields defined in the new class

- The __str__() method returns a string description for the object

- Usually you should override the __str__() method so that it returns an informative description for the object

- The __eq__() method returns True if two objects are the same

What is the output of this program?



```python
class A:
    def __init__(self, i = 0):
        self.i = i

    def m1(self):
        self.i += 1

    def __str__(self):
        return ’The content of this object is:’+str(self.i)

x = A(8)
print(x)
```

What is the output of this program?

```
class A:
    def __new__(self):
        print("A's __new__() invoked")

    def __init__(self):
        print("A's __init__() invoked")

class B(A):
    def __new__(self):
        print("B's __new__() invoked")

    def __init__(self):
        print("B's __init__() invoked")

def main():
    b = B()
    a = A()

main() # Call the main function
```

What is the output of this program?

```python
class A:
    def __new__(self):
        self.__init__(self)
        print("A's __new__() invoked")

    def __init__(self):
        print("A's __init__() invoked")

class B(A):
    def __new__(self):
        self.__init__(self)
        print("B's __new__() invoked")

    def __init__(self):
        print("B's __init__() invoked")

def main():
    b = B()
    a = A()

main() # Call the main function
```

Polymorphism and dynamic binding

- Polymorphism means that an object of a subclass can be passed to a parameter of a superclass type
- A method may be implemented in several classes along the inheritance chain
- Python decides which method is invoked at runtime. This is known as dynamic binding

Polymorphism

- The inheritance relationship enables a subclass to inherit features from its superclass with additional new features
- A subclass is a specialization of its superclass; every instance of a subclass is also an instance of its superclass, but not vice versa
- Therefore, you can always pass an instance of a subclass to a parameter of its superclass type

Example

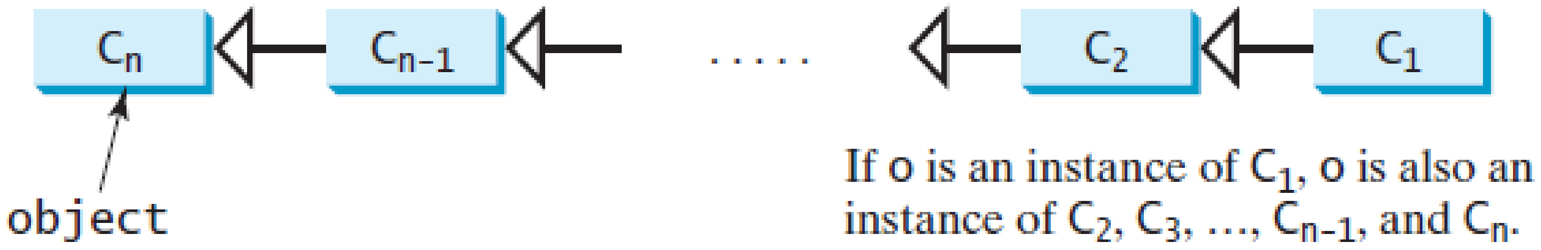
```
from CircleFromGeometricObject import Circle
from RectangleFromGeometricObject import Rectangle

def main():
    # Display circle and rectangle properties

    c = Circle(4)
    r = Rectangle(1, 3)
    displayObject(c)
    displayObject(r)
    print("Are the circle and rectangle the same size?",
        isSameArea(c, r))

# Display geometric object properties
def displayObject(g) :
    print(g.__str__())

# Compare the areas of two geometric objects
def isSameArea(g1, g2) :
    return g1.getArea() == g2.getArea()

main() # Call the main function
```

Output

```
color: green and filled: True radius: 4
color: green and filled: True width: 1 height: 3
Are the circle and rectangle the same size? False
```

Dynamic binding

- Dynamic binding works as follows: Suppose an object o is an instance of classes C1, C2, ..., Cn-1, and Cn, where C1 is a subclass of C2, C2 is a subclass of C3, ..., and Cn-1 is a subclass of Cn
- That is, Cn is the most general class, and C1 is the most specific class
- In Python, Cn is the **object** class
- If o invokes a method p, Python searches the implementation for the method p in C1, C2, ..., Cn-1, and Cn, in this order, until it is found


C_n
C_{n-1}
.....
C_2
C_1
object
If o is an instance of C_1, o is also an instance of C_2, C_3, …, C_{n-1}, and C_n.

Example

- What would be the output of this program?

```
class C1:
    def __init__(self):
        self.f  = 1

    def output(self):
        print('In C1, the f is:',self.f)

class C2(C1):
    def __init__(self):
        self.f  = 2

    def output(self):
        print('In C2, the f is:',self.f)

class C3(C2):
    def __init__(self):
        self.f  = 3

class C4(C3):
    def __init__(self):
        self.f = 4

a=C4()
print(a.f)
a.output()
```

Example

```
class Student:
    def __str__(self):
        return "Student"

    def printStudent(self):
        print(self.__str__())

class GraduateStudent(Student):
    def __str__(self):
        return "Graduate Student"

a = Student()
b = GraduateStudent()
a.printStudent()
b.printStudent()
```

Question

- Suppose you want to modify the displayObject function in previous example to perform the following tasks:

■ Display the area and perimeter of a GeometricObject instance

■ Display the diameter if the instance is a Circle, and the width and height if the instance is a Rectangle

Does this program work?

```
def displayObject(g):
    print("Area is", g.getArea())
    print("Perimeter is", g.getPerimeter())
    print("Diameter is", g.getDiameter())
    print("Width is", g.getWidth())
    print("Height is", g.getHeight())
```

Isinstance() function

- The isinstance() function can be used to determine whether an object is an instance of a class

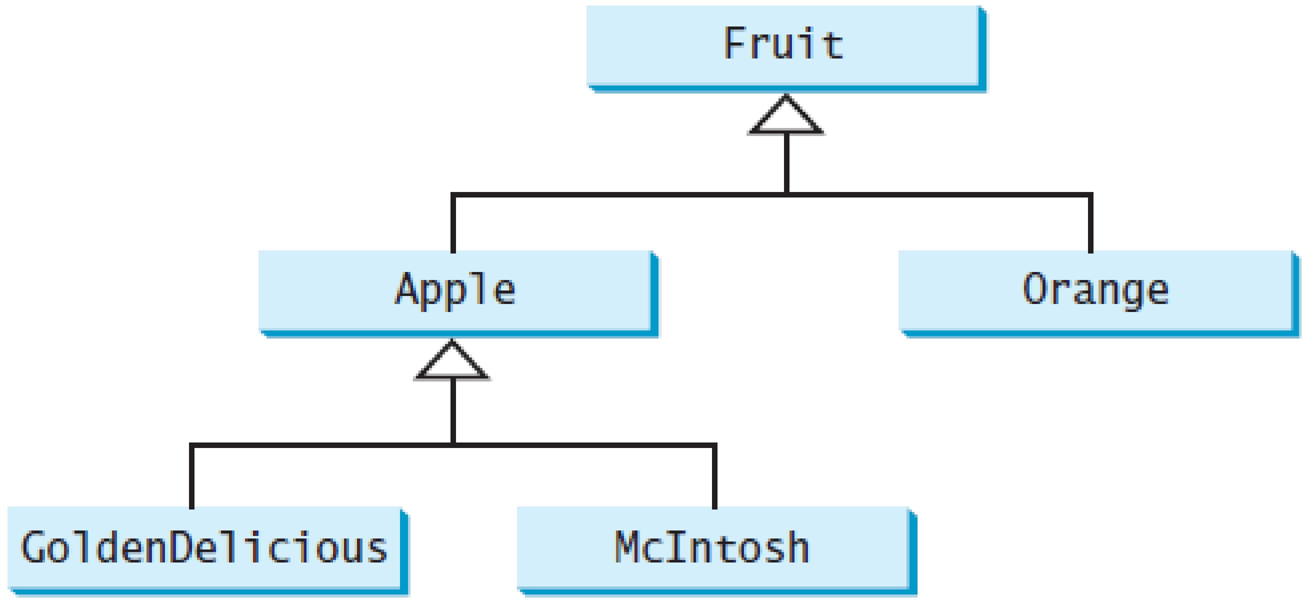
- This function determines whether an object is an instance of a class by using the following syntax

```
isinstance(object, ClassName)
```

```python
from CircleFromGeometricObject import Circle
from RectangleFromGeometricObject import Rectangle

def main():
    # Display circle and rectangle properties
    c = Circle(4)
    r = Rectangle(1, 3)
    print("Circle...")
    displayObject(c)
    print("Rectangle...")
    displayObject(r)

# Display geometric object properties
def displayObject(g):
    print("Area is", g.getArea())
    print("Perimeter is", g.getPerimeter())

    if isinstance(g, Circle):
        print("Diameter is", g.getDiameter())
    elif isinstance(g, Rectangle):
        print("Width is", g.getWidth())
        print("Height is", g.getHeight())

main() # Call the main function
```

```
Circle...
Area is 50.26548245743669
Perimeter is 25.132741228718345
Diameter is 8
Rectangle...
Area is 3
Perimeter is 8
Width is 1
Height is 3
```

Practice



Assume that the following statements are given:

```
goldenDelicious = GoldenDelicious()
orange = Orange()
```

Questions

(a) Is goldenDelicious an instance of Fruit?

(b) Is goldenDelicious an instance of Orange?

(c) Is goldenDelicious an instance of Apple?

(d) Is goldenDelicious an instance of GoldenDelicious?

(e) Is goldenDelicious an instance of McIntosh?

(f) Is orange an instance of Orange?

(g) Is orange an instance of Fruit?

(h) Is orange an instance of Apple?

(i) Suppose the method makeAppleCider is defined in the Apple class. Can goldenDelicious invoke this method? Can orange invoke this method?

(j) Suppose the method makeOrangeJuice is defined in the Orange class. Can orange invoke this method? Can goldenDelicious invoke this method?

Practice

```python
class Person:
    def getInfo(self):
        return "Person"

    def printPerson(self):
        print(self.getInfo())

class Student(Person):
    def getInfo(self):
        return "Student"

Person().printPerson()
Student().printPerson()
```

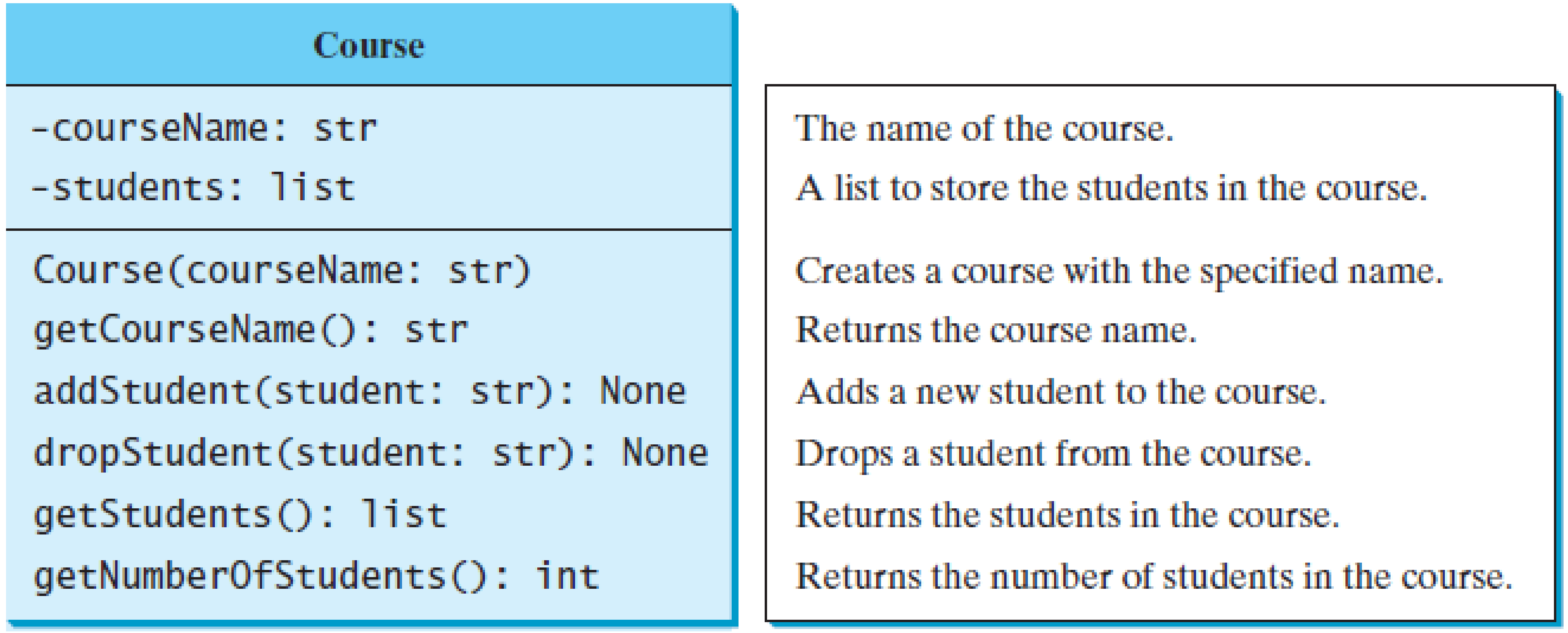
(a)

```python
class Person:
    def __getInfo(self):
        return "Person"

    def printPerson(self):
        print(self.__getInfo())

class Student(Person):
    def __getInfo(self):
        return "Student"

Person().printPerson()
Student().printPerson()
```

(b)

What would be the outputs?

Practice: course class



Course	
-courseName: str	The name of the course.
-students: list	A list to store the students in the course.
Course(courseName: str)	Creates a course with the specified name.
getCourseName(): str	Returns the course name.
addStudent(student: str): None	Adds a new student to the course.
dropStudent(student: str): None	Drops a student from the course.
getStudents(): list	Returns the students in the course.
getNumberOfStudents(): int	Returns the number of students in the course.

Answer

```
from Course import Course

def main():

    course1 = Course("Data Structures")
    course2 = Course("Database Systems")

    course1.addStudent("Peter Jones")
    course1.addStudent("Brian Smith")
    course1.addStudent("Anne Kennedy")

    course2.addStudent("Peter Jones")
    course2.addStudent("Steve Smith")

    print("Number of students in course1:",
        course1.getNumberOfStudents())
    students = course1.getStudents()
    for student in students:
        print(student, end = ", ")

    print("\nNumber of students in course2:",
        course2.getNumberOfStudents())

main() # Call the main function
```

```
Number of students in course1: 3
Peter Jones, Brian Smith, Anne Kennedy,
Number of students in course2: 2
```

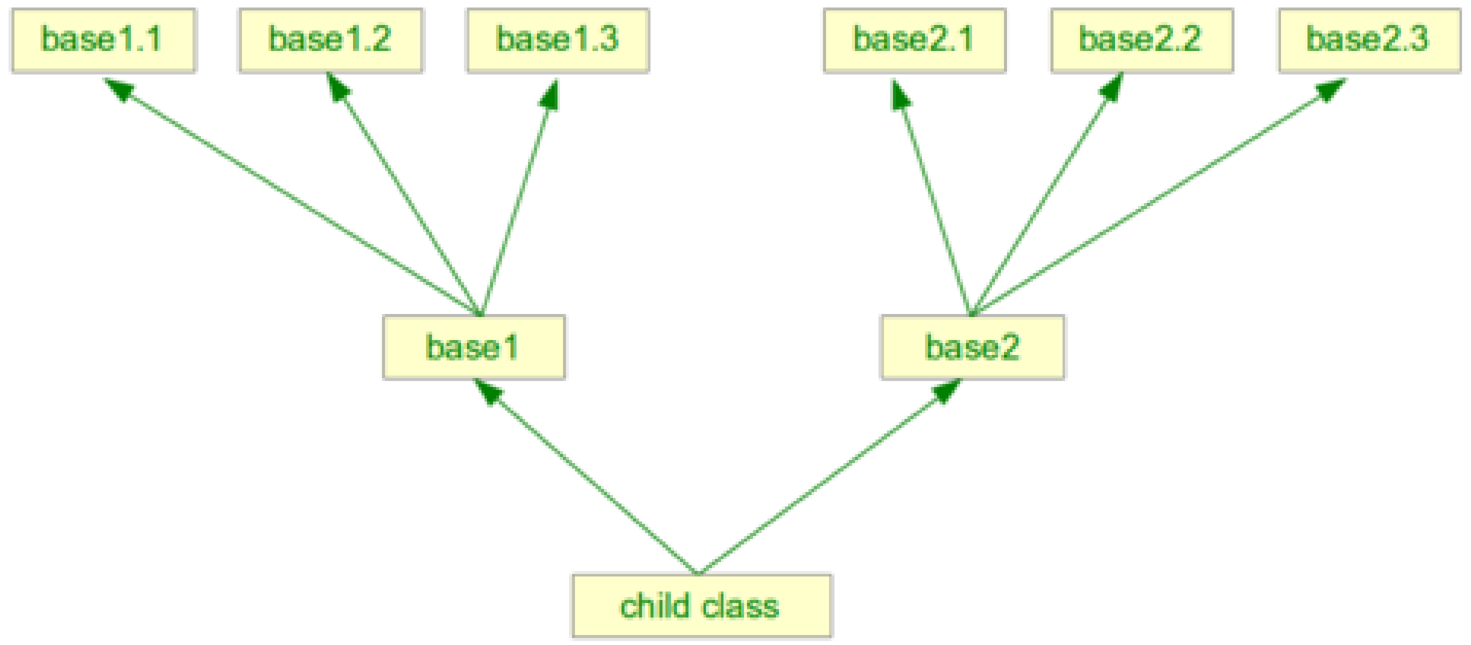
Answer

```
class Course:
    def __init__(self, courseName):
        self.__courseName = courseName
        self.__students = []

    def addStudent(self, student):
        self.__students.append(student)

    def getStudents(self):
        return self.__students

    def getNumberOfStudents(self):
        return len(self.__students)

    def getCourseName(self):
        return self.__courseName

    def dropStudent(student):
        print("Left as an exercise")
```

Multiple Inheritance

- In Python, we can define new class from multiple classes
- This is called multiple inheritance
- Multiple inheritance is a feature in which a class can inherit attributes and methods from more than one parent class

Inheritance Tree



- The inheritance relationship in Python can be represented by a tree structure

Example

```
class A():
    def __init__(self, a=100):
        self.a=a

class B():
    def __init__(self, b=200):
        self.b=b

class C(A, B):
    def __init__(self, a, b, c=300):
        super().__init__(a)
        super().__init__(b)
        self.c=c

    def output(self):
        print(self.a)
        print(self.c)
        print(self.b)

def main():
    c = C(1, 2, 3)
    c.output()

main()
```

Example

```
class A():
    def __init__(self, a=100):
        self.a=a

class B():
    def __init__(self, b=200):
        self.b=b

class C(A, B):
    def __init__(self, a, b, c=300):
        A.__init__(self, a)
        B.__init__(self, b)
        self.c=c

    def output(self):
        print(self.a)
        print(self.c)
        print(self.b)

def main():
    c = C(1, 2, 3)
    c.output()

main()
```