User Defined Classes

CS 18000
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Objectives

In this module, we will study how to create user defined classes including:

- Creating objects from user defined classes
- Adding data members and methods to classes
- Class and object methods
- Argument passing for methods in Java
- Scope of variables

Problem

- *Create a program that reads in details about your course staff and then prints them out in a neat table.*
  - *Instructor (me), Course Coordinator, and TA.*
  - *For each individual, we need to record the following (String) values:*
    - *First Name, Last Name*
    - *Email*
    - *Office*

Sample output

Instructor:
Sunil Prabhakar
Office: LWSN 3144F
Email: sunil@purdue.edu
Course Coordinator:
Lorenzo Martino
Office: HAAS 144
Email: lmartino@purdue.edu
Teaching Assistant:
Asmaa Sallam
Office: LWSN B116B
Email: asallam@purdue.edu

Solution

- Since we are creating multiple versions of the same data and performing the same operations, it would be very helpful to have a class for saving each person's data and printing it out neatly.
- No such standard class exists.
- We will create one: CS180Staff
- Our program will also be a separate class that will use this CS180Staff class.
  - this will be our controller class: CourseStaff

The CS180Staff class

- We want each object of this class to
  - store the data for a single person:
    - these are data members of each object
    - ***firstName, lastName, email, office***
  - input the values for each person
    - this is a behavior for which we define a method
    - ***readDetails();***
  - print out the details of the person neatly
    - this is a behavior for which we define a method
    - ***printNeatly()***;

CS180Staff class

```
import javax.swing.*;

public class CS180Staff {

    private String firstName, lastName, email, office;

    void getDetails(){
        firstName = JOptionPane.showInputDialog(null, "Enter First Name:");
        lastName = JOptionPane.showInputDialog(null, "Enter Last Name:");
        email = JOptionPane.showInputDialog(null, "Enter email:");
        office = JOptionPane.showInputDialog(null, "Enter office:");
    }

    void printNeatly(){
        System.out.println("    " + firstName + " " + lastName);
        System.out.println("    Email: " +  email);
        System.out.println("    Office: " +  office);
    }
}
```

Controller class: CourseStaff

```
public class CourseStaff {
    public static void main(String[] args){

        CS180Staff instructor, coordinator,ta;

        instructor = new CS180Staff();
        instructor.getDetails();

        coordinator = new CS180Staff();
        coordinator.getDetails();

        ta = new CS180Staff();
        ta.getDetails();

        System.out.println("Instructor:");
        instructor.printNeatly();

        System.out.println("Coordinator:");
        coordinator.printNeatly();

        System.out.println("Teaching Assistant:");
        ta.printNeatly();
    }
}
```

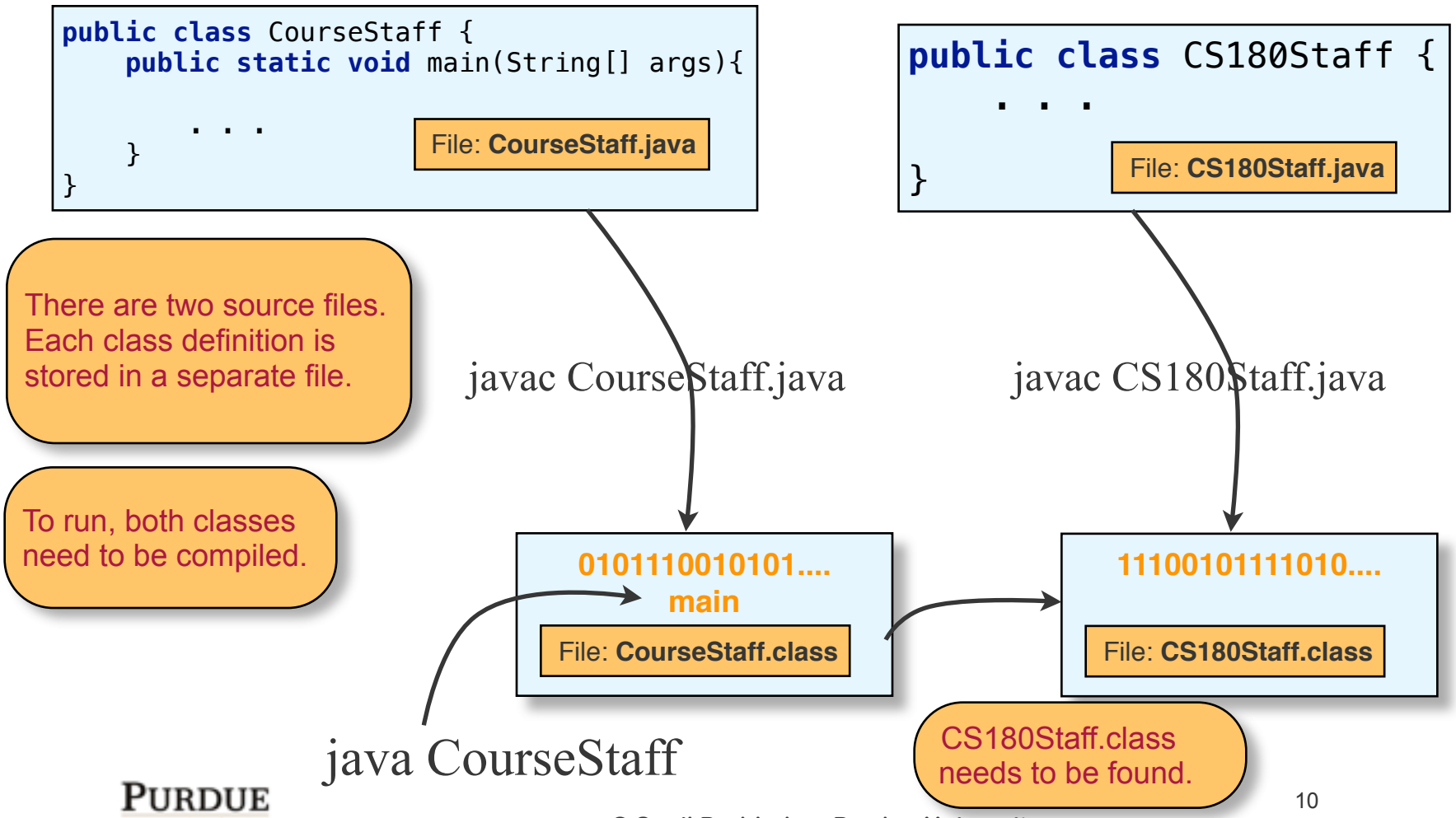
CS180Staff class

```
import javax.swing.*;

public class CS180Staff {

    private  String firstName, lastName, email, office;

    void getDetails(){
        firstName = JOptionPane.showInputDialog(null, "Enter First Name:");
        lastName = JOptionPane.showInputDialog(null, "Enter Last Name:");
        email = JOptionPane.showInputDialog(null, "Enter email:");
        office = JOptionPane.showInputDialog(null, "Enter office:");
    }

    void printNeatly(){
        System.out.println("    " + firstName + " " + lastName);
        System.out.println("    Email: " +  email);
        System.out.println("    Office: " +  office);
    }
}
```

Data Members declared outside any method

Methods.

Files and Classes

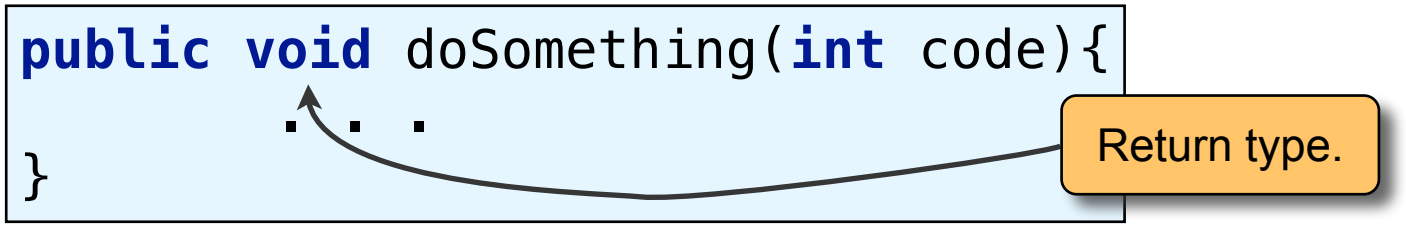


Methods

- Note that we have created two methods for the CS180Staff class.
- Each corresponds to a well-defined piece of work.
- This makes it easy to use methods.
- Similarly, the Math class methods all perform a well-defined operation.
- Any number of methods can be defined for a class.
- Method names should give clues to their function. Typically verbs (e.g, printDetails()).

Adding methods

- Methods for a class are defined as follows:

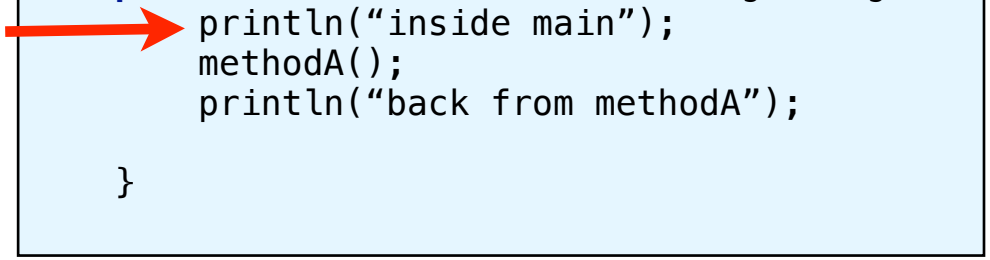


- The name of the method is preceded by a type indicating the type of value returned by this method when it finishes. The return type can be a
  - a primitive type,
  - a Class, or
  - **void** -- indicating that nothing is returned
- A method may take arguments (e.g., main)

Execution flow

- Our programs begin execution at the first statement in the *main* method.
- Statement are executed in order.
- When a method is called,
  - the execution moves to the first line of that method
  - each statement is executed in order, until
  - we get a **return** statement, or the end of the method
  - then control returns back to the caller.

Example flow

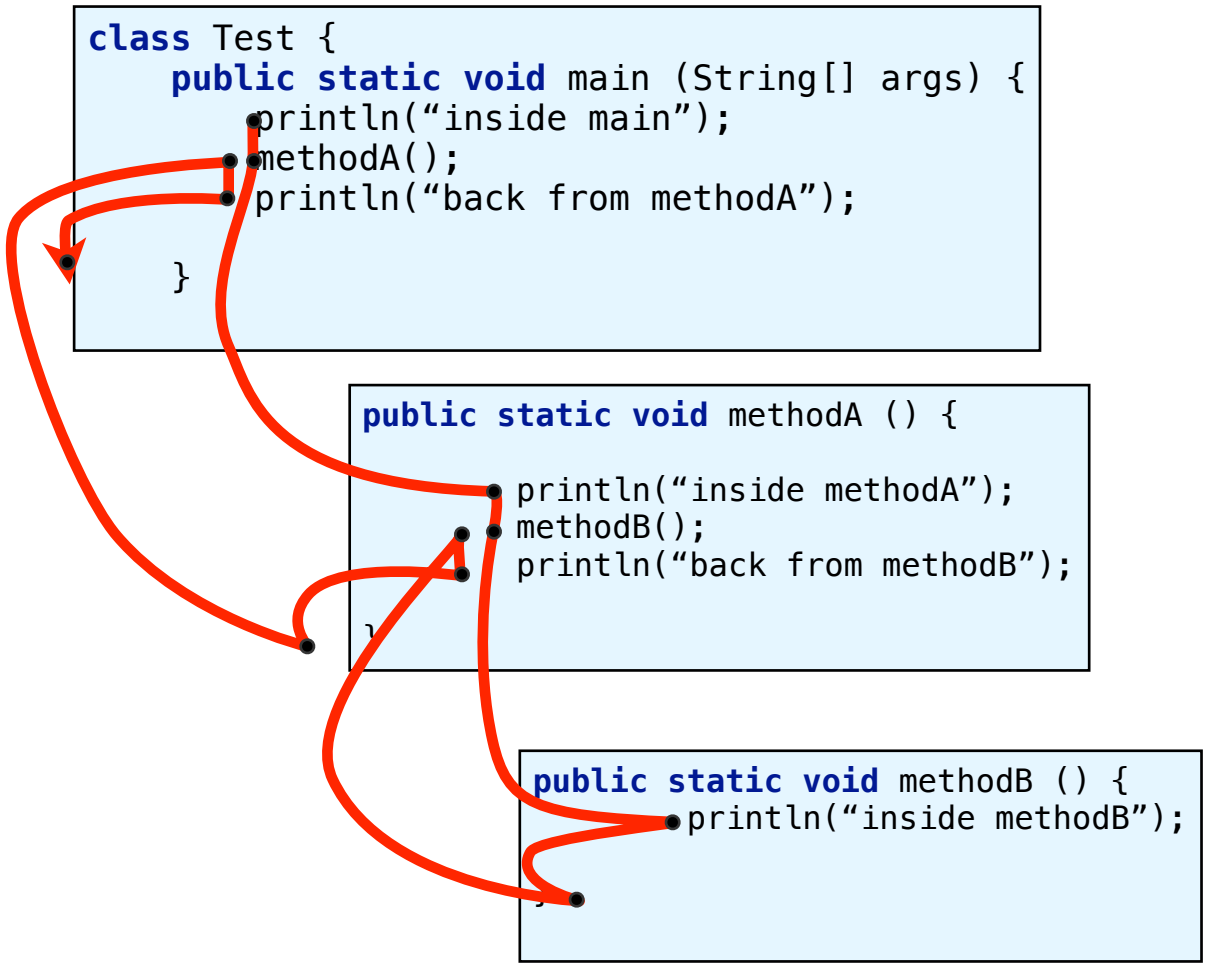


```
class Test {
    public static void main (String[] args) {
        println("inside main");
        methodA();
        println("back from methodA");

    }
```

```
public static void methodA () {

        println("inside methodA");
        methodB();
        println("back from methodB");

}
```

```
public static void methodB () {
        println("inside methodB");

}
```

Sample Execution Flow



Adding Data Members

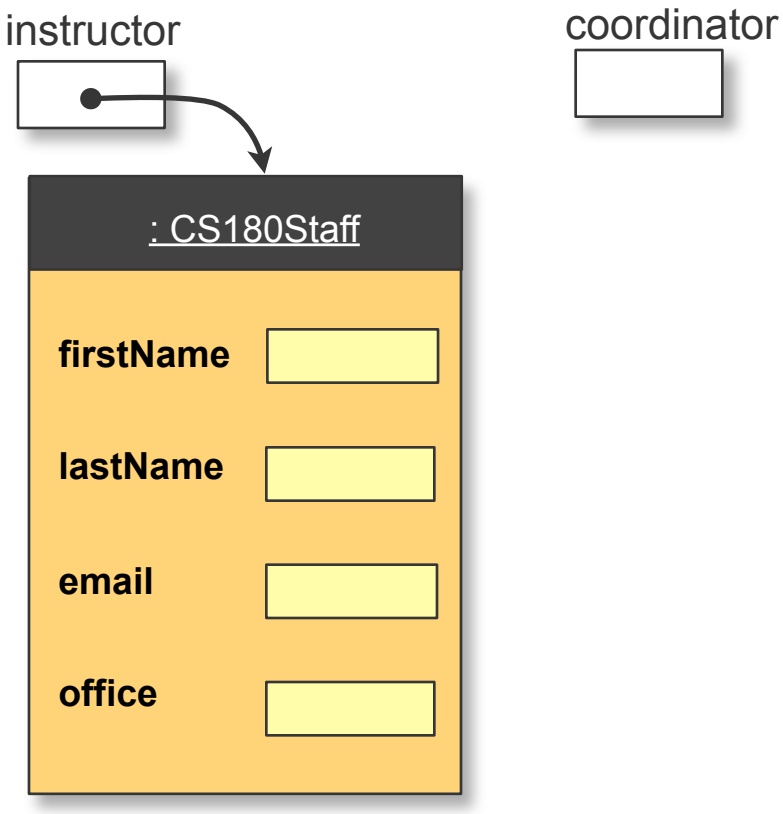
- Data members are declared outside any method. Typically before any method.

```
private      String     firstName;
```

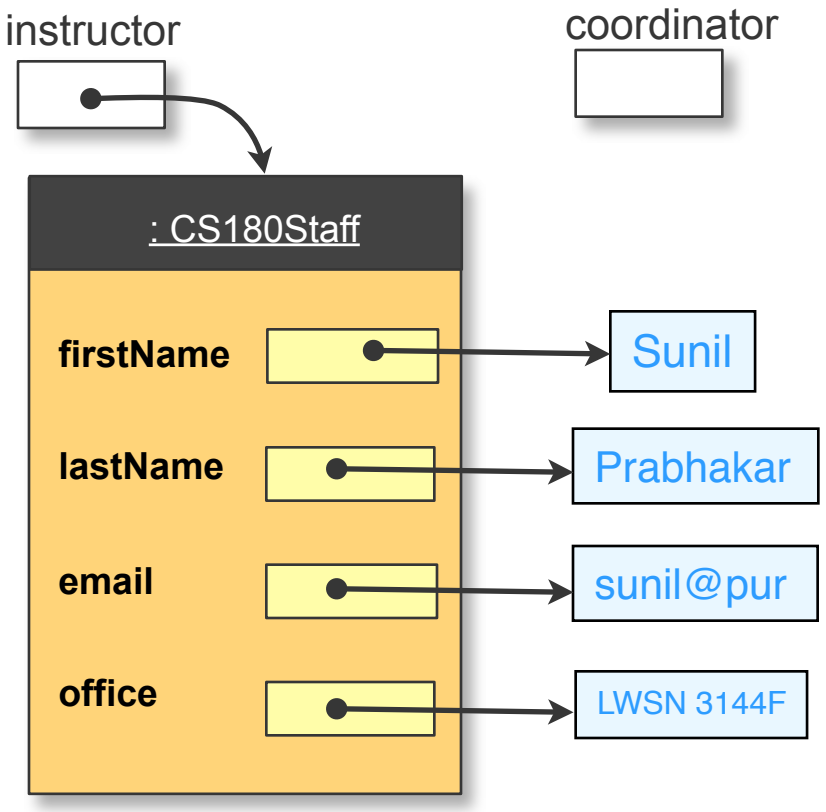
- **private** is a modifier. We will understand it later. It is an alternative to **public** which we have seen before.
  - this is optional -- if left out, it is assumed to be **public**
- Each object of this class will get its own copy of each data member.

What is happening?

```
private     instructor, coordinator;

instructor = new CS180Staff();

instructor.getDetails();
```



What is happening?

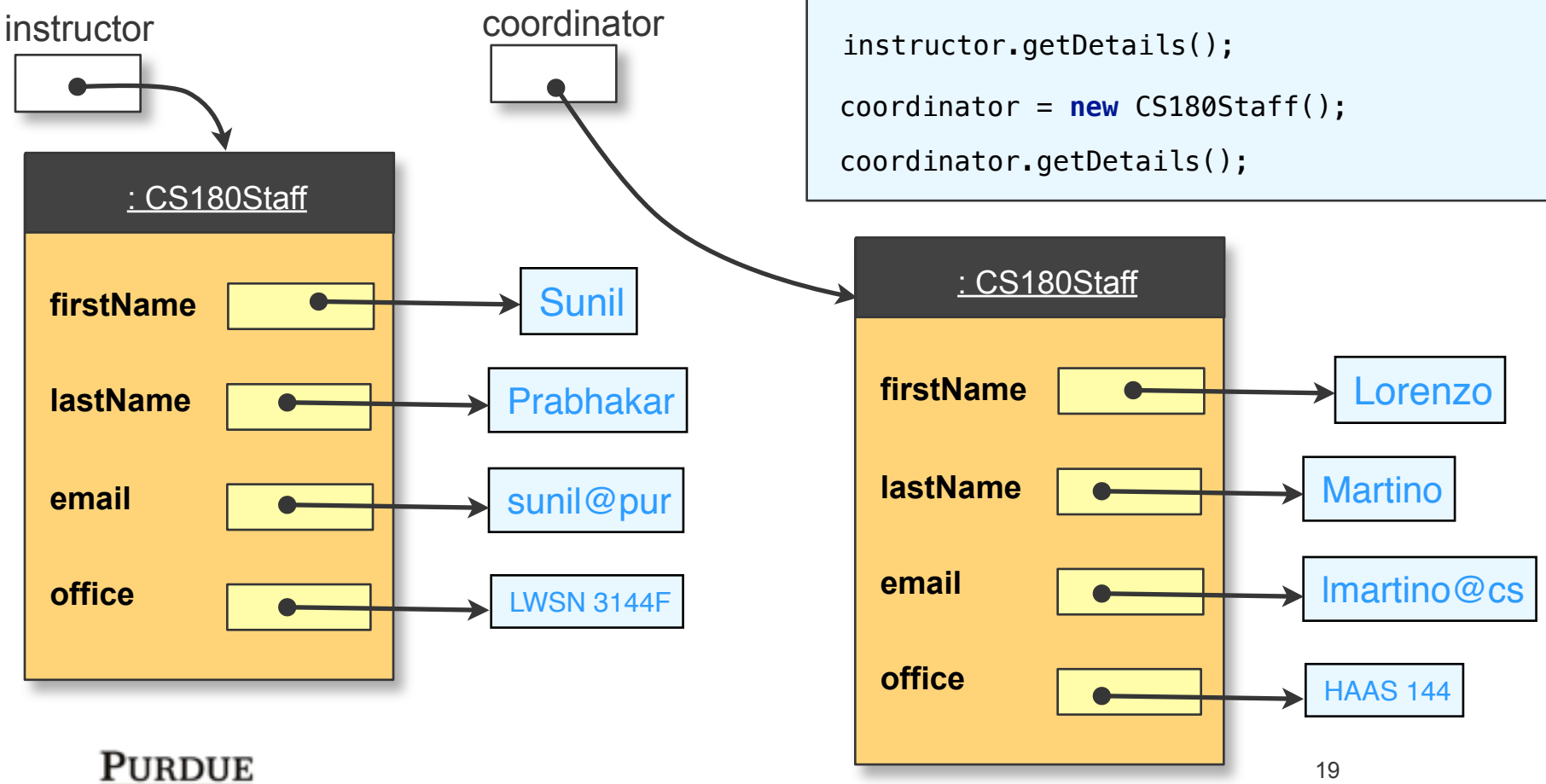



```
private     instructor, coordinator;

instructor = new CS180Staff();

instructor.getDetails();
```

```
void getDetails(){
  firstName = JOptionPane.showInputDialog
                (null, "Enter First Name:");

   lastName = JOptionPane.showInputDialog
                (null, "Enter Last Name:");

      email = JOptionPane.showInputDialog
                  (null, "Enter Email:");

     office = JOptionPane.showInputDialog
                  (null, "Enter Office:");


}
```

What is happening?

```
private     instructor, coordinator;
instructor = new CS180Staff();
instructor.getDetails();
coordinator = new CS180Staff();
coordinator.getDetails();
```



Important point

- Calling **new** CS180Staff creates a new object of this class with its own copy of all data members.
- When a method is called on such an object it modifies only that object's copies of the data members (e.g., firstName).
  - Thus instructor.getDetails() causes only the data members of the object referenced by instructor to be affected, not other CS180Staff objects.

Problem: Course Participants

- *Create a program to input course participants info for Staff (as before), and 2 students, then print it out neatly. Each student*
  - *has a name, gpa (double), and*
  - *is identified by her ID (String)*
  - *a student object must always have a valid ID.*
- *We should be able to read and change the name and gpa of the student at any time, but not the ID.*

The Student class

```
class Student {
    private String name, id;
    private double gpa;

    public void getDetails(){
        name = JOptionPane.showInputDialog(null, "Enter Name:");
        id = JOptionPane.showInputDialog(null, "Enter ID:");
        gpa = 0.0;
    }

    public void printNeatly(){
        System.out.println("    " + name);
        System.out.println("    ID: " +  id);
        System.out.println("    GPA: " +  gpa);
    }

    public void setName(String studentName){
        name = studentName;
    }
    public String getName(){
        return name;
    }
// CONTINUED ...
```

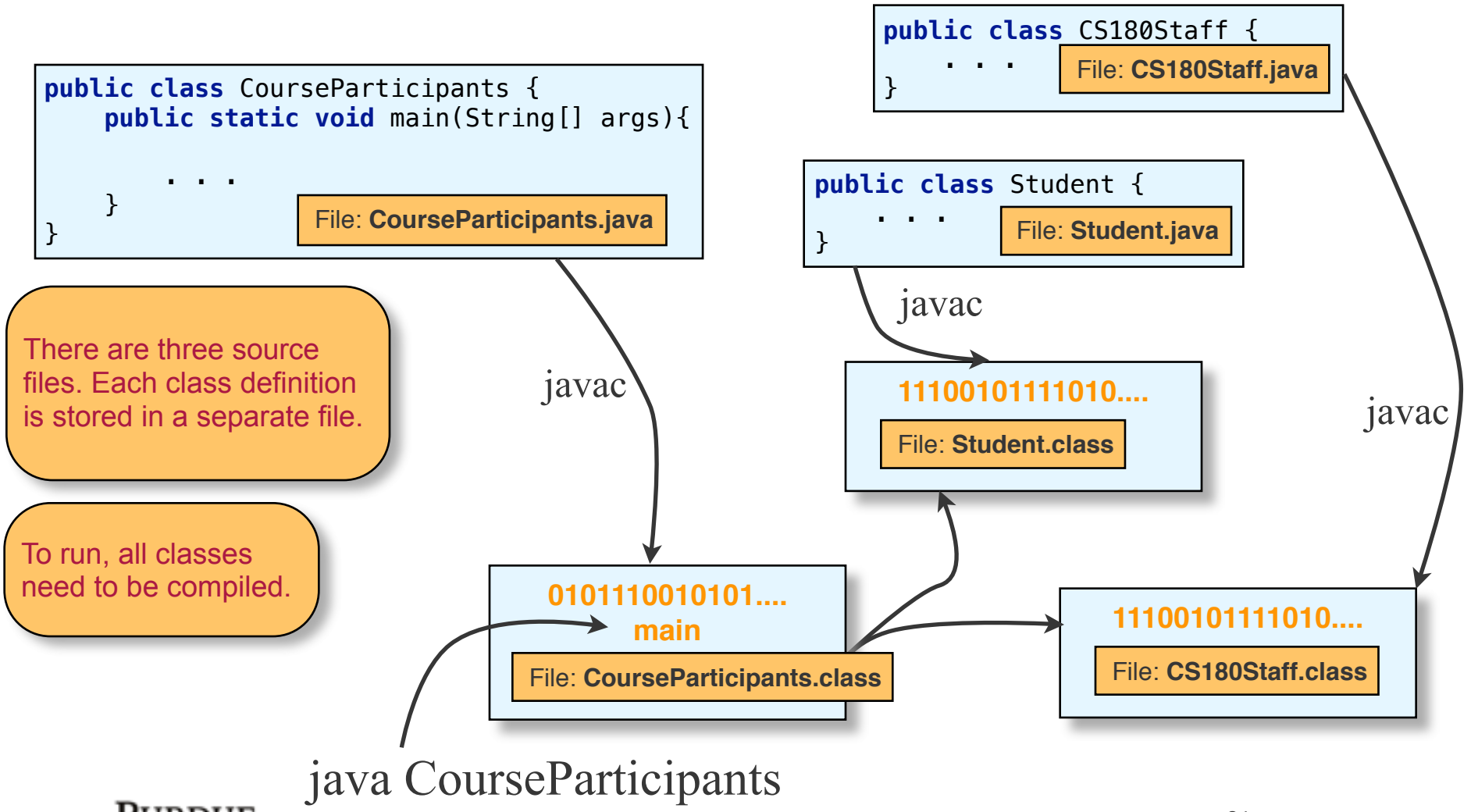
```
  // ...
  public String getId(){
          return id;
  }

  public double getGpa(){
          return gpa;
  }

  public void setGpa(double g){
          gpa = g;
  }
}
```

Controller class: CourseParticipants

```
public class CourseParticipants {
    public static void main(String[] args){

        CS180Staff instructor, coordinator,ta;
        Student student1, student2;

        instructor = new CS180Staff();
        instructor.getDetails();
        . . .
        student1 = new Student();
        student1.getDetails();

        student2 = new Student();
        student2.getDetails();

        . . .
        student1.printNeatly();
        student2.printNeatly();
    }
}
```

Note: same method names but different behavior for CS180Staff and Student objects.

Files and Classes



Two types of methods

- There are two types of methods:
  - object methods
  - class methods
- A class method is defined **with** the **static** keyword.
- An object method is defined **without** the **static** keyword.
- An object method must been called on an object of the class

Calling Class Methods

- Methods defined with the **static** keyword are called Class Methods.
- These methods are called using the class name.

```
class ComputeSine {
    public static void main() {
        double sine, angleRad = 3.4;
        String text;

        text = JOptionPane.showMessageDialog(null, "Enter Angle in Radians");
        angleRad = Double.parseDouble(text);

        sine = Math.sin(angleRad);
    }
}
```

Class names

Calling Object Methods

- Methods defined without the **static** keyword are called Object Methods.
- These methods can only be called on an object of the given class.

```
import javax.swing.*;

class Test {
    public static void main() {
        Student s;
        String n;

        s = new Student();
        s.getId();
        n = getName();
    }
}
```

getName() must be called on a Student object.

From Outside the Class

need the class name to call a class method

```
class Test {
    . . .
    SampleClass obj;

  ☹classMethodA();

    SampleClass.classMethodA();

  ☹objectMethodA();

  ☹obj.objectMethodA();

    obj = new SampleClass();

    obj.objectMethodA();
    . . .
}
```

```
class SampleClass {

    public static void classMethodA(){
        . . .
    }

    public void objectMethodA(){
        . . .
    }

}
```

obj does not reference a valid SampleClass object.

obj does not reference a valid SampleClass object.

From Within the Class

A **class** method can directly call another **class** method of the same class.

A class method needs an object of the class in order to call an object method

An object method does not need to use the class name in order to call a class method

An **object** method can directly call another **object** method of the same class without specifying an object.

```
class SampleClass {
    public static void classMethodA(){
        SampleClass obj;

        classMethodB();
        objectMethodA(); ☹
        obj = new SampleClass();
        obj.objectMethodA();
    }

    public static void classMethodB(){
        . . .
    }

    public void objectMethodA(){
        classMethodA();
        SampleClass.classMethodA();
        objectMethodB();

    }

    public void objectMethodB(){
        . . .
    }
}
```

Calling Methods of Same Class

```
class Student {
    private String id;
    private String name;

    public void setName(String newName){
        . . .
    }
    private void setId(String newID){
        setName("ID changed");
        . . .
    }
    public String getId(){
        . . .
    }
}
```

No object specified.

setName() will use the same object as the one on which setId() was called.

Remember ...

- A class method needs a class name when called from
  - outside the class; or
  - a object method of the same class
- An object method needs to be called on an object of that class
  - when called from another object method of the same class, this object is implicit and not specified explicitly.
- Note: main is a class (static) method.

Initialization

```
class Student {
    private String name = "Unknown", id = "?";
    private double gpa= 0.0;
    …
}
```

- Works for name and gpa, but is misleading. Can set it later.
- What about ID? We won't be able to change it. Thus, we need an id at object creation time.
- For this we use a special method called a *Constructor* -- this is called when an object is created using the **new** keyword.

A Constructor

```
class Student {
    . . .
    public Student() {
        ...
    }
    . . .
}
```

- A constructor is a method defined within the class (like any other method).
  - it may or may not take any arguments
- However,

  it should always be a **public** method
  - it has no return type
  - its name is the same as the class name
- It is not necessary to define a constructor -- in this case the compiler creates a default constructor.

StudentV2 (with a Constructor)

```
class StudentV2 {
    private String name, id;
    private double gpa;

    public StudentV2(String studentID){
        id = studentID;
        name = "Unknown";
        gpa = 0.0;
    }

    . . .
}
```

Using StudentV2 Objects

```
public class TestClass {
    public static void main(String[] args){

        StudentV2 student;

        student = new StudentV2("3478734");
        student.printNeatly();
    }
}
```

- Since the constructor for Student expects a String argument, we can no longer create student objects without providing this argument.
- Now a student object will have the given ID when created.

Constructors

- Each class must have a constructor if we are to create objects of the class.
- A constructor without arguments is called a default constructor.
- If a class does not define any constructors then a default constructor is automatically provided by the compiler.
- If any constructors are defined in the class, no default constructor will be provided.

Multiple Constructors

- What if we want to optionally allow objects to have an ID and a name at initialization?
- We can define two versions of constructors.

```
class StudentV3 {
    ...

    public StudentV3(String studentID) {
        id = studentID;
        name = "Unknown";
        gpa = 0.0;
    }

    public StudentV3(String studentID, String sName) {
        id = studentID;
        name = sName;
        gpa = 0.0;
    }

    ...
}
```

Multiple Constructors

- Which one is executed to create a new object?
- Depends upon how many (and what types of) arguments are passed to it.
  - More later.

```
class Test {
    public static void main(String[] args){
        StudentV3 student;

        student = new StudentV3();

        student = new StudentV3("677632");

        student = new StudentV3("7658478", "John Doe");

    }
}
```

This version not available now!

Return values

- If the return type of a method is **void**, it returns nothing.

Otherwise, it must end with a **return** statement:

```
return <expression>;
```

- The expression may be an identifier, an expression, or a literal.
- The type of the expression must be compatible with the return type of the method.
- A **return** causes the method to return to the caller.

Problem

- *Extend the student class so that it recomputes the gpa when grades are reported. The class will not keep track of grades -- only the gpa.*
  - *recordGrade(); will be called to ask the Student object to record a grade. It should prompt for the number of credits for the course, and the grade expressed as an integer (4 for A, 3 for B, etc…) and then recompute the GPA.*

The StudentV4 Class

```
class StudentV4 {
    . . .
    private int totalCredits;
    public StudentV4(String studentID, String sName){
        . . .
        totalCredits = 0;
    }
    public void recordGrade(){
        int grade, credit;
        credit = Integer.parseInt(JOptionPane.showInputDialog(null,
                "Enter Number of Credits");
        grade = Integer.parseInt(JOptionPane.showInputDialog(null,
                "Enter Grade (as integer)");
        recomputeGpa(credit, grade);
    }

    public void recomputeGpa(int newCredit, int newGrade){
        double totalGradeCredits;

        totalGradeCredits = gpa * totalCredits;
        totalCredits += newCredit;
        totalGradeCredits += newCredit * newGrade;
        gpa = totalGradeCredits / totalCredits;
    }
    . . .
}
```

Using StudentV4

```
class TestStudentV4 {
    public static void main (String[] args) {
        StudentV4 jane;

        jane = new StudentV4("2342342", "Jane Doe");

        jane.recordGrade();
        jane.printNeatly();

        jane.recordGrade();
        jane.printNeatly();
    }
}
```

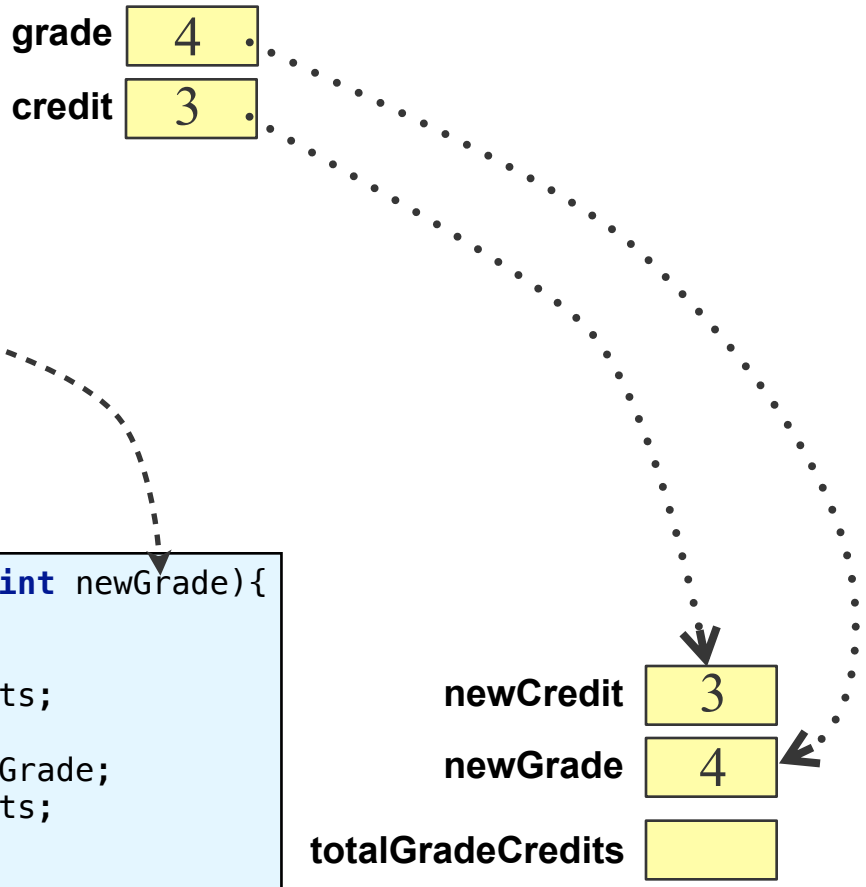
Method Arguments

- If a method takes arguments, every call to the method must provide values for these.
- The number and type of arguments expected by a method are declared by the method.
- Each time a method is called
  - New storage is created for its arguments
  - These arguments are initialized with copies of the values from the method call.

Initializing arguments

```
public void recordGrade(){
    int grade, credit;
    . . .
    recomputeGpa(credit, grade);
}
```

```
public void recomputeGpa(int newCredit, int newGrade){
    double totalGradeCredits;

    totalGradeCredits = gpa * totalCredits;
    totalCredits += newCredit;
    totalGradeCredits += newCredit * newGrade;
    gpa = totalGradeCredits / totalCredits;
    }
    . . .
}
```



Matching arguments

```
public void methodA(){
    int i, j;
    double x, y;
    . . .
    methodB(i, x);

☹   methodB(x, i);

☹   methodB(i);

    methodC(i, x);

    methodC(x, i);

☹   methodD(i, x);

    methodD(i, x, 5);

}
```

```
public void methodB(int a, double b){
    . . .
}
```

```
public void methodC(double a, double b){
    . . .
}
```

```
public void methodD(int a, double b, int c){
    . . .
}
```

Pass by value

```
public void methodA(){
    int i;
    i = 1;

    doubleUp(i);
    System.out.println("i = " + i);
}
```

i = 1

```
public void doubleUp(int a){
    a = 2 * a;
    System.out.println("a = " + a);
}
```

a = 2

- Only a copy of the value of i is passed. Changes to a do not affect the value of i.
- This is called *Pass by value*

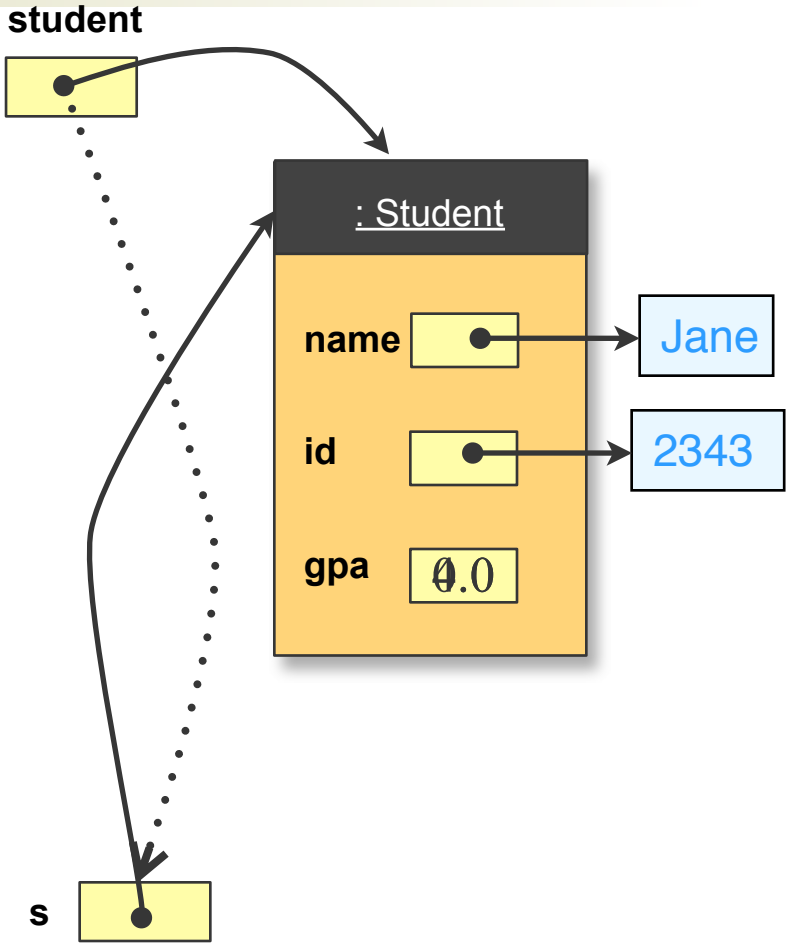
Objects as arguments

- Methods can take object arguments as well.
- The class of the object in the call must be compatible with the class of the object in the method declaration.
  - for now this means the same class
- As with assignment of reference types, only the reference is copied over.
  - the object being referenced is not copied!

Passing Objects

```
public void methodA(){
    Student student;

    student = new Student("2343", "Jane");
    changeGpa(student);
    System.out.println("Gpa = " + student.getGpa());
}
```

```
Gpa = 4.0
```




```
public void changeGpa(Student s){
    s.setGpa(4.0);

}
```

Returning Objects

- As with arguments passed to a method,
  - when a method returns a primitive data type, the value is returned.
  - when a method returns a class data type, the reference to an object is returned.
- For example,
  - A constructor returns the reference to the newly created object.

Protecting Object Data

```
class Test {
    public static void main (String[] arg){
        Student s = new Student("4343");
        s.id = "234";
        s.name = "Jane";
        s.setID("234");
        s.setName("Jack");
        System.out.println(s.getName() + s.getID());
    }
```

```
class Student {
    public String id;
    public String name;

    public void setId(String newId){
        . . .
    }

    public void setName(String newName){
        . . .
    }

    public String getId(){
        . . .
    }
    public String getName(){
        . . .
    }
}
```

ID can be changed from outside!

Encapsulation

- One of the key benefits of OOP
- Limit who can view/modify what data members and how
  - avoids accidental or intentional errors
- Improves program reliability and reuse
- Achieved by
  - hiding data members from outside the class
  - limiting which methods can be called directly from outside the class
  - using **public** and **private** modifiers

Visibility modifiers

- A data member or method that is declared **public** can be accessed by the code in any class.
- A **private** data member can only be accessed code that is part of the same class.
- A **private** method can only be called from code that is part of the same class.

Protecting Object Data

```
class Test {
    public static void main (String[] arg){
        Student s = new Student("4343");
        s.id = "234";
        s.name = "Jane";
        s.setID("234");
        s.setName("Jack");
        System.out.println(s.getName()
                + s.getID());
    }
}
```

```
class Student {
    private String id;
    public String name;

    private void setId(String newId){
        . . .
    }

    public void setName(String newName){
        . . .
    }

    public String getId(){
        . . .
    }
    public String getName(){
        . . .
    }
}
```

id and setId() are inaccessible.

Guidelines

- Implementation details (data members) should be **private**
  - Use accessor/mutator methods
- Internal methods should be **private**
- Constructors are usually **public**
- Constants may be made **public** if useful (e.g. Math.PI)
- Default value is **public**.

Accessor and Mutator Methods

- Since most data members are usually defined to be private, it is common practice to provide methods to read and modify the values of data members.
  - Accessor methods are methods that retrieve the value of private data members. E.g., getName(), getId()
  - Mutator methods are methods that modify the value of private data members. E.g., setName().

Identifier types

- Identifiers can be declared almost anywhere in a program.
- There are three main types of declarations:
  - Data members of a class
    - Declared outside any method
    - Usually at the beginning of the class definition
  - Formal parameters of a method
  - Local variables inside a method

Identifier extent and scope

- Each identifier refers to a piece of memory.
- That piece is reserved upon declaration.
- The lifetime of this reservation is called the extent of the identifier.
- The ability to access this location from a given line of code is called scope.
- Important to understand both.
- Extent and scope depend upon the type

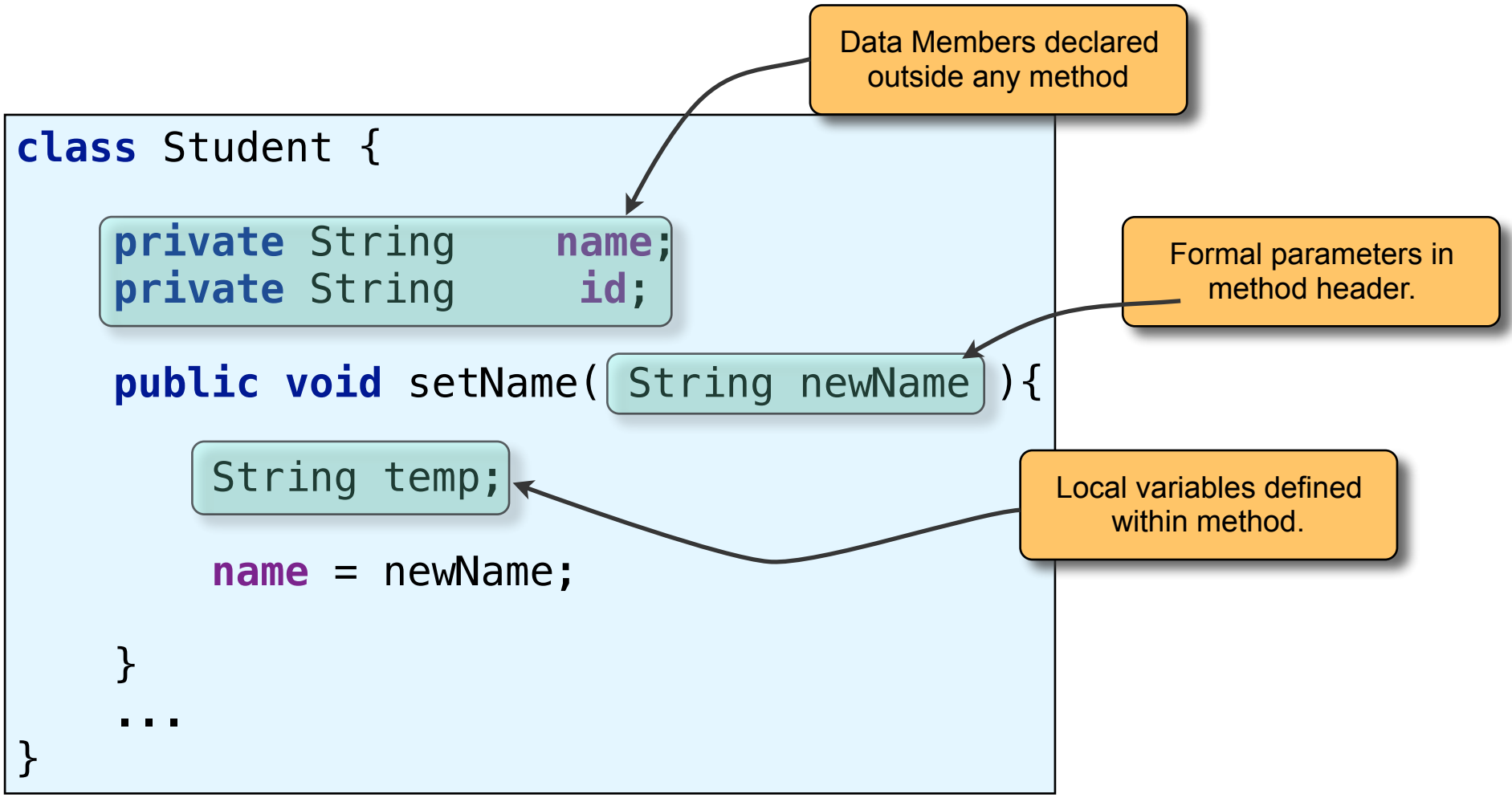
Extent

- Object data members
  - created when an object is created (by **new**)
  - destroyed when the object is garbage collected (no more references to it)
  - must be unique within each class
- Formal parameters
  - created each time the method is called
  - destroyed when the method finishes execution
  - must be unique for each method
- Local variables
  - created upon declaration
  - destroyed at end of block
  - must be unique for each block,
- Limiting extent allows compilers to reuse space

Which one do we mean?

- It is legal to reuse the name of a data member as a formal parameter, or a local variable.
- Each use of the identifier in a method is matched with exactly one of these as follows:
  - A local variable, or parameter, if it exists.
  - A data member, otherwise.
- Thus, a data member can be masked!
- Can lead to subtle errors.

Identifiers



Masked Data Member

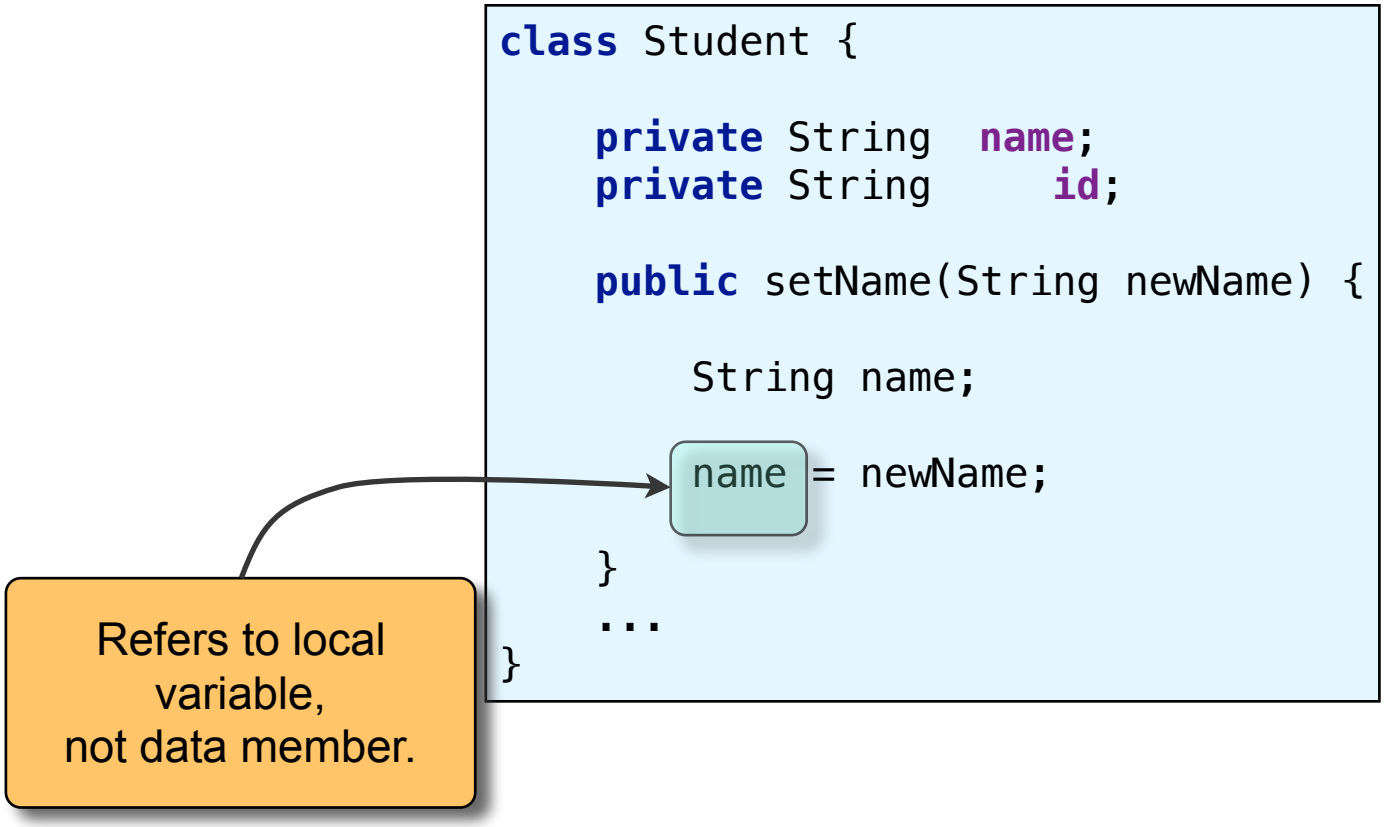
```
class Student {

    private String   name;
    private String     id;

    public setName(String name) {

        String temp;

        name = name;

    }
    ...
}
```

Refer to formal parameter, not data member.

```
class Student {

    private String   name;
    private String     id;

    public setName(String name) {

        String temp;

        this.name = name;

    }
    ...
}
```

Refers to data member.

Masked Data Member 2



Remember, ….

- A local variable can be declared just about anywhere!
- Its scope (the area of code from where it is visible) is limited to the enclosing braces.
- Statements within a pair of braces are called a block.
- Local variables are destroyed when the block finishes execution.
- Data members of a class are declared outside any method. Their scope is determined by public and private modifiers.