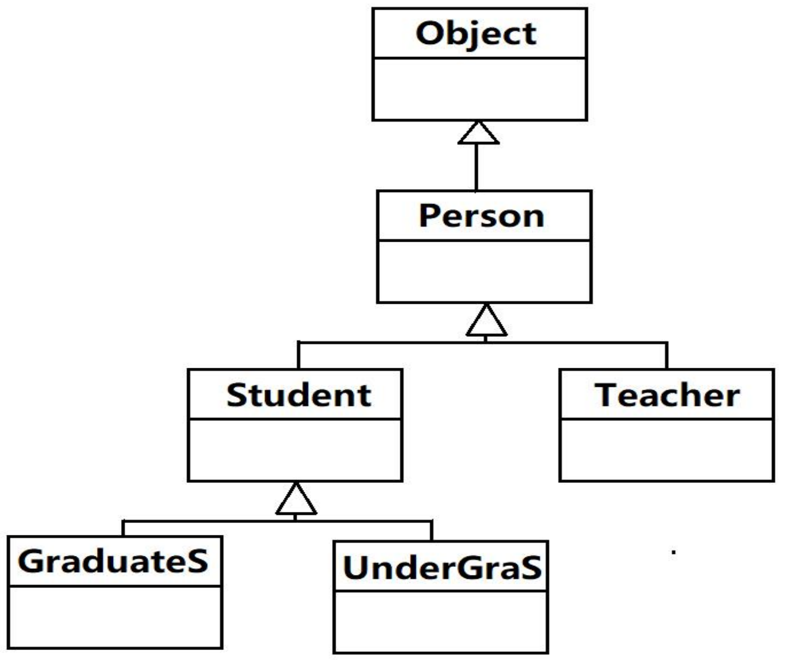
Object-Oriented Programming

Inheritance (Cont.)

United International College

Review



- Class inheritance
- `extends`
- Overriding methods
- Calling parent methods using `super`
- `super()` parent constructor call
- `this()` constructor call

Outline

- `final` modifier
- `Object` class
- `instanceof` operator
- `toString` and `equals` methods
- Dynamic Binding
- Subtyping polymorphism
- Type casting: upcasts and downcasts

Last Week: Person

```
public class Person {
    private String name;
    private int age;
    public Person(String name, int age) {
        this.name = name;
        this.age = age;
    }
    public String getName(){
        return name;
    }
    public int getAge(){
        return age;
    }
    public String getInfo() {
        return "Person "+ name + " is " + age;
    }
}
```

Person.java

Last Week: Student

```
public class Student extends Person {
    private String school;
    public Student(String name, int age, String school) {
        super(name, age);
        this.school = school;
    }
    public Student(String name, int age) {
        this(name, age, "UIC");
    }
    public String getSchool() {
        return school;
    }
    @Override
    public String getInfo() {
        return "Student "+ getName() + " is " + getAge() +
                 " and at " + school;
    }
    public String getParentInfo() {
        return super.getInfo();
    }
}
```

Student.java

Last Week: Test

```
public class Test1 {
    public static void main(String arg[]){
        Person p = new Person("Alice", 22);
        System.out.println("Person's name: " + p.getName());
        System.out.println("Person's age: " + p.getAge());
        System.out.println("Person's info: " + p.getInfo());
        Student s = new Student("Alice", 22, "UIC");
        System.out.println("Student's name: " + s.getName());
        System.out.println("Student's age: " + s.getAge());
        System.out.println("Student's school: " + s.getSchool());
        System.out.println("Student's info: " + s.getInfo());
        System.out.println("parent's info: " + s.getParentInfo());
        Student t = new Student("Bob", 21);
        System.out.println("Student's info: " + t.getInfo());
    }
}
```

Test1.java

The `final` Modifier

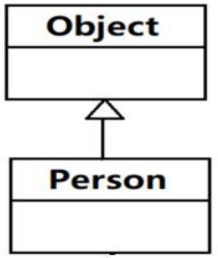
- If the modifier **`final`** is placed before the definition of a ***variable***, the value of this variable cannot be changed.
- If the modifier **`final`** is placed before the definition of a ***method***, then that method cannot be redefined (overridden) in a subclass.
- If the modifier **`final`** is placed before the definition of a ***class***, then that class cannot have subclasses.
- The Java Language Specification recommends listing modifiers in the following order:
  - [public/protected/private]
  - abstract
  - static
  - final
  - …

Examples

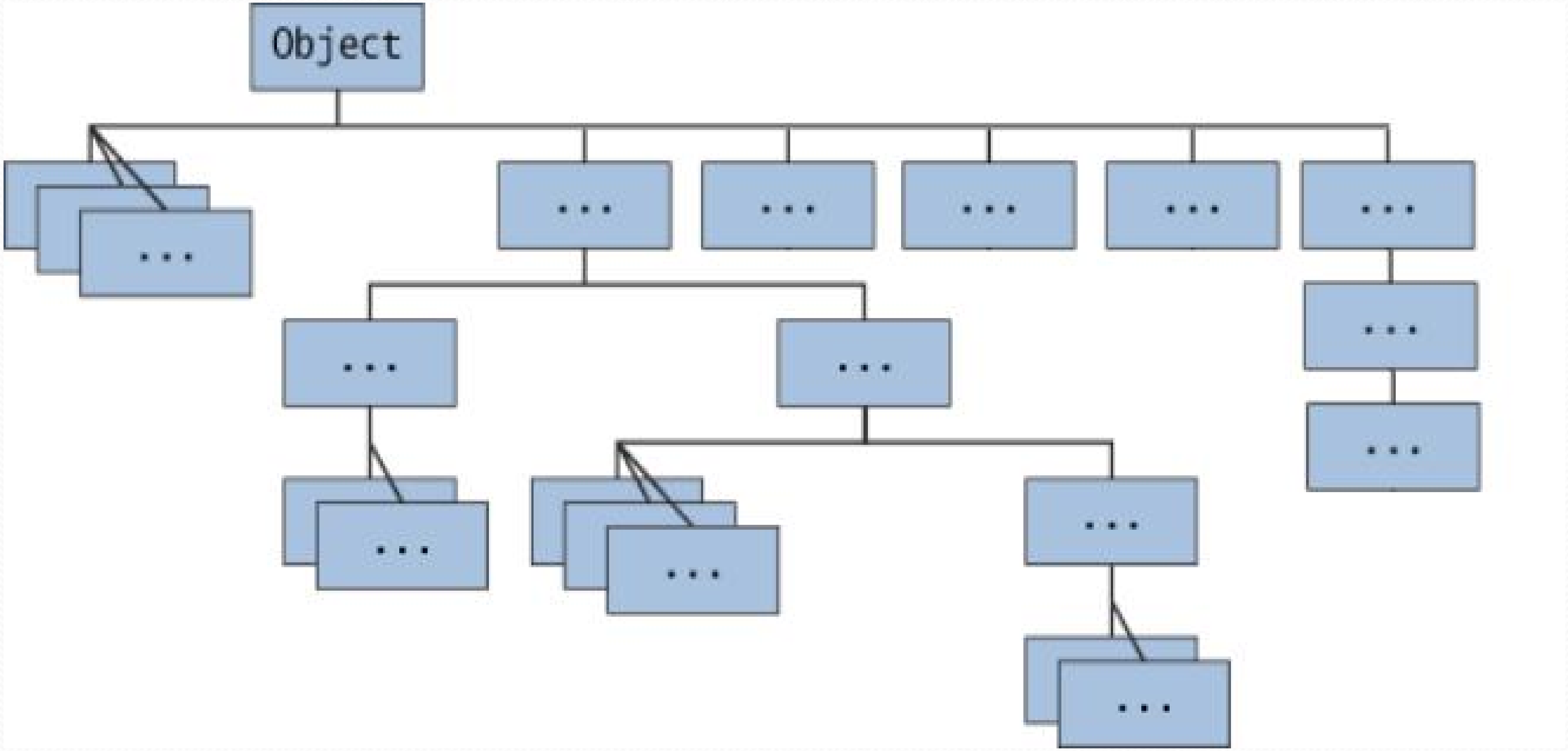
- Make a local variable `final` in the `main` method in the `Test` class: `final int x = 3;` Then, `x = 5;` is a compile-time error.
- Make the `getInfo()` method of the `Person` class `final`: `public final String getInfo(){…}`. Then, the `getInfo()` method in the subclass `Student` becomes a compile-time error.
- Make the `Person` class `final`: `final class Person {…}`. Then, `class Student extends Person{…}` becomes a compile-time error.

The `Object` Class

- In Java, every class is a descendent of the class `Object`:
  - Every class has `Object` as its ancestor.
  - Every object of every class is of type `Object`, as well as being of the type of its own class.
- If a class is defined without explicitly deriving from another class, it is still automatically a derived class of the class `Object`.
- Example: `class Person extends Object { … }`



The `Object` Class



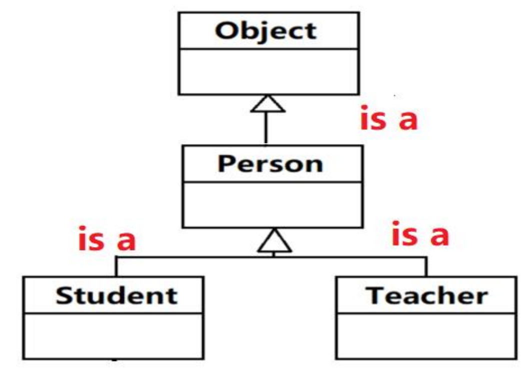
The `Object` Class

- The class `Object` is in the package `java.lang` which is always imported automatically.
- The class `Object` has some methods.
  - `toString` method
  - `equals` methods
- Because `Object` is the ancestor of every class, every class automatically inherits these methods.
- However, these inherited methods should be overridden with definitions more appropriate to a given class.
  - Some Java library classes assume that every class has its own version of such methods.

The Object Class

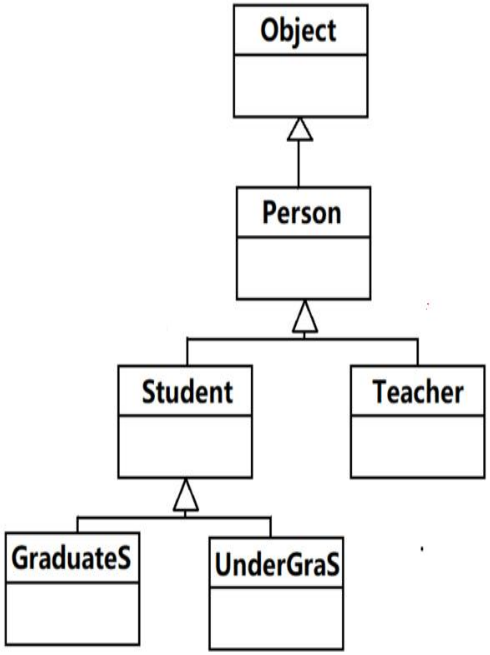
- Example: method println `println(Object x)`
  - `Person p = new Person("Alice", 22);`
  - `Student s = new Student("Bob", 20, "UIC")`
  - `System.out.println(p);`
  - `System.out.println(s);`

- Methods with a parameter of type `Object`
  - A parameter of type `Object` can be replaced by an object of any class whatsoever
  - It's subtype polymorphism



instanceof

- Since the type used for an object can be changed, how do we know what kind of object it really is?
- object **instanceof** class
  - test if the object is an instance of the class
  - or an instance of the child/descendent of the class
- Compile time: error "incompatible conditional operand types" if class is not the object's parent class/children class
- Run time
  - return true if the object is an instance the class or an instance of a child/descendent of the class
  - return false otherwise



instanceof

```
public class Test {
    public static void main(String arg[]){
        Person p = new Person("Alice", 22);
        System.out.println(p instanceof Object);  // true
        System.out.println(p instanceof Person);  // true
        System.out.println(p instanceof Student); // false
        Student s = new Student("Alice", 22, "UIC");
        System.out.println(s instanceof Teacher); // error
    }
}
```

Incompatible conditional operand types Student and Teacher

toString method

- The java `toString()` method is used when we need a string representation of an object.

- This method can be overridden to customize the string representation of a specific class.

Example

```
public class Person {
    ...
    @Override
    public String toString() {
        return "I am " + name + " and I am " + age;
    }
}
```

Person.java

```
public class Test2 {
    public static void main(String arg[]){
        Person p = new Person("Alice", 22);
        System.out.println(p); // Same as:
        System.out.println(p.toString());
    }
}
```

```
I am Alice and I am 22
I am Alice and I am 22
```

Test2.java

`equals` method

- The `equals` method
  - `object1.equals(object2)`
  - compares `object1` and `object2` using the `equals` method of `object1`.

- The result may or may not be the same as: `object2.equals(object1)` because the two objects might be from different classes with different `equals` methods.

`equals` method

- This method can be overridden to customize the comparison of objects for specific classes.
- The **`equals`** method should always have a parameter of type **`Object`** so that we can compare the current object with any other object from any other class:

```
public boolean equals(Object otherObject) {
    . . .
}
```

Example

```
public class Person {
    ...
    @Override
    public boolean equals(Object obj)
    {
        if (this == obj)  // test whether they are same object
            return true;
        if (obj == null)  // input object is null
            return false;
// make sure obj is Person type or its child, so it can cast to
Person type safely
        if (obj instanceof Person)
        {
            Person p = (Person)obj; // type casting to Person type
            // compare all the instance variables
            if (this.name.equals(p.getName())&& this.age == p.getAge())
                return true;
        }
        return false;
    }
}
```

Person.java

Example

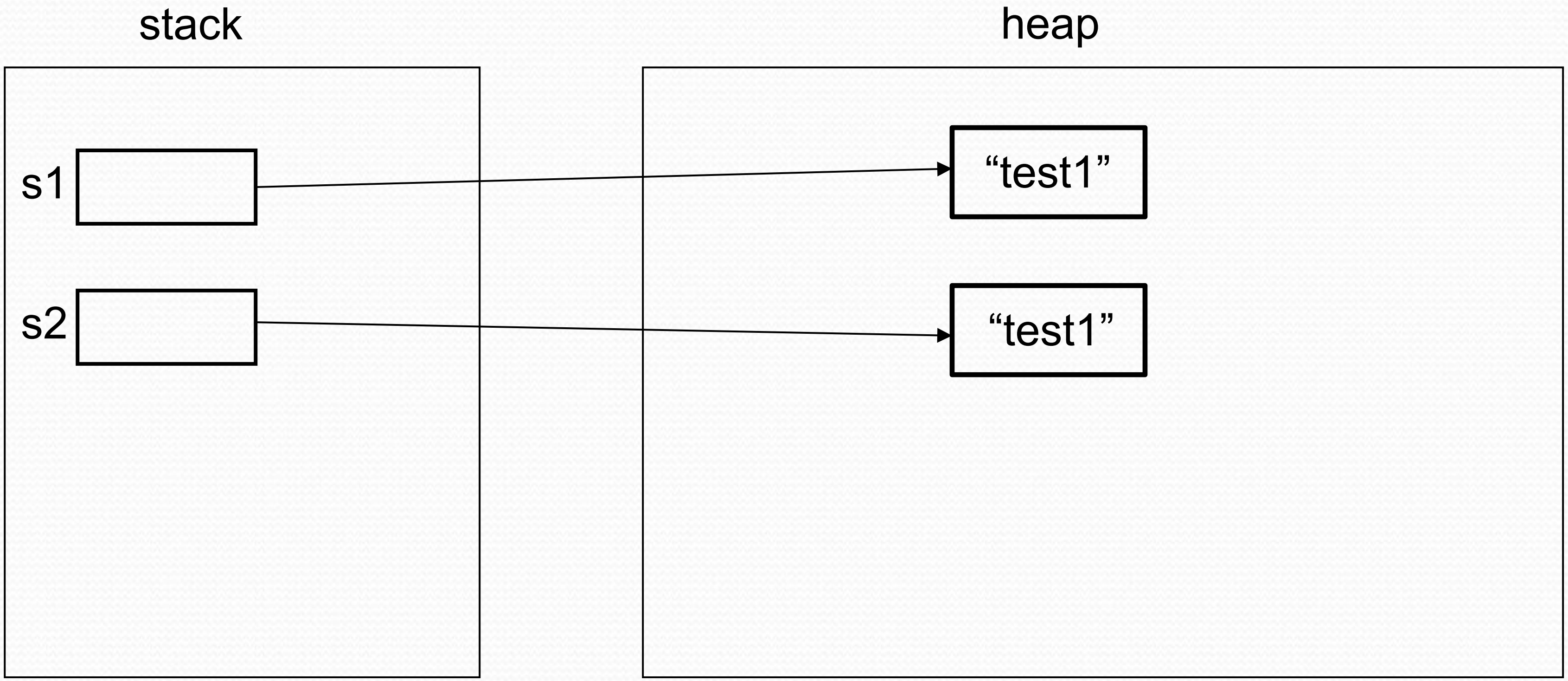
```
public class Test3 {
    public static void main(String arg[]){
        String s1 = new String("test1");
        String s2 = new String("test1");
        System.out.println(s1 == s2);       // Same object?
        System.out.println(s1.equals(s2));  // Same values?
        Person p1 = new Person("Alice", 22);
        Person p2 = new Person("Alice", 22);
        Person p3 = new Person("Bob", 20);
        System.out.println(p1 == p2);       // Same object?
        System.out.println(p1.equals(p2));  // Same values?
        System.out.println(p1.equals(s1));  // Same values?
        System.out.println(p1.equals(p3));  // Same values?


    }
}
```

Test3.java

Example

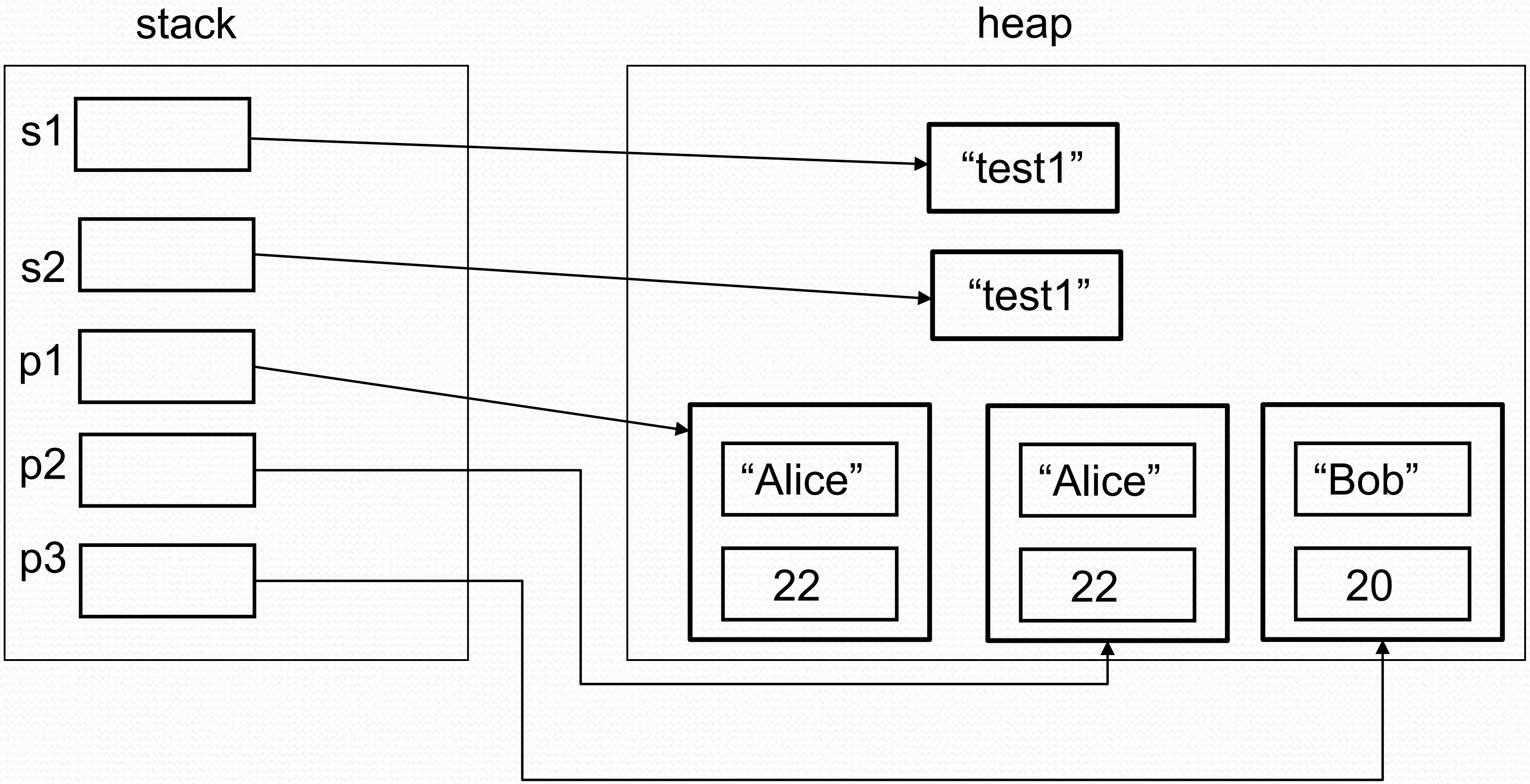
```
String s1 = new String("test1");
String s2 = new String("test1");
```



```
System.out.println(s1 == s2);        // Same object?
System.out.println(s1.equals(s2));   // Same values?
```

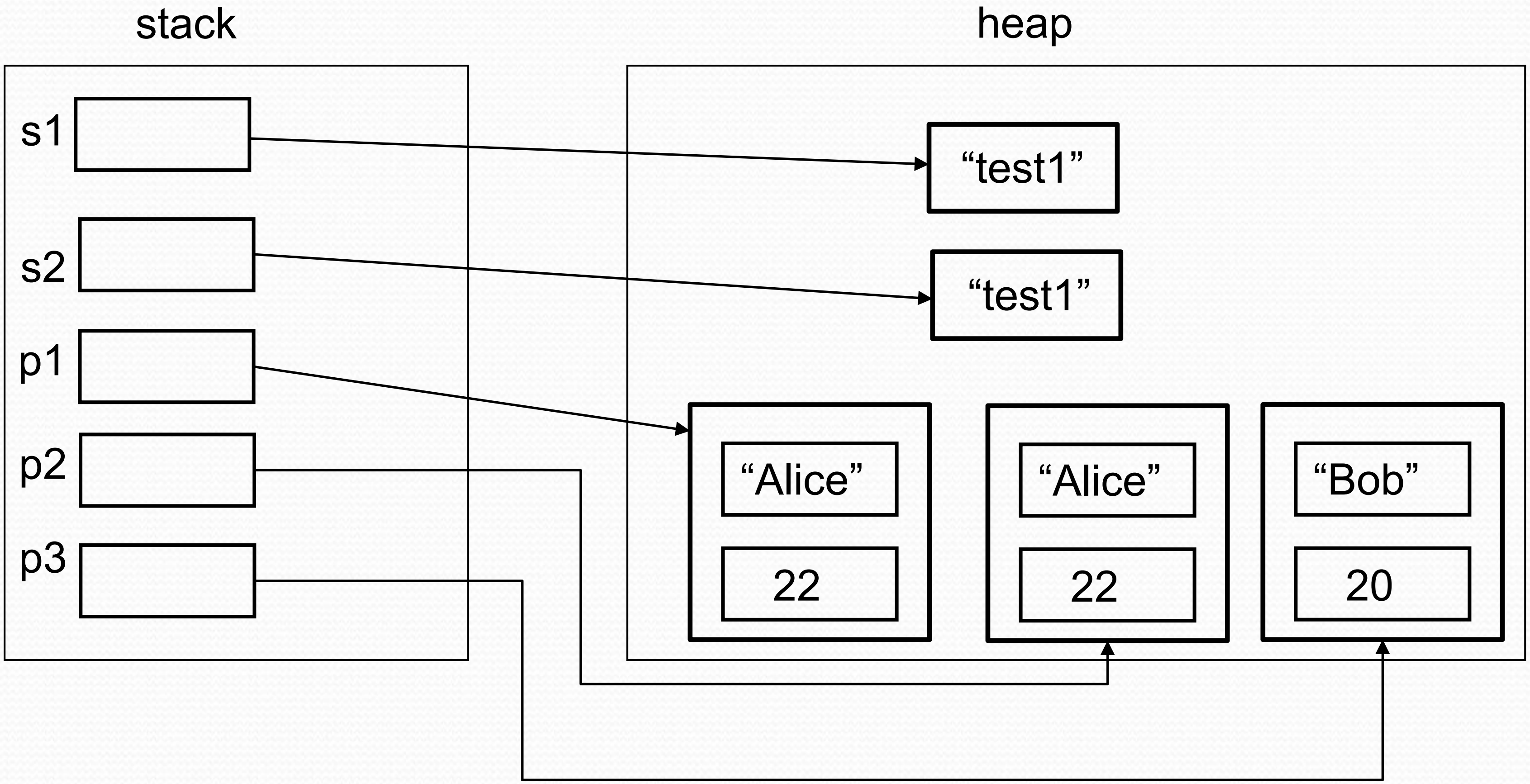
Example

```
Person p1 = new Person("Alice", 22);
Person p2 = new Person("Alice", 22);
Person p3 = new Person("Bob", 20);
```



Example

```
System.out.println(p1 == p2);          // Same object?
System.out.println(p1.equals(p2));    // Same values?
System.out.println(p1.equals(s1));    // Same values?
System.out.println(p1.equals(p3));    // Same values?
```



Dynamic Binding

- Connecting a method call to a method body is called *binding*.
- Automatically selecting the appropriate method at runtime is called dynamic binding or late binding.
- When binding is performed before the program is run (by the compiler, if there is one), it's called early binding.
- All method binding in Java uses late binding unless the method is **static** or **final** (**private** methods are implicitly **final**).

Dynamic Binding

- When the program runs and uses dynamic binding to call a method, then the virtual machine must call the version of the method that is appropriate for the actual type of the object.
  - If the actual type class defines the matched method, then the method is called.
  - Otherwise, the superclass of the actual type class is searched, and so on.
  - Finally, the **Object** class is searched.

```
Person p = new Student("Alice", 22,"UIC");
System.out.println(p.getInfo());
// First, search Student class for getInfo() method
// If not found, search Person class for getInfo() method
```

Dynamic Binding and Method Overriding

- Multiple implementations of the same method occur in different classes along the same hierarchy.
- A child class overrides the implementation of a method provided by its parent class.
- Example:
  `Student.getInfo()` overrides `Person.getInfo()`
- Dynamic binding then uses the first method with the right signature when searching bottom-up in the class hierarchy.

Overriding vs. Overloading

Do not confuse overriding with overloading:

- Overriding takes place in the subclass: a new method with the same name and same signature hides the method inherited from the parent class.
- Overloading takes place in the same class: a new method with the same name but a different signature is defined and does not hide the existing method.
- Note that the method signature consists of the method name and the parameter list

Subtyping Polymorphism

- Subtyping polymorphism: an object from a subclass can be used as if it were an object from a superclass.
  - Also called the *Liskov substitution principle*.
- **`Student`** inherits all the non-private methods of **`Person`**.
- So a **`Student`** object has all the methods necessary to act as a **`Person`** object!
- So Java allows us to use a **`Student`** object in any place where a **`Person`** object would work too.

Example

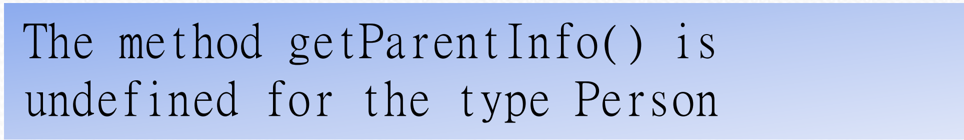
```
public class Test4 {
    public static void main(String arg[]){
        Student s = new Student("Alice", 22, "UIC");
        Person p = s; // Using s as a Person object.
        System.out.println("Person's name: " + p.getName());
        System.out.println("Person's age: " + p.getAge());
        // Student's getInfo method is used, not Person's!
        System.out.println("Person's info: " + p.getInfo());
    }
}
```

```
Person's name: Alice
Person's age: 22
Person's info: Student Alice is 22
and at UIC
```

When calling the `p.getInfo()` method, dynamic binding starts searching in the `Student` class, not in the `Person` class, even though `p` is of type `Person`, because the object really is an object from the `Student` class. So Alice’s school is printed!

Example

```
public class Test4 {
    public static void main(String arg[]){
      Student s = new Student("Alice", 22, "UIC");
      Person p = s; // Using s as a Person object.
        ...
      System.out.println("parent's info:"+ p.getParentInfo());
    }
}
```



```
The method getParentInfo() is
undefined for the type Person
```

The **`Student`** object has a **`getParentInfo`** method but you cannot use this method when using the object with the **`Person`** type, because the **`Person`** class does not have such a method. The type system of Java forbids this, even though **`p`** and **`s`** both refer to the same object!

Example

```
public class Test4 {
    public static void main(String arg[]){
        Student s = new Student("Alice", 22, "UIC");
        Person p = s; // Using s as a Person object.
        ...
        Object o = s; // Using s as an Object object.
        // Person's toString method is used, not Object's!
        System.out.println(o); // Same as:
        System.out.println(o.toString());
    }
}
```

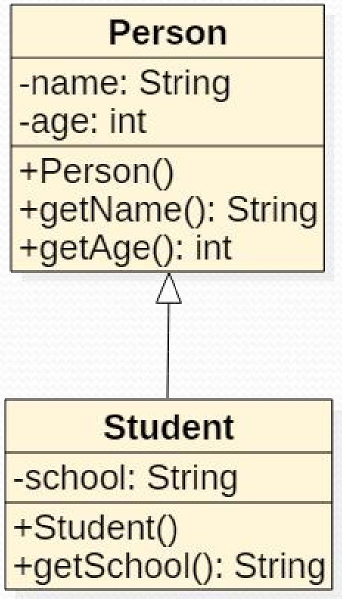
- `Student` is a subclass of `Person` (explicitly) and `Person` is a subclass of `Object` (implicitly), therefore an object from the `Student` class can be used as an object of the `Person` class or as an object of the `Object` class.
- As before, when calling the `o.toString()` method, dynamic binding starts searching in the `Student` class, not in the `Object` class. The `Student` class does not define a `toString` method but the `Person` class does, so method `toString()` of class Person is then called here.

Type Casting

- **Object typecasting** is when the type used for an object is changed, usually by assigning the object to a variable of a different type.
- The cast does not change the object itself, it only changes the type through which the object is used.
- There are two types of casts:
  - Upcast: the type of the object is changed to the type of a superclass.
  - Downcast: the type of the object is changed to the type of a subclass.

Upcast Example

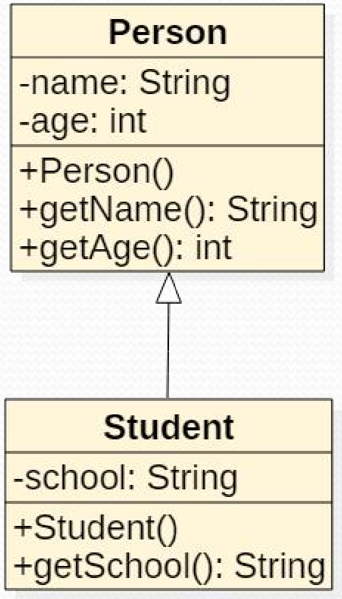
```
public class Test5 {
    public static void main(String arg[]){
        Student s = new Student("Alice", 22, "UIC");
        Person p1 = s; // Implicit upcast.
        // Or:
        Person p2 = (Person)s; // Explicit upcast.
    }
}
```



- The upcast can be implicit (added by Java) or explicit (added by the user).
- All upcasts always work, because of subtyping polymorphism.

Downcast Example

```
public class Test5 {
    public static void main(String arg[]){
        Student s = new Student("Alice", 22, "UIC");
        Person p1 = s; // Implicit upcast.
        // Or:
        Person p2 = (Person)s; // Explicit upcast.
        // Explicit downcast.
        Student s2 = (Student)p1;
    }
}
```



Person

-name: String
-age: int

+Person()
+getName(): String
+getAge(): int

Student

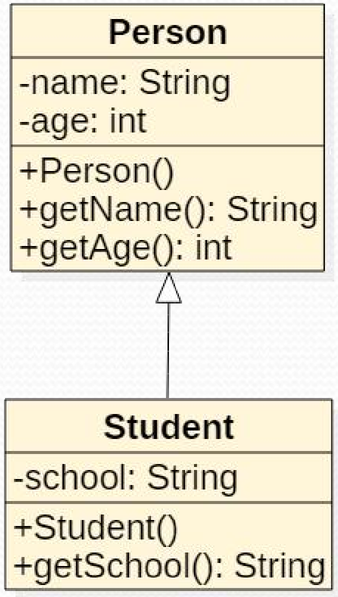
-school: String

+Student()
+getSchool(): String

- The downcast must be explicit (added by the user).
- A downcast only works if an object is downcasted back to its original type after there was an upcast!

Downcast Problem

```
public class Test5 {
    public static void main(String arg[]){
        ......
        Person p = new Person("Alice", 22);
        // Explicit downcast.
        Student s2 = (Student)p;
    }
}
```



- It is not possible to transform a person into a student by doing a downcast from **Person** to **Student**. The Java compiler will accept the downcast but the JVM will detect the problem at runtime and stop the program!
- This is because a **Person** object might not have all the required methods (such as **getSchool**) to work as a **Student** object.

Downcast Problem

```
class Person { ... }
class Student extends Person { ... }
class Teacher extends Person { ... }
...
Student s = new Student("Alice", 22, "UIC");
Person p = s; // Implicit upcast.
Teacher t = (Teacher)p; // Explicit downcast.
```

- It is not possible to transform a student into a teacher by doing an upcast from `Student` to `Person` followed by a downcast from `Person` to `Teacher`. The Java compiler will accept the downcast but the JVM will detect the problem at runtime and stop the program!
- This is because a `Student` object might not have all the required methods to work as a `Teacher` object.

Summary

- `final` modifier
- `Object` class
- `instanceof` operator
- `toString` and `equals` methods
- Dynamic binding
- Subtyping polymorphism
- Type casting: upcasts and downcasts