The central new idea in object-oriented programming -- the idea that really distinguishes it from traditional programming -- is to allow classes to express the similarities among objects that share some, but not all, of their structure and behavior.

**has-a Relationship**

```java
class Student {
    private String name;
    private Date dateOfBirth;
    ...
}
• a Student has-a String for its name
• a Student has-a Date for its dateOfBirth
```

**In UML Terms**

```
<table>
<thead>
<tr>
<th>Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
</tr>
<tr>
<td>ssn</td>
</tr>
<tr>
<td>dateOfBirth</td>
</tr>
<tr>
<td>address</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>String name</td>
</tr>
<tr>
<td>Date dateOfBirth</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>
```

**Terminology for Inheritance**

The term inheritance refers to the fact that one class can inherit part or all of its structure and behavior from another class. A subclass is created by using the extends keyword in the subclass signature.

- parent class → child class
- superclass ← subclass
- base class ← derived class
Syntax to Set Up Inheritance

- class Student extends Person
  Makes an object of Student class to also be an object of Person class.

is-a Relationship

- a Student is-a Person
- Every Student object is also a Person object.
- Class Student inherits non-private data & methods from Class Person.

Inheritance Promotes Software Reuse

- Start with a class to which you want to add fields/methods.
- Extend that class and add additional capabilities to the subclasses.
- Classes that are specified as final cannot be extended.

Programmer Decisions

- What methods and variables of the parent class can the child class see?
- What if the child wants to add a method or variable with the same name as a method or variable of the parent? Method overloading

Why Not Modify Existing Code...

...instead of subclassing?
- Source code may not be available to us and the implementation may be difficult to understand.
- Our changes could break the existing code.

Smaller Example of subclassing

<table>
<thead>
<tr>
<th>Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>String name</td>
</tr>
<tr>
<td>Person(String)</td>
</tr>
<tr>
<td>String toString()</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>String major</td>
</tr>
<tr>
<td>Student(String,String)</td>
</tr>
<tr>
<td>String toString()</td>
</tr>
</tbody>
</table>
**Simple Person class**

class Person
{
   protected String name;
   public Person ( String name )
   {
      this.name = name;
   }
   public String toString() { return name; }
}

**Another Person class**

class Person
{
   // name is non-accessible, even from subclasses
   private String name;
   public String toString()
   {
      return name;
   }
}

• Use the parent’s constructor to initialize parent variables (in a subclass, this will be a call to super() with zero or more parameters).

• Inside a subclass constructor, a call to the superclass constructor must be the first line. If not, there will be an error.

public class Student extends Person {
   private String major; // added field in subclass
   public Student ( String name, String major )
   {
      super(name); // call to Person constructor
      this.major = major;
   }
   public String toString()
   {
      return this.name + " (" + this.major + ")";
   }
}

**Object — The Top of All Hierarchies**

Every class is a subclass of the Object class (i.e., extends the Object class). Inherited methods include:

• public String toString()
• public boolean equals(Object)
Overriding vs Overloading

• Don't confuse overriding with overloading.

• Can anyone tell me the difference?

Single vs Multiple Inheritance

• Java allows only single inheritance, i.e., a subclass can extend only one superclass.

class Animal
class Dog extends Animal
class Cat extends Animal
class Human extends Animal
class Mime extends Human

• Each has
  public void speak()

public void speak() in each class contains the single print statement:

  • Animal:
    System.out.println("* generic animal noise *");
  • Dog:
    System.out.println("woof");
  • Cat:
    System.out.println("meow");
  • Human:
    System.out.println("hello");
  • Mime:
    System.out.println();

Animal [] animals = new Animal[MAX];
animals[0] = new Dog();
animals[1] = new Cat();
animals[2] = new Human();
animals[3] = new Dog();
animals[4] = new Mime();
animals[5] = new Cat();
animals[6] = new Animal();
for ( int i = 0 ; i < MAX ; i++ )
  {
    animals[i].speak();
  }
Motivation for Abstract Classes

• We shouldn’t instantiate Animal — The class is too generic!
• Let’s make Animal an abstract class.

abstract class Animal
{
    //-------------------------------
    abstract public void speak();
    //-------------------------------
}

Animal[] animals = new Animal[MAX];
animals[0] = new Dog();
animals[1] = new Cat();
animals[2] = new Human();
animals[3] = new Dog();
animals[4] = new Mime();
animals[5] = new Cat();
animals[6] = new Cat();

Interfaces

• Java only allows single inheritance, so a subclass can only have one superclass, including abstract classes.
• Interfaces can be used to achieve most of the effects of multiple inheritance. A class that implements an interface is a subtype of the interface.

Interfaces

Interfaces are like abstract classes, but they can contain no method bodies, only method stubs.

Classes that implement an interface are required to provide full method bodies for each method stub in the interface.

Interfaces

Interfaces can be a data type for a declared variable, but the instantiated type must be a subtype of the interface.

Classes can implement any number of interfaces and they must have method bodies for all method stubs in the interface.
Interfaces

Because of the inheritance model Java provides, an object can have multiple data types.

Structural recursion in Java

Recall the definition of a list in Scheme:
A list of integers (IList) is either:
– empty, or it is a
– constructed list, formed by using (cons int LON), where LON is an IList.

We can make a similar structure in Java using an Interface:

```java
public interface IList {
    // stub for method to return length of this IList
    public int length();
    // stub for method to sum all integers in this IList
    public int sum();
}
```

Structural recursion in Java

A subtype of interface IList to represent a constructed list:

```java
public class ConsList implements IList {
    int first;
    IList rest;
    // fully implemented method returns length of this IList
    public int length() {
        return 1 + this.rest.length();
    }
    // fully implemented method returns sum of numbers in this IList
    public int sum() {
        return this.first + this.rest.sum();
    }
}
```

Structural recursion in Java

A subtype of interface IList to represent an empty list:

```java
public class MTList implements IList {
    // implementation of length method for empty list
    public int length() {
        return 0;
    }
    // implementation of sum method for empty list
    public int sum() {
        return 0;
    }
}
```