Using Inheritance

Interactive Quizzes

Before you start today's lessons, test your knowledge by answering some quiz questions that relate to yesterday's lessons. Open the Quiz files by clicking the quizzes.html shortcut from the desktop of your VM. In the welcome page, JavaSEProgrammingI.html, click the links for Lessons 9, 10, and 11.

Objectives

After completing this lesson, you should be able to:

- Define inheritance in the context of a Java class hierarchy
- Create a subclass
- Override a method in the superclass
- Use the `super` keyword to reference the superclass
- Define polymorphism
- Use the `instanceof` operator to test an object's type
- Cast a superclass reference to the subclass type
- Explain the difference between abstract and non-abstract classes
- Create a class hierarchy by extending an abstract class

Duke’s Choice Classes: Common Behaviors

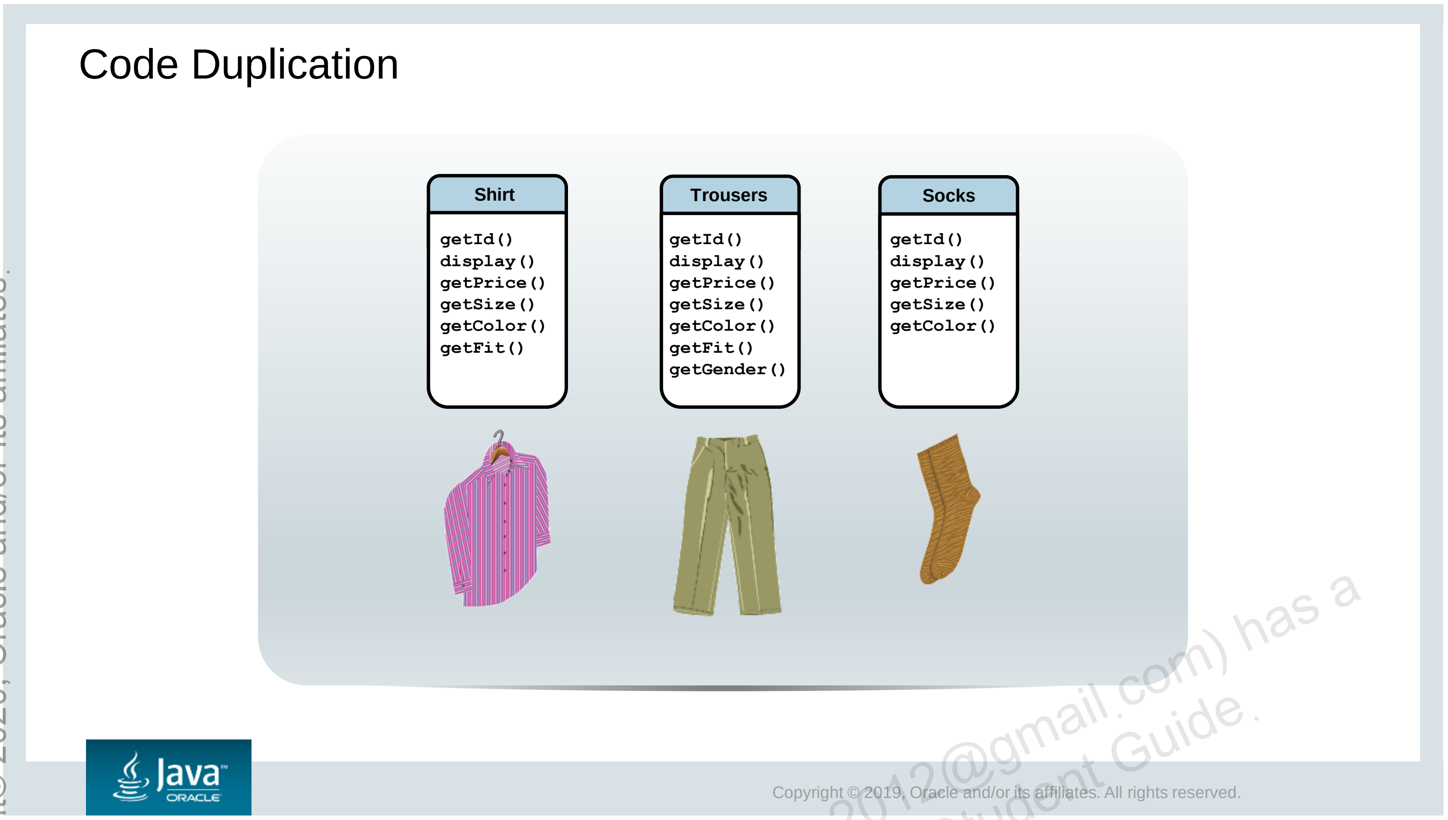
Shirt	Trousers

getId()
getPrice()
getSize()
getColor()
getFit()
	getId()
	getPrice()
	getSize()
	getColor()
	getFit()
	getGender()

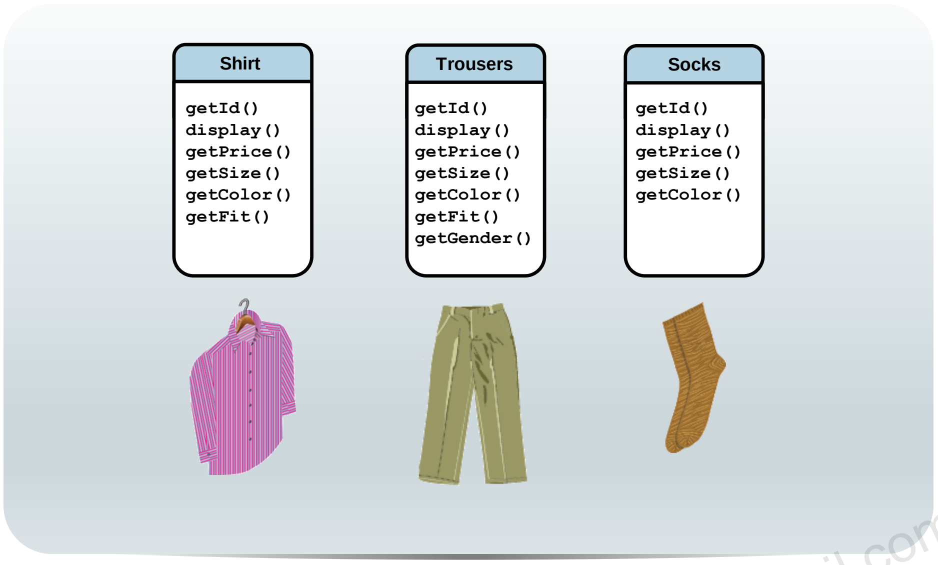
setId()
setPrice()
setSize()
setColor()
setFit()
	setId()
	setPrice()
	setSize()
	setColor()
	setFit()
	setGender()

display()	display()

The table in the slide shows a set of behaviors for some classes belonging to the Duke’s Choice shopping cart application, the `Shirt` class and the `Trousers` class. The classes are shown fully encapsulated so that all field values are accessible only through setter and getter methods. Notice how both classes use many of the same methods; this may result in code duplication, making maintenance and further expansion more difficult and error-prone.



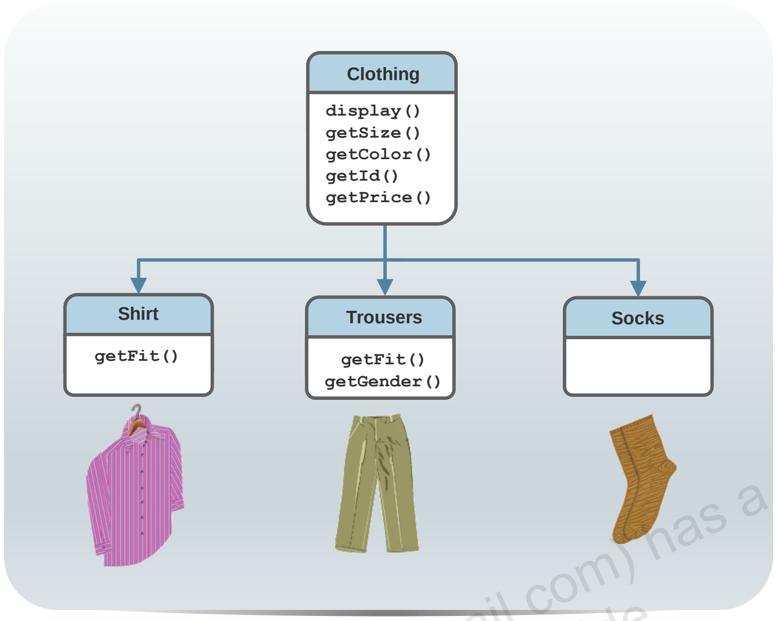
Code Duplication



If Duke's Choice decides to add a third item, socks, as well as trousers and shirts, you may find even greater code duplication. The diagram in the slide shows only the getter methods for accessing the properties of the new objects.

Inheritance

- **Inheritance** allows one class to be derived from another.
- Fields and methods are written in one class, and then inherited by other classes.
  - There is less code duplication.
  - Edits are done in one location



You can eliminate code duplication in the classes by implementing inheritance. Inheritance enables programmers to put common members (fields and methods) in one class (the superclass) and have other classes (the subclasses) inherit these common members from this new class.

An object instantiated from a subclass behaves as if the fields and methods of the subclass were in the object. For example,

- The `Clothing` class can be instantiated and have the `getId` method called, even though the `Clothing` class does not contain `getId`. It is inherited from the `Item` class.
- The `Trousers` class can be instantiated and have the `display` method called even though the `Trousers` class does not contain a `display` method; it is inherited from the `Clothing` class.
- The `Shirt` class can be instantiated and have the `getPrice` method called, even though the `Shirt` class does not contain a `getPrice` method; it is inherited from the `Clothing` class.

Inheritance Terminology

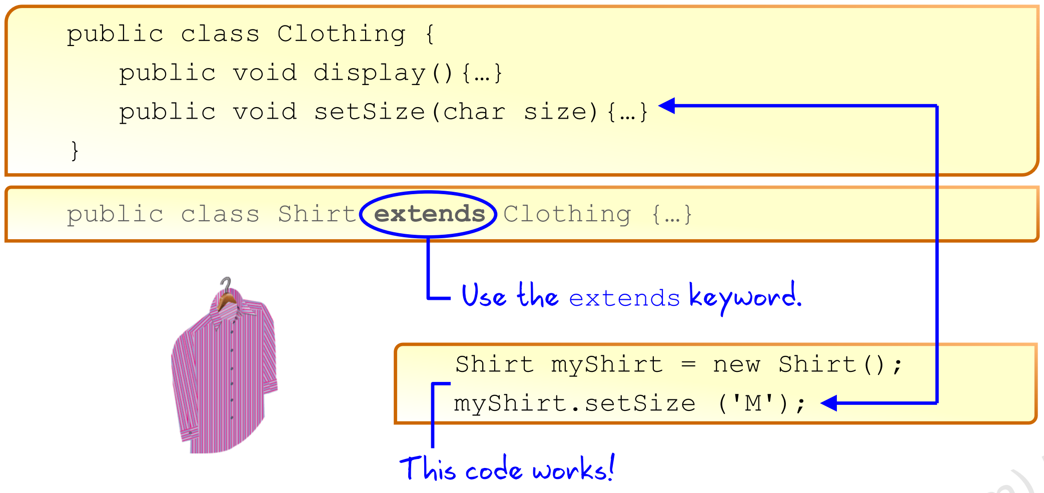
- The term inheritance is inspired by biology
  - A child inherits properties and behaviors of the parent.
  - A child *class* inherits the fields and method of a parent *class.*
- The parent class is known as the **superclass**.
  - A superclass is the common location for fields and methods.
- The child class is known as the **subclass**. A subclass extends its superclass.
  - Subclasses share the same methods as the superclass.
  - Subclasses may have additional methods that aren't found in their superclass.
  - Subclasses may override the methods they inherit from their superclass.

Inheritance is a mechanism by which a class can be derived from another class, just as a child derives certain characteristics from the parent.

Topics

- Overview of inheritance
- Working with superclasses and subclasses
- Overriding superclass methods
- Introducing polymorphism
- Creating and extending abstract classes

Implementing Inheritance



```
public class Clothing {
    public void display(){…}
    public void setSize(char size){…}
}
```

```
public class Shirt extends Clothing {…}
```

```
Shirt myShirt = new Shirt();
myShirt.setSize ('M');
```

In the code example above, an inheritance relationship between the `Shirt` class and its parent, the `Clothing` class, is defined. The keyword `extends` creates the inheritance relationship:

```
public class Shirt extends Clothing…
```

As a result, `Shirt` objects share the `display` and `setSize` methods of the `Clothing` class. Although these methods are not actually written in the `Shirt` class, they may be used by all `Shirt` objects. Therefore, the following code can be successfully compiled and run:

```
Shirt myShirt = new Shirt();
myShirt.setSize('M');
```

More Inheritance Facts

- A subclass has access to all of the public fields and methods of its superclass.
- A subclass may have unique fields and methods not found in the superclass.

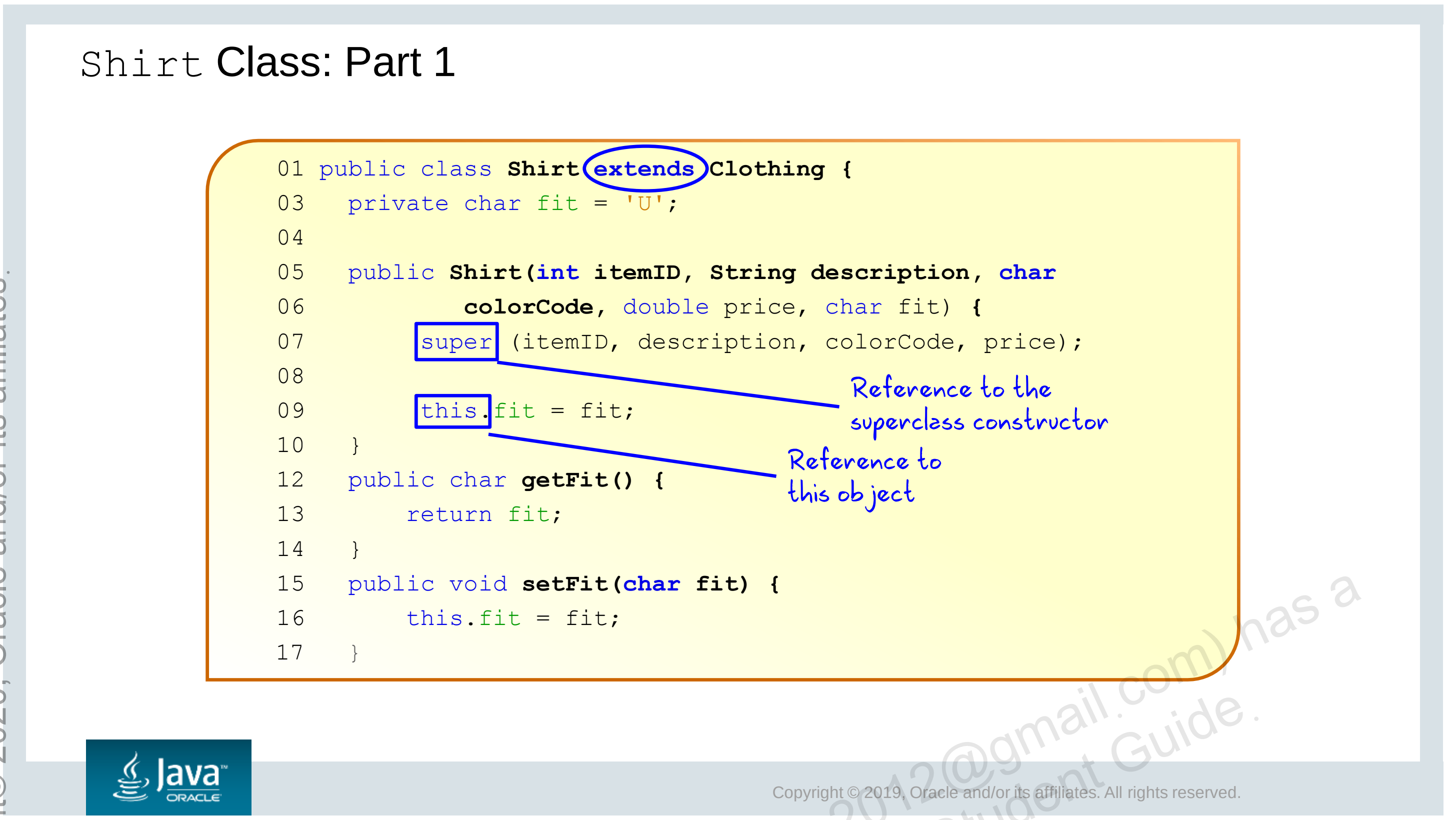
```
                 subclass         superclass
public class Shirt extends Clothing {
    private int neckSize;
    public int getNeckSize(){
        return neckSize;
    }
    public void setNeckSize(int nSize){
        this.neckSize = nSize;
    }
}
```

The subclass not only has access to all of the public fields and methods of the superclass, but it can also declare additional fields and methods that are specific to its own requirements.

Clothing Class: Part 1

```
public class Clothing {
  // fields given default values
  private int itemID = 0;
  private String desc = "-description required-";
  private char colorCode = 'U';
  private double price = 0.0;

  // Constructor
  public Clothing(int itemID, String desc, char color,
     double price ) {
      this.itemID = itemID;
      this.desc = desc;
      this.colorCode = color;
      this.price = price;
  }
}
```

The code in the slide shows the fields and the constructor for the Clothing superclass.



Shirt Class: Part 1

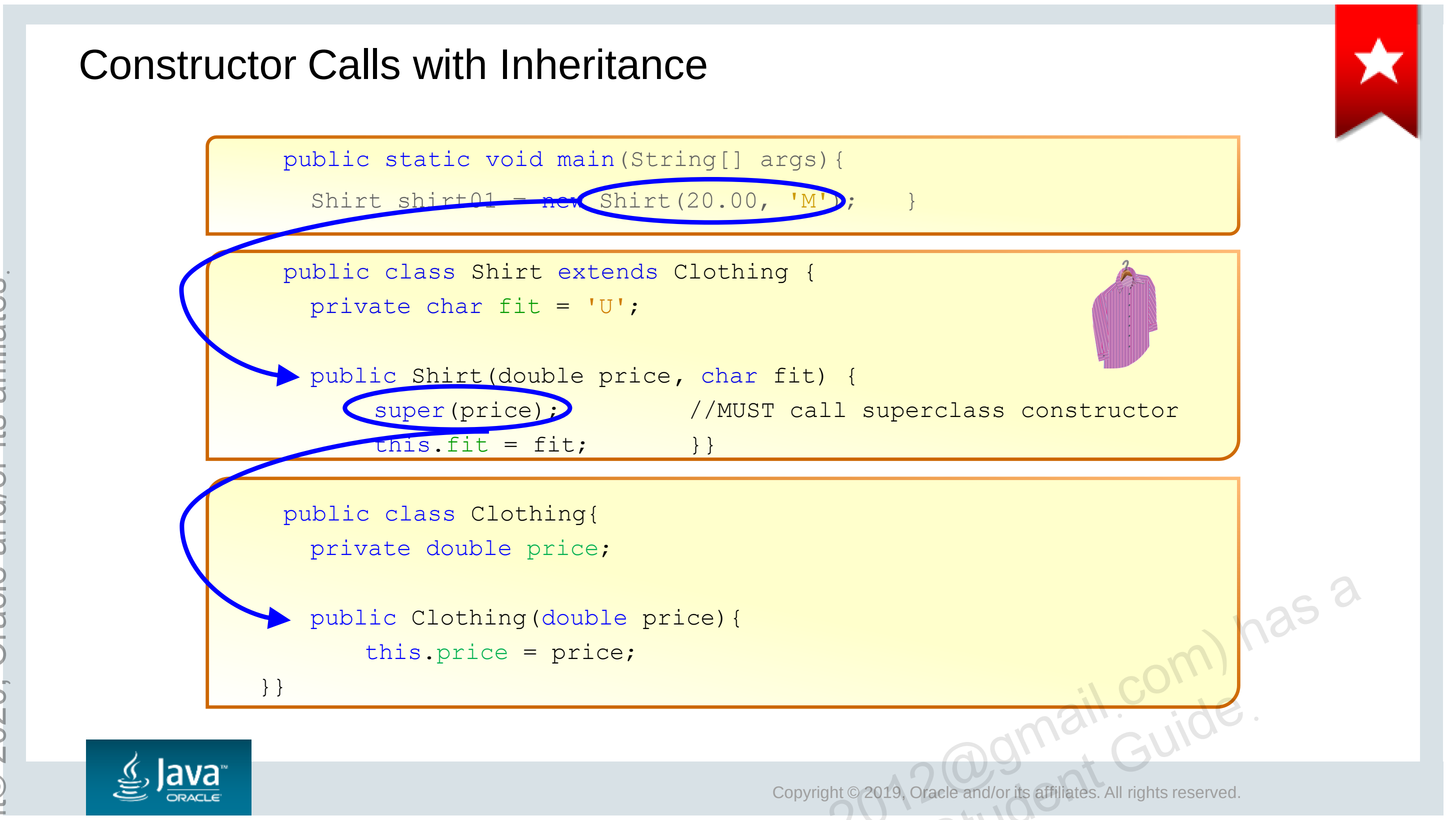
```
public class Shirt extends Clothing {
  private char fit = 'U';

  public Shirt(int itemID, String description, char
          colorCode, double price, char fit) {
      super (itemID, description, colorCode, price);

      this.fit = fit;
  }
  public char getFit() {
      return fit;
  }
  public void setFit(char fit) {
      this.fit = fit;
  }
```

Reference to the superclass constructor

Reference to this object

The slide shows the code of the `Shirt` subclass. As you have seen in an earlier example, the `extends` keyword enables the `Shirt` class to inherit all the members of the `Clothing` class. The code declares attributes and methods that are unique to this class. Attributes and methods that are common with the `Clothing` class are inherited and do not need to be declared. It also includes two useful keywords and shows a common way of implementing constructors in a subclass.

- `super` refers to the superclass. In the example in the slide, the `super` keyword is used to invoke the constructor on the superclass. By using this technique, the constructor on the superclass can be invoked to set all the common attributes of the object being constructed. Then, as in the example here, additional attributes can be set in following statements.
- `this` refers to the current object instance. The only additional attribute that `Shirt` has is the `fit` attribute, and it is set after the invocation of the superclass constructor. The `this` keyword is necessary here as the constructor method parameter is also named `fit`). However, even when not strictly necessary, it is good programming practice because it makes the code more readable.



Constructor Calls with Inheritance

```
public static void main(String[] args){
  Shirt shirt01 = new Shirt(20.00, 'M');    }
```

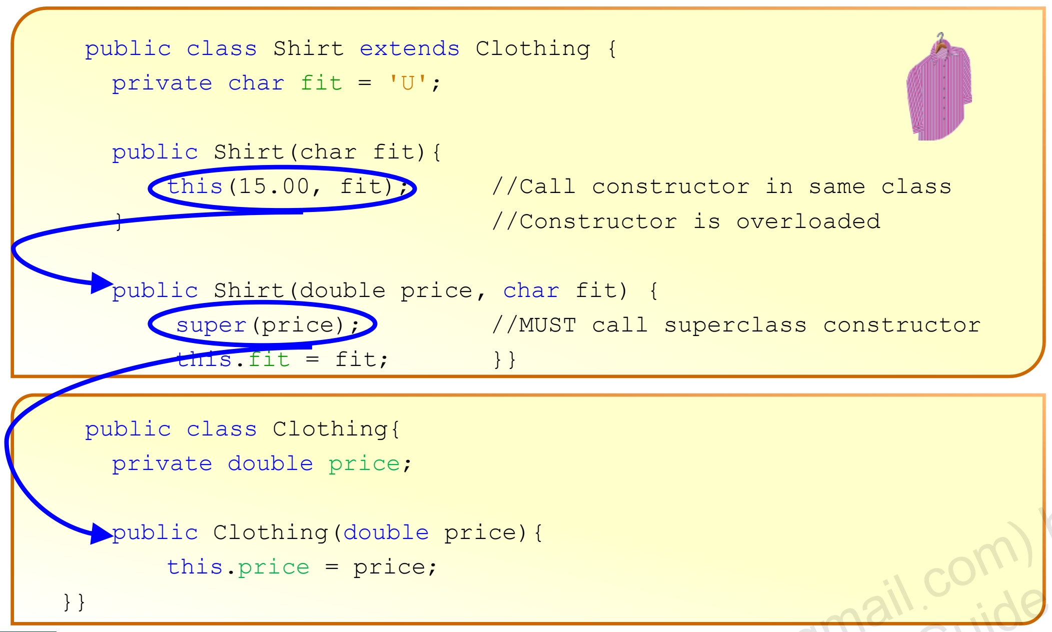
```
public class Shirt extends Clothing {
  private char fit = 'U';

  public Shirt(double price, char fit) {
      super(price);         //MUST call superclass constructor
      this.fit = fit;       }}
```

```
public class Clothing{
  private double price;

  public Clothing(double price){
      this.price = price;
}}
```

Within the constructor of a subclass, you must call the constructor of the superclass. If you call a superclass constructor, the call must be the first line of your constructor. This is done using the keyword `super`, followed by the arguments to be passed to the superclass constructor.

The constructor of the subclass sets variables that are unique to the subclass. The constructor of the superclass sets variables that originate from the superclass.

Inheritance and Overloaded Constructors



```
public class Shirt extends Clothing {
  private char fit = 'U';

  public Shirt(char fit){
      this(15.00, fit);      //Call constructor in same class
  }                          //Constructor is overloaded

  public Shirt(double price, char fit) {
      super(price);          //MUST call superclass constructor
      this.fit = fit;        }}
```

```
public class Clothing{
  private double price;

  public Clothing(double price){
      this.price = price;
}}
```

Use the `this` keyword to call another constructor within the same class. This is how you call an overloaded constructor.

Use the `super` keyword to call a constructor in the superclass. When you have overloaded subclass constructors, all of your constructors must eventually lead to the superclass constructor. If you call a superclass constructor, the call must be the first line of your constructor.

If your superclass constructors are overloaded, Java will know which superclass constructor you are calling based on the number, type, and order of arguments that you supply.

Exercise 12-1: Creating a Subclass, Part 1

1. Open the project **Exercise_12-1**.
2. Examine the Item class. Pay close attention to the overloaded constructor and also the display method.
3. In the **exercise_12_1** package, create a new class called Shirt that inherits from Item.
4. In the Shirt class, declare two private char fields: size and colorCode.
5. Create a constructor method that takes 3 args (price, size, colorCode). The constructor should:
   - Call the 2-arg constructor in the superclass
     - Pass a String literal for the desc arg ("Shirt").
     - Pass the price argument from this constructor.
   - Assign the size and colorCode fields.

In this exercise, you create the Shirt class, which extends the Item class.

Exercise 12-1: Creating a Subclass, Part 2

In the `ShoppingCart` class:

6. Declare and instantiate a `Shirt` object, using the 3-arg constructor.
7. Call the `display` method on the object reference.
   – Notice where the `display` method is actually coded.

In this exercise, you create the `Shirt` class, which extends the Item class.

Topics

- Overview of inheritance
- Working with superclasses and subclasses
- Overriding superclass methods
- Introducing polymorphism
- Creating and extending abstract classes

More on Access Control

Access level modifiers determine whether other classes can use a particular field or invoke a particular method

- At the top level—public, or *package-private* (no explicit modifier).
- At the member level—public, private, protected, or *package-private* (no explicit modifier).

Stronger access privileges

Modifier	Class	Package	Subclass	World
`public`	Y	Y	Y	Y
`protected`	Y	Y	Y	N
No modifier	Y	Y	N	N
`private`	Y	N	N	N

In the diagram, the first data column indicates whether the class itself has access to the member defined by the access level. As you can see, a class always has access to its own members. The second column indicates whether classes in the same package as the class (regardless of their parentage) have access to the member. The third column indicates whether subclasses of the class declared outside this package have access to the member. The fourth column indicates whether all classes have access to the member

Note: packages will be covered in greater detail in lesson titled “Deploying and Maintaining the Soccer Application”.

Overriding Methods

Overriding: A subclass implements a method that already has an implementation in the superclass.

Access Modifiers:

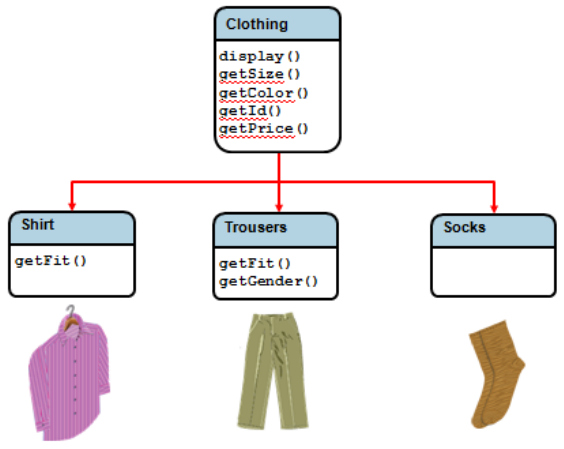
- The method can only be overridden if it is accessible from the subclass
- The method signature in the subclass cannot have a more restrictive (stronger) access modifier than the one in the superclass

Subclasses may implement methods that already have implementations in the superclass. In this case, the methods in the subclass are said to override the methods from the superclass.

- For example, although the `colorCode` field is in the superclass, the color choices may be different in each subclass. Therefore, it may be necessary to override the accessor methods (getter and setter methods) for this field in the individual subclasses.
- Although less common, it is also possible to override a field that is in the superclass. This is done by simply declaring the same field name and type in the subclass.

Review: Duke's Choice Class Hierarchy

Now consider these classes in more detail.



Clothing Class: Part 2

```
public void display() {
  System.out.println("Item ID: " + getItemID());
  System.out.println("Item description: " + getDesc());
  System.out.println("Item price: " + getPrice());
  System.out.println("Color code: " + getColorCode());
}
public String getDesc (){
    return desc;
}
public double getPrice() {
    return price;
}
public int getItemID() {
    return itemID;
}
protected void setColorCode(char color){
    this.colorCode = color; }
```

Assume that the remaining get/set methods are included in the class.

The code in the slide shows the display method for the `Clothing` superclass and also some of the getter methods and one of the setter methods. The remaining getter and setter methods are not shown here.

Of course, this `display` method prints out only the fields that exist in `Clothing`. You would need to override the `display` method in `Shirt` in order to display all of the `Shirt` fields.

Shirt Class: Part 2

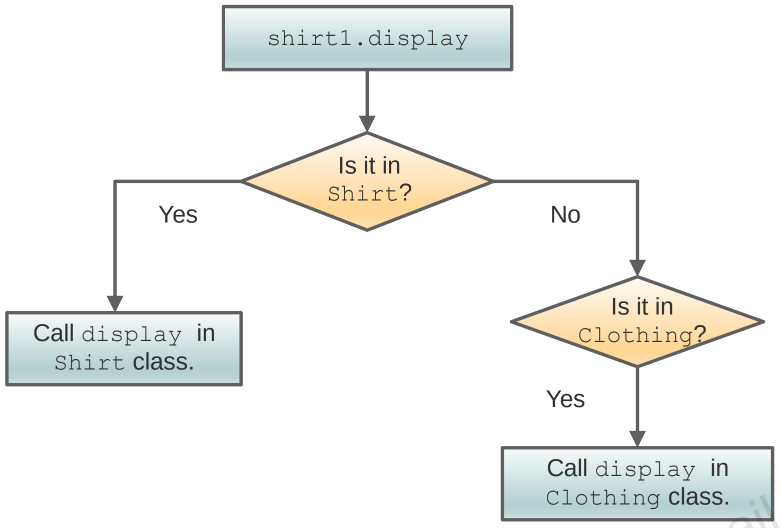
```java
// These methods override the methods in Clothing
public void display() {
    System.out.println("Shirt ID: " + getItemID());
    System.out.println("Shirt description: " + getDesc());
    System.out.println("Shirt price: " + getPrice());
    System.out.println("Color code: " + getColorCode());
    System.out.println("Fit: " + getFit());
}

protected void setColorCode(char colorCode) {
    //Code here to check that correct codes used
    super.setColorCode(colorCode);
}
}
```

Call the superclass's version of setColorCode.

Notice that the `display` method overrides the `display` method of the superclass and is more specific to the `Shirt` class because it displays the shirt's fit property.

- The `Shirt` class does not have access to the private fields of the `Clothing` class such as `itemID`, `desc`, and `price`. The `Shirt` class's `display` method must, therefore, call the public getter methods for these fields. The getter methods originate from the `Clothing` superclass.
- The `setColorCode` method overrides the `setColorCode` method of the superclass to check whether a valid value is being used for this class. The method then calls the superclass version of the very same method.

Overriding a Method: What Happens at Run Time?



The `shirt01.display` code is called. The Java VM:

- Looks for `display` in the `Shirt` class
  - If it is implemented in `Shirt`, it calls the `display` in `Shirt`.
  - If it is not implemented in `Shirt`, it looks for a parent class for `Shirt`.
- If there is a parent class (Clothing in this case), it looks for `display` in that class.
  - If it is implemented in `Clothing`, it calls `display` in `Clothing`
  - If it is not implemented in `Clothing`, it looks for a parent class for `Clothing`... and so on.

This description is not intended to exactly portray the mechanism used by the Java VM, but you may find it helpful in thinking about which method implementation gets called in various situations.

Exercise 12-2: Overriding a Method in the Superclass

1. Open **`Exercise_12-2`** or continue editing **`Exercise_12-1`**.

In the `Shirt` class:

2. Override the `display` method to do the following:
   - Call the superclass's display method.
   - Print the `size` field and the `colorCode` field.
3. Run the code. Do you see a different display than you did in the previous exercise?

In this exercise, you override a method the `display` method to show the additional fields from the `Shirt` class.

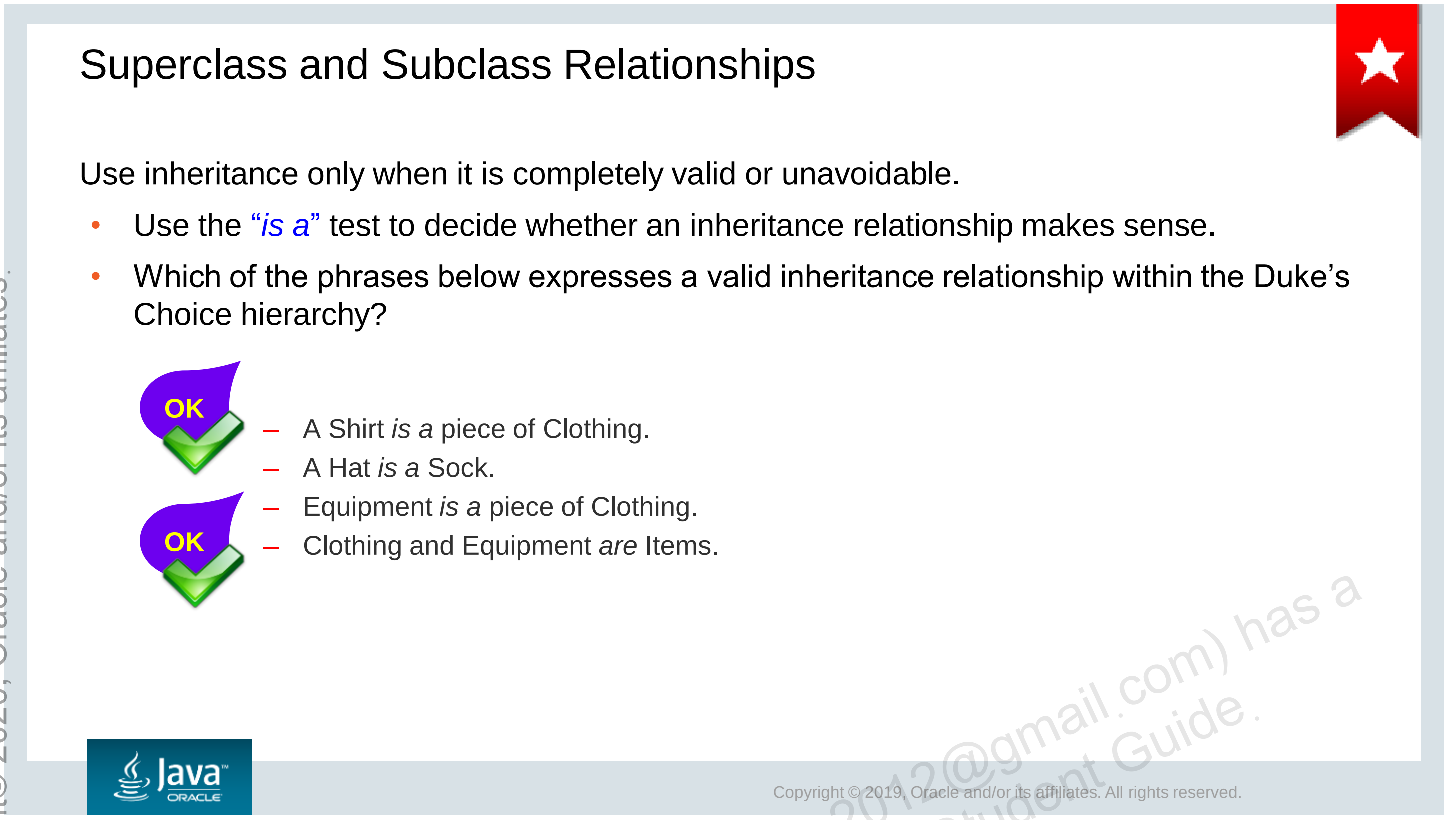
Topics

- Overview of inheritance
- Working with superclasses and subclasses
- Overriding superclass methods
- Introducing polymorphism
- Creating and extending abstract classes

Polymorphism

- Polymorphism means that the same message to two different objects can have different results.
  - “Good night” to a child means “Start getting ready for bed.”
  - “Good night” to a parent means “Read a bedtime story.”
- In Java, it means the same method is implemented differently by different classes.
  - This is especially powerful in the context of inheritance.
  - It relies upon the “is a” relationship.

You already used polymorphism when you overrode a method in the superclass, thereby allowing two classes to have the same method name but with a different outcome. In this lesson, we will examine this relationship in more detail and also introduce some other ways of implementing polymorphism.



Superclass and Subclass Relationships

Use inheritance only when it is completely valid or unavoidable.

- Use the *"is a"* test to decide whether an inheritance relationship makes sense.
- Which of the phrases below expresses a valid inheritance relationship within the Duke's Choice hierarchy?
  - [✓ A Shirt *is a* piece of Clothing.]
  - A Hat *is a* Sock.
  - Equipment *is a* piece of Clothing.
  - [✓ Clothing and Equipment *are* Items.]

In this lesson, you have explored inheritance through an example:

- In the Duke's Choice shopping cart, shirts, trousers, hats, and socks are all types of clothing. So `Clothing` is a good candidate for the superclass to these subclasses (types) of clothing.
- Duke's Choice also sells equipment, but a piece of equipment is *not* a piece of clothing. However, clothing and equipment are both items, so `Item` would be a good candidate for a superclass for these classes.

Using the Superclass as a Reference

So far, you have referenced objects only with a reference variable of the same class:

- To use the `Shirt` class as the reference type for the `Shirt` object:

```
Shirt myShirt = new Shirt();
```

- But you can also use the superclass as the reference:

```
Clothing garment1 = new Shirt();
Clothing garment2 = new Trousers();
```

Shirt is a (type of) Clothing.
Trousers is a (type of) Clothing.

A very important feature of Java is this ability to use not only the class itself but any superclass of the class as its reference type. In the example shown in the slide, notice that you can refer to both a `Shirt` object and a `Trousers` object with a `Clothing` reference. This means that a reference to a `Shirt` or `Trousers` object can be passed into a method that requires a `Clothing` reference. Or a `Clothing` array can contain references to `Shirt`, `Trousers`, or `Socks` objects as shown below.

- `Clothing[] clothes = {new Shirt(), new Shirt(), new Trousers(), new Socks()};`

Polymorphism Applied

```
Clothing c1 = new ??();

c1.display();
c1.setColorCode('P');
```

c1 could be a Shirt, Trousers, or Socks object.

The method will be implemented differently on different types of objects. For example:

- Trousers objects show more fields in the display method.
- Different subclasses accept a different subset of valid color codes.

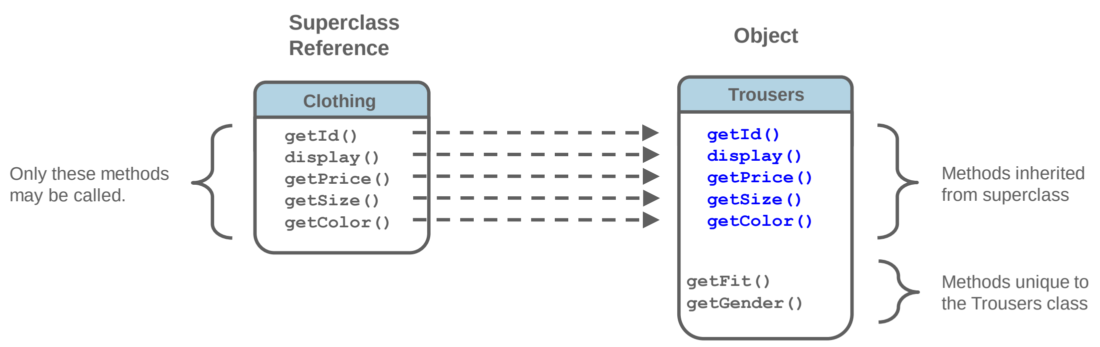
Polymorphism is achieved by invoking one of the methods of the superclass—in this example, the `Clothing` class.

This is a polymorphic method call because the runtime engine does not know, or *need* to know, the type of the object (sometimes called the *runtime* type). The correct method—that is, the method of the actual object—will be invoked.

In the example in the slide, the object could be any subclass of `Clothing`. Recall that some of the subclasses of `Clothing` implemented the `display` and `setColorCode` methods, thereby overriding those methods in the `Clothing` class.

Here you begin to see the benefits of polymorphism. It reduces the amount of duplicate code, and it allows you to use a common reference type for different (but related) subclasses.

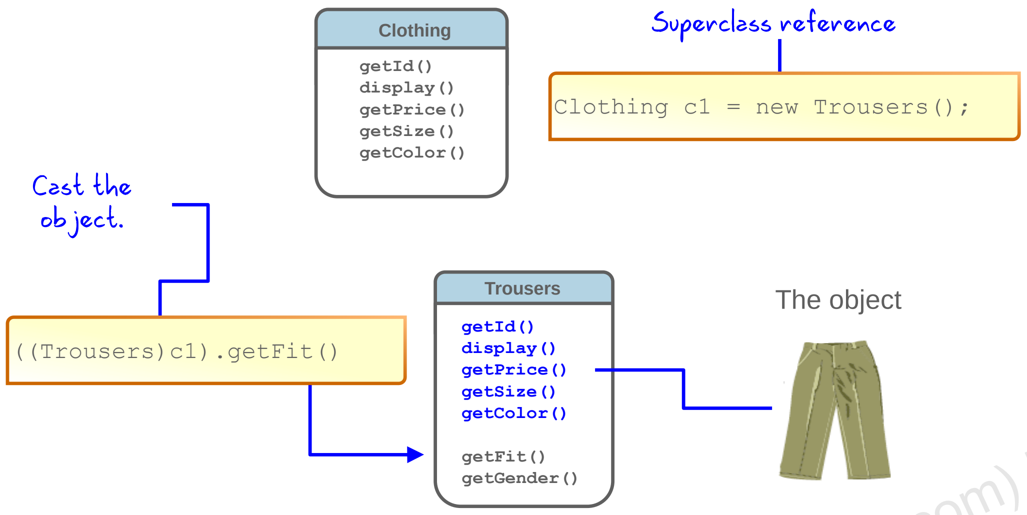
Accessing Methods Using a Superclass Reference



```
Clothing c1 = new Trousers();
c1.getId();   OK
c1.display(); OK
c1.getFit();  NO!
```

Using a reference type `Clothing` does not allow access to the `getFit` or `getGender` method of the `Trousers` object. Usually this is not a problem, because you are most likely to be passing `Clothing` references to methods that do not require access to these methods. For example, a `purchase` method could receive a `Clothing` argument because it needs access only to the `getPrice` method.

Casting the Reference Type



Given that a superclass may not have access to all the methods of the object it is referencing, how can you access those methods? The answer is that you can do so by replacing the superclass reference with:

- A reference that is the same type as the object. The code in this example shows a `Clothing` reference being cast to a `Trousers` reference to access the `getFit` method, which is not accessible via the `Clothing` reference. Note that the inner parentheses around `Trousers` are part of the cast syntax, and the outer parentheses around `(Trousers)c1` are there to apply the cast to the `Clothing` reference variable. Of course, a `Trousers` object would also have access to the nonprivate methods and fields in its superclass.
- An Interface that declares the methods in question and is implemented by the class of the object. Interfaces are covered in the next lesson.

instanceof Operator

Possible casting error:

```
public static void displayDetails(Clothing cl) {

   cl.display();
   char fitCode = ((Trousers)cl).getFit();
   System.out.println("Fit: " + fitCode);
}
```

What if cl is not a Trousers object?

instanceof operator used to ensure there is no casting error:

```
public static void displayDetails(Clothing cl) {
   cl.display();
   if (cl instanceof Trousers) {
       char fitCode = ((Trousers)cl).getFit();
       System.out.println("Fit: " + fitCode);
   }
   else { // Take some other action }
```

instanceOf returns true if cl is a Trousers object.

The first code example in the slide shows a method that is designed to receive an argument of type `Clothing`, and then cast it to `Trousers` to invoke a method that exists only on a `Trousers` object. But it is not possible to know what object type the reference, `cl`, points to. And if it is, for example, a `Shirt`, the attempt to cast it will cause a problem. (It will throw a `ClassCastException`. Throwing exceptions is covered in the lesson titled "Handling Exceptions.")

You can code around this potential problem with the code shown in the second example in the slide. Here the `instanceof` operator is used to ensure that `cl` is referencing an object of type `Trousers` before the cast is attempted.

If you think your code requires casting, be aware that there are often ways to design code so that casting is not necessary, and this is usually preferable. But if you do need to cast, you should use `instanceof` to ensure that the cast does not throw a `ClassCastException`.

Exercise 12-3: Using the `instanceof` Operator, Part 1

1. Open **`Exercise_12-3`** or continue editing **`Exercise_12-2`**.

In the `Shirt` class:

2. Add a public `getColor` method that converts the `colorCode` field into the corresponding color name:
   - Example: 'R' = "Red"
   - Include at least 3 colorCode/color combinations.
3. Use a `switch` statement in the method and return the color String.

In this exercise, you use the `instanceof` operator to test the type of an object before casting it to that type.

Exercise 12-3: Using the `instanceof` Operator, Part 2

In the `ShoppingCart` class:

4. Modify the `Shirt` object's declaration so that it uses an `Item` reference type instead.
5. Call the `display` method of the object.
6. Use `instanceof` to confirm that the object is a `Shirt`.
   - If it is a `Shirt`:
     - Cast the object to a `Shirt` and call the `getColor` method, assigning the return value to a String variable.
     - Print out the color name using a suitable label.
   - If it is not a `Shirt`, print a message to that effect.
7. Test your code. You can test the non-Shirt object condition by instantiating an Item object instead of a `Shirt` object.

In this exercise, you use the `instanceof` operator to test the type of an object before casting it to that type.

Topics

- Overview of inheritance
- Working with superclasses and subclasses
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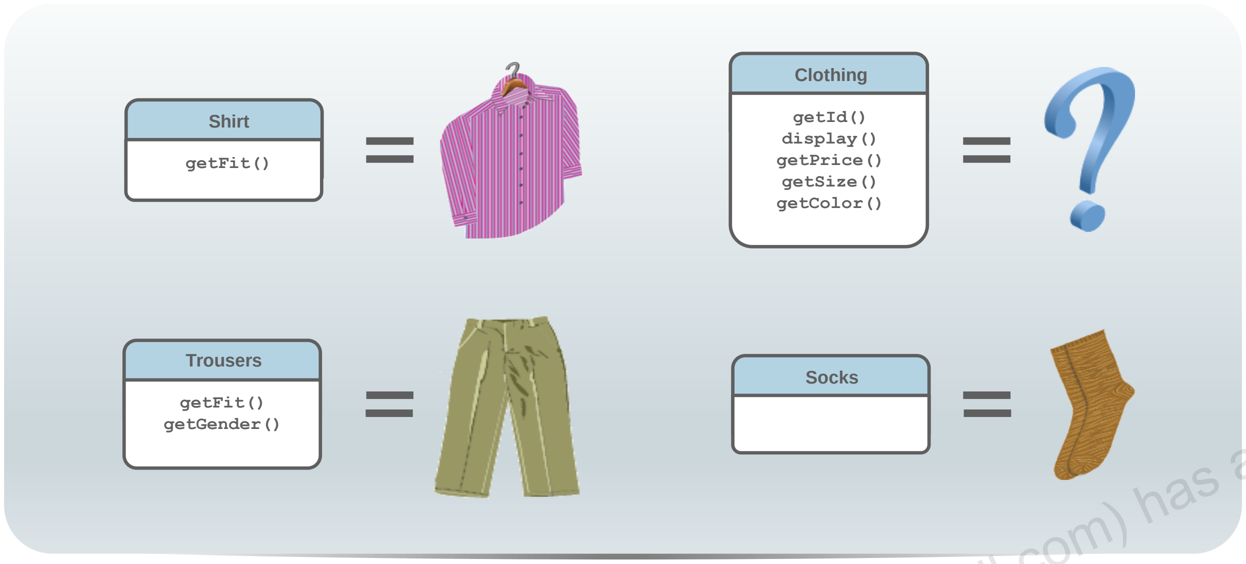
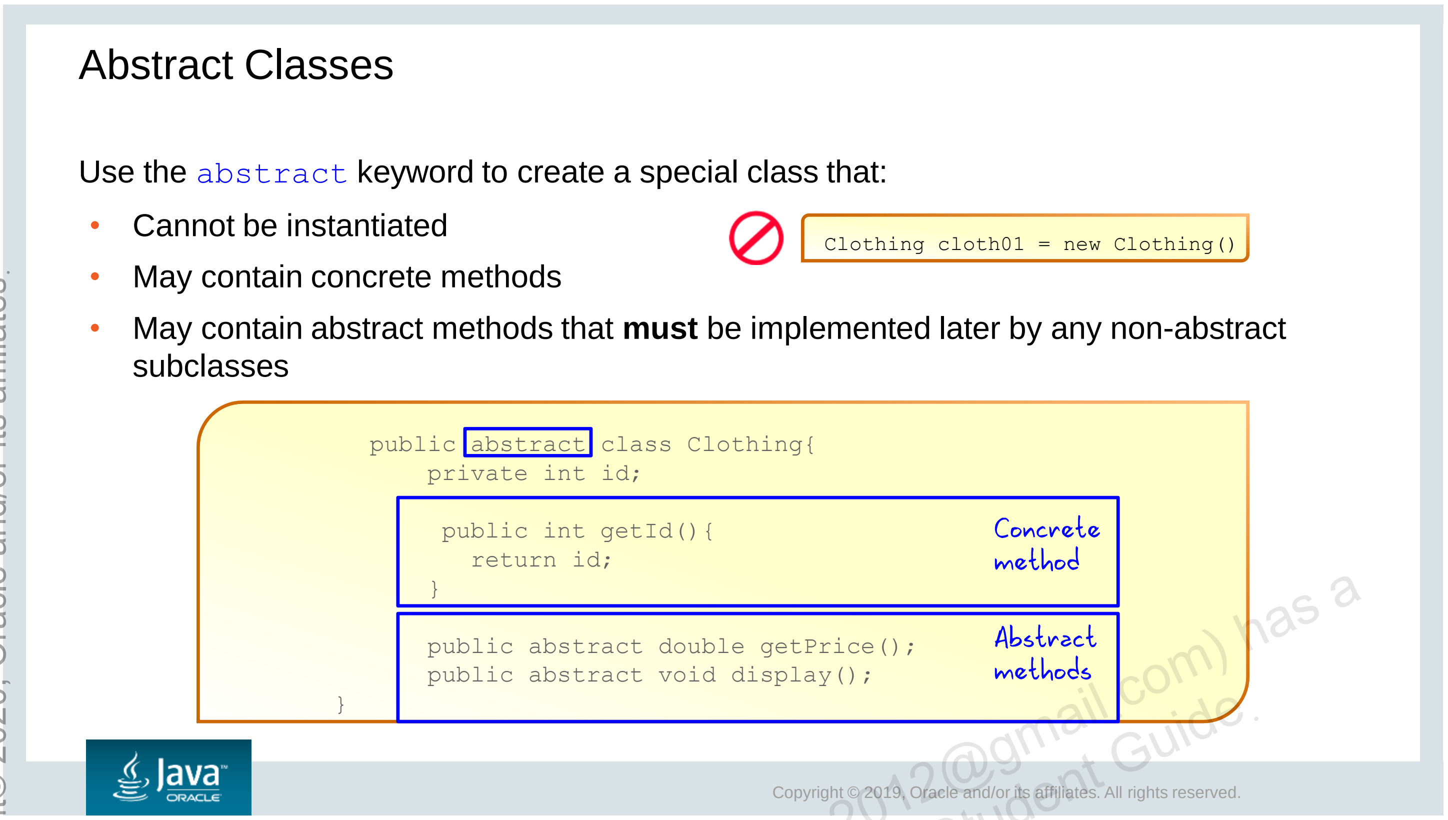
Abstract Classes



Sometimes a superclass makes sense as an object, and sometimes it does not. Duke's Choice carries shirts, socks, and trousers, but it does not have an individual item called “clothing.” Also, in the application, the superclass `Clothing` may declare some methods that may be required in each subclass (and thus can be in the superclass), but cannot really be implemented in the superclass.



Abstract Classes

Use the `abstract` keyword to create a special class that:

- Cannot be instantiated
- May contain concrete methods
- May contain abstract methods that **must** be implemented later by any non-abstract subclasses

```
Clothing cloth01 = new Clothing()
```

```
public abstract class Clothing{
    private int id;

     public int getId(){
       return id;
     }

    public abstract double getPrice();
    public abstract void display();
}
```

An abstract class cannot be instantiated. In fact, in many cases it would not make sense to instantiate them (Would you ever want to instantiate a `Clothing`?). However these classes can add a helpful layer of abstraction to a class hierarchy. The abstract class imposes a requirement on any subclasses to implement all of its abstract methods. Think of this as a contract between the abstract class and its subclasses.

- The example above has a concrete method, `getId`. This method can be called from the subclass or can be overridden by the subclass.
- It also contains two abstract methods: `getPrice` and `display`. Any subclasses of `Clothing` must implement these two methods.

Extending Abstract Classes

```
public abstract class Clothing{
    private int id;

    public int getId(){
       return id;
    }
    protected abstract double getPrice();    //MUST be implemented
    public abstract void display();  }       //MUST be implemented
```

```
public class Socks extends Clothing{
    private double price;

    protected double getPrice(){
        return price;
    }
    public void display(){
        System.out.println("ID: " +getID());
        System.out.println("Price: $" +getPrice());
}}
```

The `Socks` class extends the Clothing class. The `Socks` class implements the abstract `getPrice` and `display` methods from the `Clothing` class. A subclass is free to call any of the concrete methods or newly implemented abstract methods from an abstract superclass, including within the implementation of an inherited abstract method, as shown by the call to `getID` and `getPrice` within the `display` method.

Summary

In this lesson, you should have learned the following:

- Define inheritance in the context of a Java class hierarchy
- Create a subclass
- Override a method in the superclass
- Use the `super` keyword to reference the superclass
- Define polymorphism
- Use the `instanceof` operator to test an object's type
- Cast a superclass reference to the subclass type
- Explain the difference between abstract and non-abstract classes
- Create a class hierarchy by extending an abstract class

Inheritance enables programmers to put common members (variables and methods) in one class and have other classes *inherit these common members* from this new class.

The class containing members common to several other classes is called the *superclass* or the *parent class*. The classes that inherit from, or extend, the superclass are called *subclasses* or *child classes*.

Inheritance also allows object methods and fields to be referred to by a reference, that is, the type of the object, the type of any of its superclasses, or an interface that it implements.

Abstract classes can also be used as a superclass. They cannot be instantiated, but by including abstract methods that must be implemented by the subclasses, they impose a specific public interface on the subclasses.

Practice Overview

- 12-1: Creating a Class Hierarchy
- 12-2: Creating a `GameEvent` Hierarchy