13

Using Interfaces

Objectives

After completing this lesson, you should be able to:

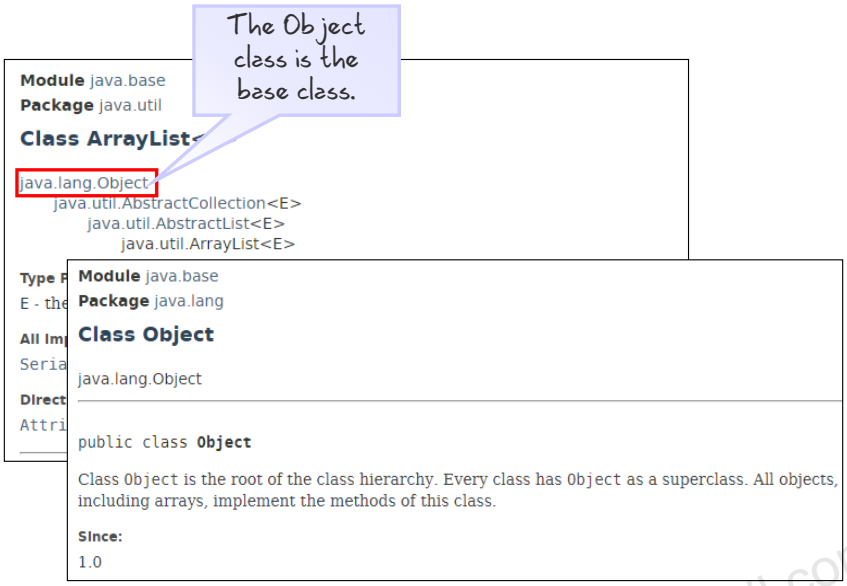
- Override the `toString` method of the `Object` class
- Implement an interface in a class
- Cast to an interface reference to allow access to an object method
- Use the local variable type inference feature to declare local variables using `var`
- Write a simple lambda expression that consumes a `Predicate`

Topics

- Polymorphism in the JDK foundation classes
- Using Interfaces
- Using local variable type inference
- Using the `List` interface
- Introducing lambda expressions

In this section, you will look at a few examples of interfaces found in the foundation classes.

The `Object` Class

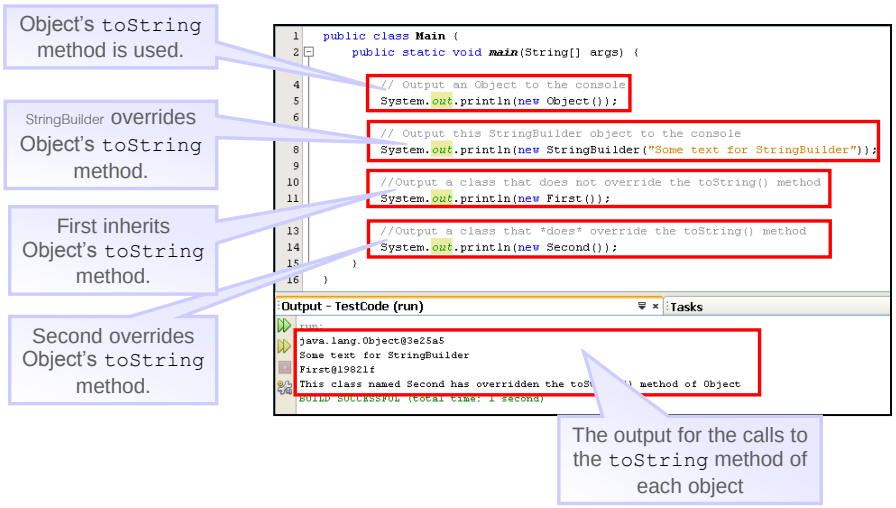


All classes have at the very top of their hierarchy the `Object` class. It is so central to how Java works that all classes that do not explicitly extend another class automatically extend `Object`.

So all classes have `Object` at the root of their hierarchy. This means that all classes have access to the methods of `Object`. Being the root of the object hierarchy, `Object` does not have many methods—only very basic ones that all objects must have.

An interesting method is the `toString` method. The `Object toString` method gives very basic information about the object; generally classes will override the `toString` method to provide more useful output. `System.out.println` uses the `toString` method on an object passed to it to output a string representation.

Calling the `toString` Method



All objects have a `toString` method because it exists in the `Object` class. But the `toString` method may return different results depending on whether or not that method has been overridden. In the example in the slide, `toString` is called (via the `println` method of `System.out`) on four objects:

- **An `Object` object:** This calls the `toString` method of the base class. It returns the name of the class (`java.lang.Object`), an `@` symbol, and a hash value of the object (a unique number associated with the object).
- **A `StringBuilder` object:** This calls the `toString` method on the `StringBuilder` object. `StringBuilder` overrides the `toString` method that it inherits from Object to return a `String` object of the set of characters it is representing.
- **An object of type `First`, a test class:** First does not override the `toString` method, so the `toString` method called is the one that is inherited from the `Object` class.
- **An object of type `Second`, a test class:** `Second` is a class with one method named `toString`, so this overridden method will be the one that is called.

There is a case for re-implementing the `getDescription` method used by the `Clothing` classes to instead use an overridden `toString` method.

Overriding `toString` in Your Classes

Shirt class example

```
1  public String toString(){
2    return "This shirt is a " + desc + ";"
3       + " price: " + getPrice() + ","
4       + " color: " + getColor(getColorCode());
5  }
```

Output of `System.out.println(shirt);`:

- Without overriding `toString`
  `examples.Shirt@73d16e93`
- After overriding `toString` as shown above
  `This shirt is a T Shirt; price: 29.99, color: Green`

The code example here shows the `toString` method overridden in the `Shirt` class.

When you override the `toString` method, you can provide useful information when the object reference is printed.

Topics

- Polymorphism in the JDK foundation classes
- Using Interfaces
- Using local variable type inference
- Using the `List` interface
- Introducing lambda expressions

The Multiple Inheritance Dilemma

Can I inherit from *two* different classes? I want to use methods from both classes.

```
public class Red{
    public void print(){
        System.out.print("I am Red");
    }
}
```

```
public class Blue{
    public void print(){
        System.out.print("I am Blue");
    }
}
```

```
public class Purple extends Red, Blue{
      public void printStuff() {
         print();
      }
}
```

Which implementation of `print()` will occur?

The Java Interface

- An interface is similar to an abstract class, except that:
  - Methods are implicitly abstract (except default, static, and private methods)
  - A class does not *extend* it, but *implements* it
  - A class may implement more than one interface
- All abstract methods from the interface must be implemented by the class.

```
1 public interface Printable {
2     public void print();
3 }
```

Implicitly abstract

```
1 public class Shirt implements Printable {
2       ...
3       public void print(){
4               System.out.println("Shirt description");
5       }
6 }
```

Implements the `print()` method.

When a class implements an interface, it enters into a contract with the interface to implement all of its abstract methods. Therefore, using an interface lets you enforce a particular public interface (set of public methods).

- In first example above, you see the declaration of the `Printable` interface. It contains only one method, the `print` method. Notice that there is no method block. The method declaration is just followed by a semicolon.
- In the second example, the `Shirt` class implements the `Printable` interface. The compiler immediately shows an error until you implement the `print` method.

Note: A method within an interface is assumed to be abstract unless it uses the `default, static, or private` keywords. Default methods are new as of Java 8. They're covered in more detail in the course *Java SE Programming II*.

No Multiple Inheritance of State

- Multiple Inheritance of methods is not a problem
- Multiple Inheritance of state is a big problem
  - Abstract classes may have instance and static fields.
  - Interface fields must be static final.

Key difference between abstract classes and interfaces

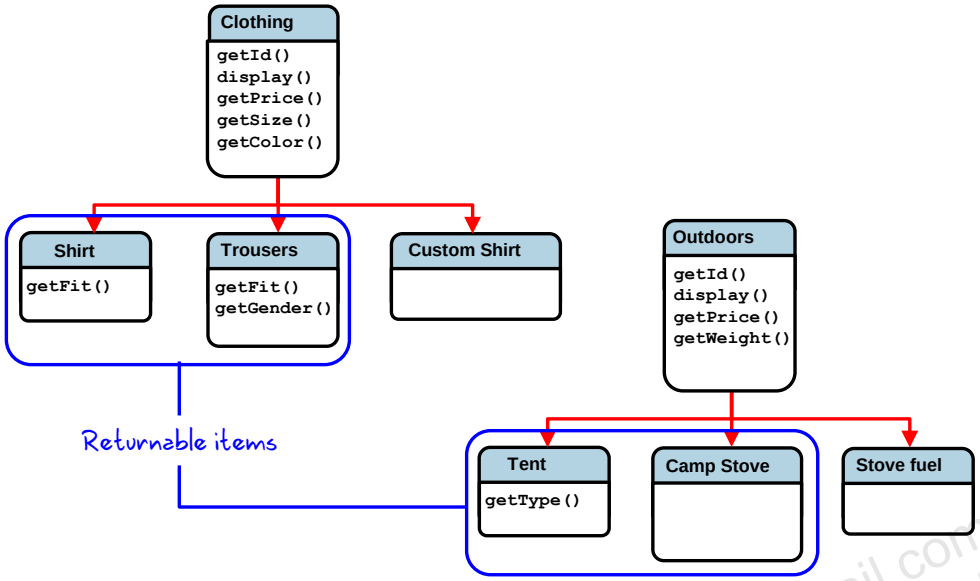
```
public abstract class Red{
    public String color = "Red";
}
```

```
public abstract class Blue{
    public String color = "Blue";
}
```

```
public class Purple extends Red, Blue{
      public void printStuff() {
         System.out.println(color);
      }
}
```

Which value of `color` will print?

Multiple Hierarchies with Overlapping Requirements



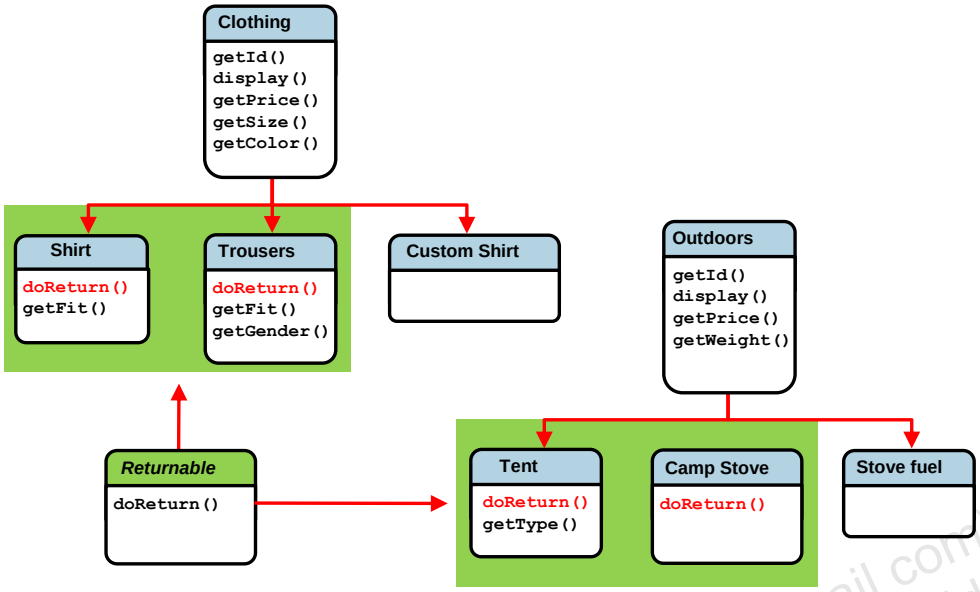
A more complex set of classes may have items in two different hierarchies. If Duke's Choice starts selling outdoor gear, it may have a completely different superclass called `Outdoors`, with its own set of subclasses (for example, `getWeight` as an `Outdoors` method).

In this scenario, there may be some classes from each hierarchy that have something in common. For example, the custom shirt item in `Clothing` is not returnable (because it is made manually for a particular person), and neither is the `Stove` fuel item in the `Outdoors` hierarchy. All other items are returnable.

How can this be modeled? Here are some things to consider:

- A new superclass will not work because a class can extend only one superclass, and all items are currently extending either `Outdoors` or `Clothing`.
- A new field named returnable, added to every class, could be used to determine whether an item can be returned. This is certainly possible, but then there is no single reference type to pass to a method that initiates or processes a return.
- You can use a special type called an *interface* that can be implemented by any class. This interface type can then be used to pass a reference of any class that implements it.

Using Interfaces in Your Application



The diagram in the slide shows all returnable items implementing the Returnable interface with its single method, `doReturn`. Methods can be declared in an interface, but they cannot be implemented in an interface. Therefore, each class that implements Returnable must implement `doReturn` for itself. All returnable items could be passed to a `processReturns` method of a Returns class and then have their `doReturn` method called.

Implementing the `Returnable` Interface

`Returnable` interface

```
01  public interface Returnable {
02   public String doReturn();
03 }
```

Implicitly abstract method

`Shirt` class

Now, Shirt 'is a' Returnable.

```
01  public class Shirt extends Clothing implements Returnable {
02   public Shirt(int itemID, String description, char colorCode,
03                double price, char fit) {
04      super(itemID, description, colorCode, price);
05      this.fit = fit;
06   }
07  public String doReturn() {
08    // See notes below
09     return "Suit returns must be within 3 days";
10  }
11  ...< other methods not shown > ...       } // end of class
```

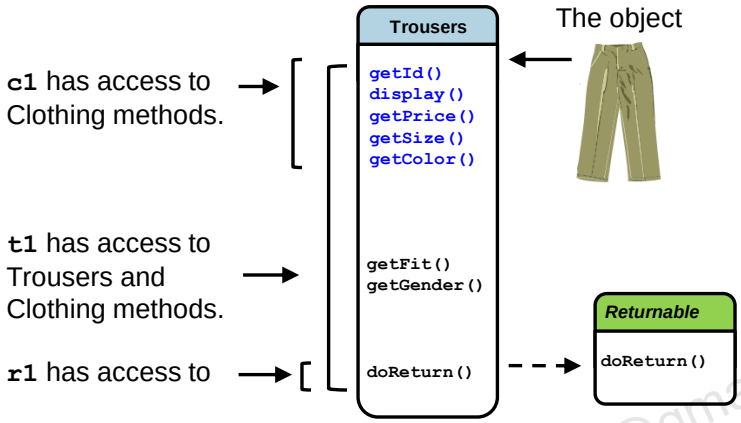
Shirt implements the method declared in Returnable.

The code in this example shows the `Returnable` interface and the `Shirt` class. Notice that the abstract methods in the Returnable class are stub methods (that is, they contain only the method signature).

- In the Shirt class, only the constructor and the `doReturn` method are shown.
- The use of the phrase "`implements Returnable`" in the Shirt class declaration imposes a requirement on the `Shirt` class to implement the `doReturn` method. A compiler error occurs if `doReturn` is not implemented. The `doReturn` method returns a `String` describing the conditions for returning the item.
- Note that the `Shirt` class now has an "is a" relationship with `Returnable`. Another way of saying this is that `Shirt` *is a* `Returnable`.

Access to Object Methods from Interface

```
Clothing c1 = new Trousers();
Trousers t1 = new Trousers();
Returnable r1 = new Trousers();
```



The reference used to access an object determines the methods that can be called on it. So in the case of the interface reference shown in the slide (r1), only the `doReturn` method can be called.

The `t1` reference has access to all of the methods shown above. This is because of the “is a” relationship. The `Trousers` class extends `Clothing`; therefore, a `Trousers` object is a (type of) `Clothing`. It implements Returnable and, therefore, it is a `Returnable`. `Clothing` is the root class and, consequently, the `least` specific. A reference of this type can only access the methods of the `Clothing` class (and, of course `Object`, which is the root of all classes).

Casting an Interface Reference

```
Clothing c1 = new Trousers();
Trousers t1 = new Trousers();
Returnable r1 = new Trousers();
```

- The `Returnable` interface does not know about `Trousers` methods:

```
r1.getFit()                 //Not allowed
```

- Use **casting** to access methods defined outside the interface.

```
((Trousers)r1).getFit();
```

- Use `instanceof` to avoid inappropriate casts.

```
if(r1 instanceof Trousers) {
       ((Trousers)r1).getFit();
}
```

If a method receives a `Returnable` reference and needs access to methods that are in the `Clothing` or `Trousers` class, the reference can be cast to the appropriate reference type.

Quiz

Which methods of an object can be accessed via an interface that it implements?

a. All the methods implemented in the object's class
b. All the methods implemented in the object's superclass
c. The methods declared in the interface

Answer: c

Quiz

How can you change the reference type of an object?

a. By calling `getReference`
b. By casting
c. By declaring a new reference and assigning the object

Answer: b, c

Topics

- Polymorphism in the JDK foundation classes
- Using Interfaces
- Using local variable type inference
- Using the `List` interface
- Introducing lambda expressions

What is This Feature?

- Local variable type inference is a new language feature in Java 10.
- Use `var` to declare local variables.
- The compiler infers the datatype from the variable initializer.

Before Java 10

```
ArrayList list = new ArrayList<String>();
```

Datatype declared twice

Now

```
var list = new ArrayList<String>();
```

Datatype declared once

Benefits

- There's less boilerplate typing.
- Code is easier to read with variable names aligned.

```
String desc = "shirt";
ArrayList<String> list = new
ArrayList<String>();
int price = 20;
double tax = 0.05;
```

```
var desc = "shirt";
var list = new ArrayList<String>();
var price = 20;
var tax = 0.05;
```

- It won't break old code.
  - Keywords cannot be variables names.
  - `var` is not a keyword.
  - `var` is a reserved type name.
  - It's only used when the compiler expects a variable type.
  - Otherwise, you can use `var` as a variable name. But it's a bad name...

You're starting to notice variable type declarations growing more complex. In larger scale applications seeing a declaration as "ArrayList<String>" is only the beginning. With longer declarations, it becomes harder to read code and perceive functionality. Not only does the var keyword simplify the declarations, if variables are declared near each other, their names align for easier readability.

Where Can it be Used?

Yes

- Local variables
  ```
  var x = shirt1.toString();
  ```
- `for` loop
  ```
  for(var i=0; i<10; i++)
  ```
- `for-each` loop
  ```
  for(var x : shirtArray)
  ```

No

- Declaration without an initial value
  ```
  var price;
  ```
- Declaration and initialization with a null value
  ```
  var price = null;
  ```
- Fields
  ```
  public var price;
  ```
- Parameters
  ```
  public void setPrice(var price){}
  ```
- Method return types
  ```
  public var getPrice(){
      return price;
  }
  ```

Additionally, `var` cannot be used in these scenarios:

- Compound declarations
  ```
  var price=19.95, tax=0.08;
  ```
- Array initializer
  ```
  var price = {9.99, 19.95, 15.00};
  ```

Why is The Scope So Narrow?

- Larger scopes increase the potential for issues or uncertainty in inferences.
- To prevent issues, Java restricts the usage of `var`.

```
public var getSomething(var something){
      return something;
}
```

How should this compile?
`something` could be anything!

Exercise 13-1: Local Variable Type Inference

1. Open the project **`Exercise_13-1`** in NetBeans.
2. Edit `TestClass.java`.
3. Replace the variable declarations with the `var` variable type inference feature in the following cases. Note which cases produce an error.
   - As a local variables
   - As a reference to Collection
   - In the enhanced for loop
   - As the index counter in the traditional for loop
   - Saving the returned value from a method
   - As a method return type

Topics

- Polymorphism in the JDK foundation classes
- Using Interfaces
- Using local variable type inference
- Using the List interface
- Introducing lambda expressions

The Collections Framework

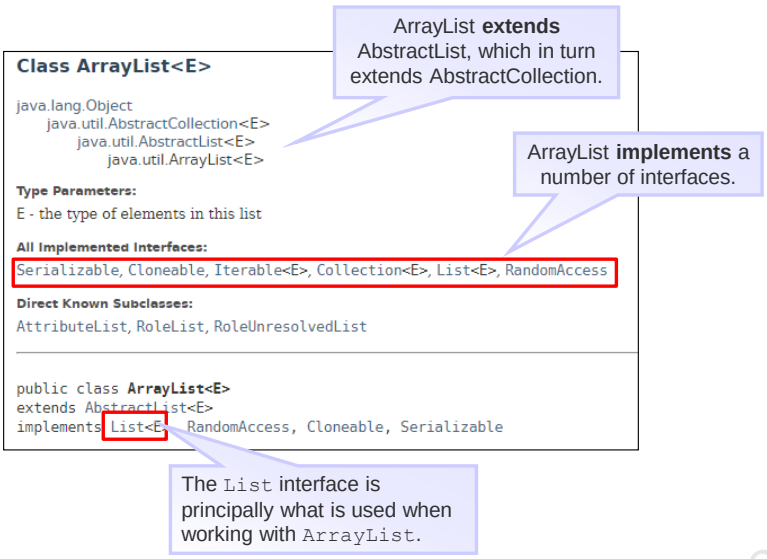
The collections framework is located in the `java.util` package. The framework is helpful when working with lists or collections of objects. It contains:

- Interfaces
- Abstract classes
- Concrete classes (Example: `ArrayList`)

You were introduced to the `java.util` package when you learned to use the `ArrayList` class. Most of the classes and interfaces found in `java.util` provide support for working with collections or lists of objects. You will consider the List interface in this section.

The collections framework is covered in much more depth in the *Java SE Programming* II course.

`ArrayList` Example



Some of the best examples of inheritance and the utility of Interface and Abstract types can be found in the Java API.

`List` Interface

All of these object types can be assigned to a `List` variable:

```
1    ArrayList words = new ArrayList<String>();
2    List mylist = words;
```

```
1      var words = new ArrayList();
2      var mylist = words;
```

Using local variable type inference

The `List` interface is implemented by many classes. This means that any method that requires a `List` may actually be passed a `List` reference to any objects of these types (but not the abstract classes, because they cannot be instantiated). For example, you might pass an `ArrayList` object, using a `List` reference. Likewise, you can assign an `ArrayList` object to a `List` reference variable as shown in the code example above.

- In line 1, an `ArrayList` of `String` objects is declared and instantiated using the reference variable `words`.
- In line 2, the `words` reference is assigned to a variable of type `List<String>`.

Example: `Arrays.asList`

The `java.util.Arrays` class has many static utility methods that are helpful in working with arrays.

- Converting an array to a `List`:

```
1   String[] nums = {"one","two","three"};
2   List<String> myList = Arrays.asList(nums);
```

List objects can be of many different types. What if you need to invoke a method belonging to `ArrayList`?

```
mylist.replaceAll()
```
This works! `replaceAll` comes from List.

```
mylist.removeIf()
```
Error! `removeIf` comes from Collection (superclass of ArrayList).

As you saw on the previous slide, you can store an `ArrayList` object reference in a variable of type `List` because `ArrayList` implements the `List` interface (therefore, `ArrayList` *is a* `List`).

Occasionally you need to convert an array to an `ArrayList`. How do you do that? The `Arrays` class is another very useful class from `java.util`. It has many static utility methods that can be helpful in working with arrays. One of these is the `asList` method. It takes an array argument and converts it to a `List` of the same element type. The example above shows how to convert an array to a `List`.

- In line 1, a `String` array, `nums`, is declared and initialized.
- In line 2, the `Arrays.asList` method converts the `nums` array to a `List`. The resulting `List` object is assigned to a variable of type `List<String>` called `myList`.

Recall that any object that implements the `List` interface can be assigned to a `List` reference variable. You can use the `myList` variable to invoke any methods that belong to the List interface (example: `replaceAll`). But what if you wanted to invoke a method belonging to ArrayList or one of its superclasses that is not part of the List interface (example: `removeIf`)? You would need a reference variable of type ArrayList.

Example: `Arrays.asList`

Converting an array to an `ArrayList`:

```
1 String[] nums = {"one","two","three"};
2 List<String> myList = Arrays.asList(nums);
3 ArrayList<String> myArrayList = new ArrayList(myList);
                    or
  var myArrayList = new ArrayList(myList);
```

Shortcut:

```
1 String[] nums = {"one","two","three"};
2 ArrayList<String> myArrayList = new ArrayList( Arrays.asList(nums));
                    or
   var myArrayList = new ArrayList(Arrays.asList(nums));
```

Building upon the previous example, this slide example shows how to convert an array to an `ArrayList`.

- In the first example, the conversion is accomplished in three steps:
  - Line 1 declares the `nums String` array.
  - Line 2 converts the `nums` array to a `List` object, just as you saw on the previous slide.
  - Line 3 uses the `List` object to initialize a new `ArrayList`, called `myArrayList`. It does this using an overloaded constructor of the `ArrayList` class that takes a `List` object as a parameter.
- The second example reduces this code to two lines by using the `Arrays.asList(nums)` expression as the `List` argument to the ArrayList constructor.
- The `myArrayList` reference could be used to invoke the `removeIf` method you saw on the previous slide.

Exercise 13-2: Converting an Array to an ArrayList, Part 1

1. Open the project **`Exercise_13-2`** in NetBeans or create your own Java Main Class named `TestClass`
2. Convert the days array to an `ArrayList`.
   - Use Arrays.asList to return a List.
   - Use that List to initialize a new ArrayList.
   - Preferably do this all on one line.
3. Iterate through the ArrayList, testing to see if an element is "sunday".
   - If it is a "sunday" element, print it out, converting it to upper case.
     Use String class methods:
     - public boolean equals (Object o);
     - public void toUpperCase();
   - Else, print the day anyway, but not in upper case.

In this exercise, you convert a `String` array to an `ArrayList` and manipulate list values.

Exercise 13-2: Converting an Array to an ArrayList, Part 2

4. After the `for` loop print out the `ArrayList`.
   - While within the loop, was `"sunday"` printed in upper case?
   - Was the `"sunday"` array element converted to upper case?
   - Your instructor will explain what's going on in the next topic.

In this exercise, you convert a `String` array to an `ArrayList` and manipulate list values.

Topics

- Polymorphism in the JDK foundation classes
- Using Interfaces
- Using local variable type inference
- Using the `List` interface
- Introducing lambda expressions

Example: Modifying a List of Names

Suppose you want to modify a `List` of names, changing them all to uppercase. Does this code change the elements of the `List`?

```
1  String[] names = {"Ned","Fred","Jessie","Alice","Rick"};
2  List<String> mylist = new ArrayList(Arrays.asList(names));
3
4  // Display all names in upper case
5  for( var s: mylist){
6     System.out.print(s.toUpperCase()+", ");
7  }
8  System.out.println("After for loop: " + mylist);
```

Returns a new String to print

Output:

```
NED, FRED, JESSIE, ALICE, RICK,
After for loop: [Ned, Fred, Jessie, Alice, Rick]
```

The list elements are unchanged.

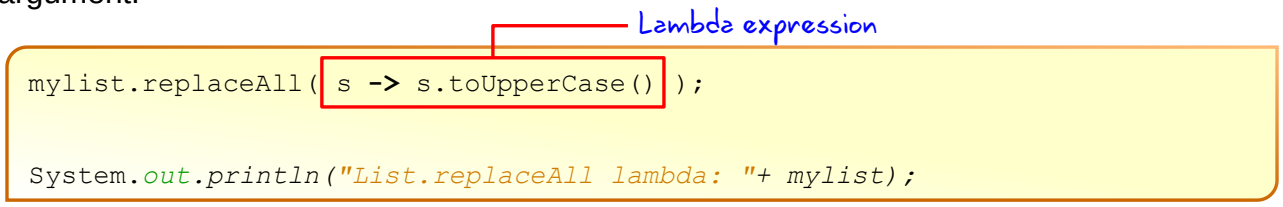
You have already seen, in the previous exercise, that the technique shown here is not effective. The above code succeeds in printing out the list of names in uppercase, but it does not actually change the list element values themselves. The `toUpperCase` method used in the `for` loop simply changes the *local* `String` variable (`s` in the example above) to uppercase.

Remember that `String` objects are immutable. You cannot change them in place. All you can do is create a new `String` with the desired changes and then reassign the reference to point to the new `String`. You could do that here, but it would not be trivial.

A lambda expression makes this much easier!

Using a Lambda Expression with `replaceAll`

`replaceAll` is a default method of the `List` interface. It takes a lambda expression as an argument.



Output:

```
List.replaceAll lambda: [NED, FRED, JESSIE, ALICE, RICK]
```


The `replaceAll` method belongs to the `List` interface. It is a default method, which means that it is a concrete method (not abstract) intended for use with a lambda expression. It takes a *particular type* of lambda expression as its argument. It iterates through the elements of the list, applying the result of the lambda expression to each element of the list.

The output of this code shows that the actual elements of the list were modified.

Lambda Expressions

Lambda expressions are like methods used as the argument for another method. They have:

- Input parameters
- A method body
- A return value

Long version:

```
mylist.replaceAll((String s) -> {return s.toUpperCase();} );
```

Declare input parameter

Arrow token

Method body

Short version:

```
mylist.replaceAll( s -> s.toUpperCase() );
```

A lambda expression is a concrete method for an Interface expressed in a new way. A lambda expression looks very similar to a method definition. You can recognize a lambda expression by the use of an arrow token (->). A lambda expression:

- Has input parameters: These are seen to the left of the arrow token.
  - In the long version, the type of the parameter is explicitly declared.
  - In the short version, the type is inferred. The compiler derives the type from the type of the List in this example. (`List<String> mylist = …`)
- Has a method body (statements): These are seen to the right of the arrow token. Notice that the long version even encloses the method body in braces, just as you would when defining a method. It explicitly uses the `return` keyword.
- Returns a value:
  - In the long version, the `return` statement is explicit.
  - In the short version it is inferred. Because the `List` was defined as a list of `Strings`, the `replaceAll` method is expecting a `String` to apply to each of its elements, so a return of `String` makes sense.

Note that you would probably never use the long version (although it does compile and run). You are introduced to this to make it easier for you to recognize the different method components that are present in a lambda expression.

The Enhanced APIs That Use Lambda

There are three enhanced APIs that take advantage of lambda expressions:

- `java.util.functions`
  - Provides target types for lambda expressions
- `java.util.stream`
  - Provides classes that support operations on streams of values
- `java.util`
  - Interfaces and classes that make up the collections framework
    - Enhanced to use lambda expressions
    - Includes List and ArrayList

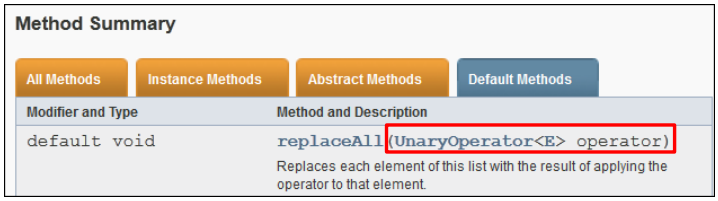
A complete explanation of lambda expressions is beyond the scope of this course. You will, however, consider just a few of the target types for lambda expressions available in `java.util.functions`.

For a much more comprehensive treatment of lambda expressions, take the *Java SE 8 New Features* course, or the *Java SE Programming II* course.

Lambda Types

A lambda *type* specifies the type of expression a method is expecting.

- `replaceAll` takes a `UnaryOperator` type expression.



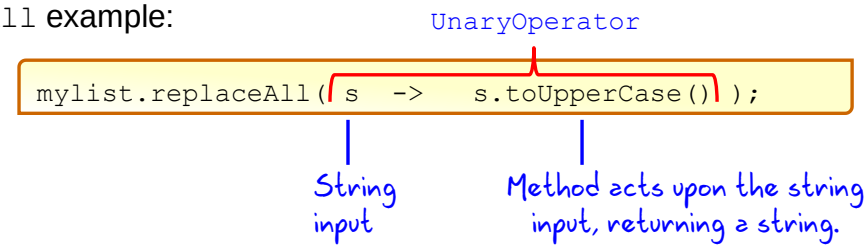
- All of the types do similar things, but have different inputs, statements, and outputs.

The lambda types can be viewed by looking at the `java.util.functions` package in the JDK API documentation. There are a great many of these, and they are actually interfaces. They specify the interface of the expression. Much like a method signature, they indicate the inputs, statements, and outputs for the expression.

The `UnaryOperator` Lambda Type

A `UnaryOperator` has a single input and returns a value of the same type as the input.

- Example: `String` *in* – `String` *out*
- The method body acts upon the input in some way, returning a value of the same type as the input value.
- `replaceAll` example:



A `UnaryOperator` has a single input and returns a value of the same type as the input. For example, it might take a single `String` value and return a `String` value, or it might take an `int` value and return an `int` value.

The method body acts upon the input in some way (possibly by calling a method), but must return the same type as the input value.

The code example here shows the `replaceAll` method that you saw earlier, which takes a `UnaryOperator` argument.

- A `String` is passed into the `UnaryOperator` (the expression). Remember that this method iterates through its list, invoking this `UnaryOperator` for each element in the list. The argument passed into the `UnaryOperator` is a single `String` element.
- The operation of the `UnaryOperator` calls `toUpperCase` on the string input.
- It returns a `String` value (the original `String` converted to uppercase).

The `Predicate` Lambda Type

A `Predicate` type takes a single input argument and returns a boolean.

- Example: `String` *in* – `boolean` *out*
- `removeIf` takes a `Predicate` type expression.
  - Removes all elements of the `ArrayList` that satisfy the `Predicate` expression

removeIf

```
public boolean removeIf(Predicate<? super E> filter)
```

- Examples:

```
mylist.removeIf (s -> s.equals("Rick"));
mylist.removeIf (s -> s.length() < 5);
```

The `Predicate` lambda expression type takes a single input argument. The method body acts upon that argument in some way, returning a `boolean`.

In the examples shown here, `removeIf` is called on the `mylist` reference (an `ArrayList`). Iterating through the list and passing each element as a `String` argument into the `Predicate` expressions, it removes any elements resulting in a return value of `true`.

- In the first example, the `Predicate` uses the `equals` method of the `String` argument to compare its value with the string "Rick". If it is equal, the `Predicate` returns `true`. The long version of the `Predicate` expression would look like this:

```
mylist.removeIf ((String s) -> {return s.equals("Rick"); } )
```

- In the second example, the `Predicate` uses the `length()` method of the `String` argument, returning `true` if the string has less than 5 characters. The long version of this `Predicate` expression would look like this:

```
mylist.removeIf ( (String s) -> {return (s.length() < 5); } )
```

Exercise 13-3: Using a `Predicate` Lambda Expression

1. Open the project **`Exercise_13-3`**.

In the `ShoppingCart` class:

2. Examine the code. As you can see, the items list has been initialized with 2 shirts and 2 pairs of trousers.
3. In the `removeItemFromCart` method, use the `removeIf` method (which takes a `Predicate` lambda type) to remove all items whose description matches the `desc` argument.
4. Print the items list. Hint: the `toString` method in the `Item` class has been overloaded to return the item description.
5. Call the `removeItemFromCart` method from the main method.
   Try different description values, including ones that return `false`.
6. Test your code.

In this exercise, you use the `removeIf()` method to remove all items of the shopping cart whose description matches some value.

Summary

In this lesson, you should have learned the following:

- Override the `toString` method of the `Object` class
- Implement an interface in a class
- Cast to an interface reference to allow access to an object method
- Use local variable type inference feature to declare local variables using `var`
- Write a simple lambda expression that consumes a `Predicate`

Polymorphism means the same method name in different classes is implemented differently. The advantage of this is that the code that calls these methods does not need to know how the method is implemented. It knows that it will work in the way that is appropriate for that object.

Interfaces support polymorphism and are a very powerful feature of the Java language. A class that implements an interface has an “is a” relationship with the interface.

Practice Overview

- 13-1: Overriding the `toString` Method
- 13-2: Implementing an Interface
- 13-3: Using a Lambda Expression for Sorting