Java 8 Upgrade

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The biggest new additions to Java in version 8 are the ones related to functional programming: lambda expressions, method references, and streams. This course will discuss each of them, along with two other new features: static and default methods in interfaces. Many new methods have been added to the standard library involving those features, including major changes to the `Comparator` interface that make sorting, partitioning, and grouping much easier. These materials will also demonstrate those capabilities.

Finally, at long last a new date/time library has been added to the language, based on the open source JodaTime framework. These materials conclude with a section on the new `java.time` package, with some interesting examples.

1. Lambda Expressions

Lambda expressions are a new syntax, introduced in Java 8, that essentially represent methods treated as first-class objects. The first key concept you need to know about them is that they never exist by themselves — they are always assigned to a *functional interface* reference.

A functional interface is an interface with a single abstract method (SAM). Normally a class implements an interface by providing implementations for all the methods in it. This can be done with a top-level class, an inner class, or even an anonymous inner class.

For example, consider the `Runnable` interface, which has been in Java since version 1.0. It contains a single abstract method called `run`, which takes no arguments and returns `void`. The `Thread` class constructor takes a `Runnable` as an argument, so an anonymous inner class implementation is shown in Anonymous Inner Class Implementation of Runnable.

Example 1. Anonymous Inner Class Implementation of Runnable

JAVA

```
public class RunnableDemo {
    public static void main(String[] args) {
        // Works in Java 7 or earlier:
        new Thread(new Runnable() {
            @Override
            public void run() {
                System.out.println(
                    "inside runnable using an anonymous inner class");
            }
        }).start();
    }
}
```

The anonymous inner class syntax consists of the word `new` followed by the `Runnable` interface name and parentheses, implying that you're defining a class without an explicit name that implements that interface. The code in the braces `{}` then overrides the `run` method, which simply prints a string to the console.

The code in Using a lambda expression in a `Thread` constructor shows the same example using a lambda expression.

Example 2. Using a lambda expression in a `Thread` constructor

```java
public class RunnableDemo {
    public static void main(String[] args) {
        new Thread(() -> System.out.println(
            "inside Thread constructor using lambda")).start();
    }
}
```

The lambda expression syntax uses an arrow to separate the dummy arguments (since there are zero arguments here, only a pair of empty parentheses is used) from the body. In this case, the body consists of a single line, so no braces are required. This is known as an expression lambda. Whatever value the expression evaluates to is returned automatically. In this case, since `println` returns `void`, the return from the expression is also `void`, which matches the return type of the `run` method.

A lambda expression must match the argument types and return type in the signature of the single abstract method in the interface. This is called being *compatible* with the method signature. The lambda expression is thus the implementation of the interface method, wrapped inside an object, which can then be assigned to a reference of that interface type.

As shown in Assigning a lambda expression to a variable, a lambda expression can also be assigned to a variable.

Example 3. Assigning a lambda expression to a variable

```java
public class RunnableDemo {
    public static void main(String[] args) {
        Runnable r = () -> System.out.println(
            "lambda expression implementing the run method");
        new Thread(r).start();
    }
}
```

There is no class in the Java library called `Lambda`. Lambda expressions can only be assigned to functional interfaces.

Assigning a lambda to the functional interface is the same as saying the lambda is the implementation of the single abstract method inside it. You can think of the lambda as the body of an anonymous inner class that implements the interface. That is why the lambda must be

compatible with the abstract method; its argument types and return type must match the signature of that method. Notably, however, the name of the method being implemented is not important. It does not appear anywhere as part of the lambda expression syntax.

This example was particularly simple because the `run` method takes no arguments and returns `void`. Consider instead the functional interface `java.io.FilenameFilter`, which has been part of the Java standard library since version 1.0. `FilenameFilter` instances are used as arguments to the `File.list` method to restrict the returned files to only those that satisfy the method.

From the Javadocs, the `FilenameFilter` class contains the single abstract method `accept`, with the following signature:

```
boolean accept(File dir, String name)
```

The `File` argument is the directory in which the file is found, and the `String` name is the name of the file.

The code in An anonymous inner class implementation of FilenameFilter implements `FilenameFilter` using an anonymous inner class to return only Java source files.

Example 4. An anonymous inner class implementation of FilenameFilter

JAVA

```
import java.io.File;
import java.io.FilenameFilter;
import java.util.Arrays;

public class UseFilenameFilter {
    public static void main(String[] args) {
        File directory = new File("./src/main/java");

        // Anonymous inner class
        String[] names = directory.list(new FilenameFilter() {
            @Override
            public boolean accept(File dir, String name) {
                return name.endsWith(".java");
            }
        });
        System.out.println(Arrays.asList(names));
    }
}
```

In this case, the `accept` method returns true if the file name ends with `.java` and false otherwise.

The lambda expression version is shown in Lambda expression implementing FilenameFilter.

Example 5. Lambda expression implementing FilenameFilter

```java
import java.io.File;
import java.io.FilenameFilter;
import java.util.Arrays;

public class UseFilenameFilter {
    public static void main(String[] args) {
        File directory = new File("./src/main/java");

        // Use lambda expression instead
        String[] names = directory.list((dir, name) -> name.endsWith(".java"));
        System.out.println(Arrays.asList(names));
    }
}
```

The resulting code is much simpler. This time the arguments are contained within parentheses, but do not have types declared. At compile time, the compiler knows that the `list` method takes an argument of type `FilenameFilter`, and therefore knows that the signature of its single abstract method (`accept`). It therefore knows that the arguments to `accept` are a `File` and a `String`, so that the compatible lambda expression arguments must match those types. The return type on `accept` is a boolean, so the expression to the right of the arrow must also return a boolean.

If you wish to specify the data types in the code, you are free to do so, as in Lambda expression is explicit data types.

Example 6. Lambda expression is explicit data types

```java
import java.io.File;
import java.io.FilenameFilter;
import java.util.Arrays;

public class UseFilenameFilter {
    public static void main(String[] args) {
        File directory = new File("./src/main/java");

        // Explicit data types
        String[] names = directory.list((File dir, String name) ->
            name.endsWith(".java"));
        System.out.println(Arrays.asList(names));
    }
}
```

Finally, if the implementation of the lambda requires more than one line, you need to use braces and an explicit return statement, as shown in A block lambda.

Example 7. A block lambda

```java
import java.io.File;
import java.io.FilenameFilter;
import java.util.Arrays;

public class UseFilenameFilter {
    public static void main(String[] args) {
        File directory = new File("./src/main/java");

        String[] names = directory.list((File dir, String name) -> {
            return name.endsWith(".java");
        });
        System.out.println(Arrays.asList(names));
    }
}
```

This is known as a block lambda. In this case the body still consists of a single line, but the braces now allow for multiple statements, each of which must be terminated with a semicolon, as usual. The `return` keyword is also required.

As stated, lambda expressions never exist alone. There is always a *context* for the expression, which indicates the functional interface to which the expression is assigned. A lambda can be an argument to a method, a return type from a method, or assigned to a reference. In each case, the

type of the assignment must be a functional interface.

2. Method References

If a lambda expression is essentially treating a method as though it was a first-class object, then a method reference treats and existing method as though it was a lambda expression.

For example, the `forEach` method in `Iterable` takes a `Consumer` as an argument. `Consumer` is one of the new functional interfaces that were added to the `java.util.function` package, which are designed to be used by the rest of the API. Using a method reference to access `println` shows that `Consumer` can be implemented as either a lambda expression or as a method reference.

Example 8. Using a method reference to access `println`

```java
Stream.of(3, 1, 4, 1, 5, 9)
        .forEach(x -> System.out.println(x));  1

Stream.of(3, 1, 4, 1, 5, 9)
        .forEach(System.out::println);      2

Consumer<Integer> printer = System.out::println;   3
Stream.of(3, 1, 4, 1, 5, 9)
        .forEach(printer);
```

1. Using a lambda expression
2. Using a method reference
3. Assigning the method reference to a functional interface

The double-colon notation provides the reference to the `println` method on the `System.out` instance, a reference of type `PrintStream`. No parentheses are placed at the end of the method reference.

If you write a lambda expression that consists of one line that invokes a method, consider using the equivalent method reference instead.

The method reference provides a couple of (minor) advantages over the lambda syntax. First, it tends to be shorter, and second, it includes the class containing the method. Both often make the code easier to read.

Method references can be used with static methods as well, as shown in Using a method reference to a static method.

Example 9. Using a method reference to a static method

```
Stream.generate(Math::random)  1
        .limit(10)
        .forEach(System.out::println);  2
```

JAVA

1 Reference to static method

2 Reference to instance method

The `generate` method on `Stream` takes a `Supplier` as an argument (another of the new interfaces in `java.util.function`), which has a method that takes no arguments and returns a single result. The `random` method in the `Math` class is compatible with that, because it takes no arguments and produces a uniformly-distributed pseudo-random double between 0 and 1. The method reference `Math::random` uses that method as the `Supplier`.

The `generate` method is a factory method on the `Stream` interface, which produces new values every time it is invoked. The result is an infinite stream, so the `limit` method is used to ensure only 10 values are produced. Those values are then printed to standard output using the `System.out::println` method reference as a `Consumer` (the argument to `forEach`, as described earlier).

In stream processing, it is also common to access an instance method using the class name in a method reference if you are processing a series of inputs. The code in Invoking the `length` method on `String` using a method reference shows the invocation of the `length` method on each individual `String` in the stream.

Example 10. Invoking the `length` method on `String` using a method reference

```
Stream.of("this", "is", "a", "stream", "of", "strings")
        .mapToInt(String::length)
        .forEach(System.out::println);
```

JAVA

The argument of the `mapToInt` method is of type `ToIntFunction` (one of several interfaces related to `Function`, another of the new interfaces in `java.util.function`) and produces an `IntStream`. That means it contains a method that takes a generic type (here a `String`, from the context) and produces an `int`. The `length` method in `String` is compatible with that requirement. Since there is no explicit reference to an individual `String`, the syntax implies that the `length` method is invoked on each `String` in the stream.

A method reference is essentially an abbreviated syntax for a lambda, which is more general. Every method reference has an equivalent lambda expression. The equivalent lambdas for Invoking the `length` method on `String` using a method reference are shown in Lambda expression equivalents for method references.

Example 11. Lambda expression equivalents for method references

JAVA

```
Stream.of("this", "is", "a", "stream", "of", "strings")
        .mapToInt(s -> s.length())
        .forEach(x -> System.out.println(x));
```

As with any lambda expression, the context matters. When referring to overloaded methods, the context will determine which version is accessed using the normal type resolution mechanism. You can also use `this` or `super` as the left-side of a method reference if there is any ambiguity.

You can even invoke constructors using method references, which are shown next.

3. Constructor References

A *constructor reference* is defined by using the keyword `new` as a method reference in order to instantiate an object.

Consider a trivial POJO[1] called `Person`, as shown in A Person class, which is a simple wrapper for a string `name`.

Example 12. A Person class

JAVA

```
public class Person {
    private String name;

    public Person() {}

    public Person(String name) {
        this.name = name;
    }

    // getters and setters ...

    // equals and hashCode overrides ...

    public String toString() {
        return String.format("Person(name:%s)", name);
    }
}
```

Given a collection of strings, you can transform it into a collection of `Person` instances using the constructor reference in Transforming strings into `Person` instances.

Example 13. Transforming strings into `Person` instances

```java
List<String> names =
            Arrays.asList("Joffrey Baratheon", "Daenerys Targaryen", "Jon Snow",
                    "Arya Stark", "Tyrion Lannister", "Margaery Tyrell");

List<Person> people = names.stream()
                           .map(Person::new)   1
                           .collect(Collectors.toList());

// equivalent lambda expression
List<Person> people = names.stream()
                           .map(name -> new Person(name))
                           .collect(Collectors.toList());
```

1 Constructor reference instantiating `Person`

The syntax `Person::new` refers to the constructor in the `Person` class. As with all lambda expressions, the context determines which constructor is executed. Because the context supplies a string, the one-arg `String` constructor is used.

Constructor references can also be used with arrays. To create an array of `Person` instances, use the technique shown in Creating an array of `Person` references.

Example 14. Creating an array of `Person` references

```java
Person[] people = names.stream()
                       .map(Person::new)   1
                       .toArray(Person[]::new);   2
```

1 Constructor reference for `Person`

2 Constructor reference for an array of `Person`

The `toArray` method argument creates an array of `Person` references of the proper size and populates it with the instantiated `Person` instances.

4. Functional Interfaces in the `java.util.function` Package

A functional interface in Java 8 is an interface with a single, abstract method. As such, it can be the target for a lambda expression or method reference.

The use of the term `abstract` here is significant. Prior to Java 8, all methods in interfaces were assumed to be abstract by default — you didn't even need to add the keyword.

For example, here is the definition of an interface called `PalindromeChecker`, shown in A Palindrome Checker interface.

Example 15. A Palindrome Checker interface

JAVA

```
@FunctionalInterface
public interface PalindromeChecker {
    boolean isPalindrome(String s);
}
```

Since all methods in an interface are public, you can leave out the access modifier, and as stated you can leave out the `abstract` keyword.

Since this interface has only a single, abstract method, it is a functional interface. Java 8 provides an annotation called `@FunctionalInterface` in the `java.lang` package, that can be applied to the interface, as shown in the code.

The annotation is not required, but is a good idea, for two reasons. First, it triggers a compile-time check that this interface does, in fact, satisfy the requirement. If the interface has either zero or more than one abstract methods, the compiler will give an error.

The other benefit to adding the `@FunctionalInterface` annotation is that it generates a statement in the JavaDocs as follows:

```
Functional Interface:
This is a functional interface and can therefore be used as the assignment
target for a lambda expression or method reference.
```

Functional interfaces can have default and static methods as well. Both default and static methods have implementations, so they don't count against the single abstract method requirement. MyInterface is a functional interface with static and default methods shows an example.

Example 16. MyInterface is a functional interface with static and default methods

```java
@FunctionalInterface
public interface MyInterface {
    int myMethod();
    // int myOtherMethod();

    default String sayHello() {
        return "Hello, World";
    }

    static void myStaticMethod() {
        System.out.println("I'm a static method in an interface");
    }
}
```

Note that if the commented method `myOtherMethod` was included, the interface would no longer satisfy the requirement. The annotation would generate an error, of the form "multiple non-overriding abstract methods found".

Interfaces can extend other interfaces, and even extend multiple other interfaces. The annotation checks the current interface. So if one interface extends an existing functional interface and adds another abstract method, it is not itself a functional interface. See Extending a functional interface — no longer functional.

Example 17. Extending a functional interface — no longer functional

```java
public interface MyChildInterface extends MyInterface {
    int myOtherMethod();
}
```

The `MyChildInterface` is not a functional interface, because it has two abstract methods: `myMethod` which it inherits from `MyInterface`, and `myOtherMethod` which it declares. Without the `@FunctionalInterface` annotation, this compiles, because it's a standard interface. It cannot, however, be the target of a lambda expression.

The phrase, "target of a lambda expression" means that a reference of the interface type can be declared and a lambda expression or method reference can be assigned to the result. For example, consider Testing a palindrome checker using a lambda, a JUnit test that checks a lambda implementation of the `PalindromeChecker` interface.

Example 18. Testing a palindrome checker using a lambda

JAVA

```
import org.junit.Test;

import java.util.Arrays;
import java.util.List;

import static org.junit.Assert.assertTrue;

public class PalindromeCheckerTest {
    private List<String> palindromes = Arrays.asList(
            "Madam, in Eden, I'm Adam",
            "Flee to me, remote elf!",
            "Go hang a salami; I'm a lasagna hog",
            "A Santa pets rats, as Pat taps a star step at NASA"
    );

    @Test
    public void isPalindromeUsingLambda() throws Exception {
        palindromes.forEach(s -> {
            StringBuilder sb = new StringBuilder();
            for (char c : s.toCharArray()) {
                if (Character.isLetter(c)) {
                    sb.append(c);
                }
            }
            String forward = sb.toString().toLowerCase();
            String backward = sb.reverse().toString().toLowerCase();
            assertTrue(forward.equals(backward));
        });
    }
}
```

The test uses the default method `forEach` on the list to iterate over the collection, passing each string to the given lambda expression. At the end of the expression is the static `assertTrue` method (note the static import) that checks the results. The `forEach` method takes a `Consumer` as an argument, which means the supplied lambda expression must take one argument and return nothing.

This is still fairly complicated, but since we know an implementation, it can be added to the interface itself, as in A palindrome checker with a static implementation method.

Example 19. A palindrome checker with a static implementation method

JAVA

```
@FunctionalInterface
public interface PalindromeChecker {
    boolean isPalidrome(String s);

    static boolean checkPalindrome(String s) {
        StringBuilder sb = new StringBuilder();
        for (char c : s.toCharArray()) {
            if (Character.isLetter(c)) {
                sb.append(c);
            }
        }
        String forward = sb.toString().toLowerCase();
        String backward = sb.reverse().toString().toLowerCase();
        return forward.equals(backward);
    }
}
```

The existence of the static method doesn't change the fact that the interface is functional. To test this, see the test method in Added test method to check the implementation.

Example 20. Added test method to check the implementation

JAVA

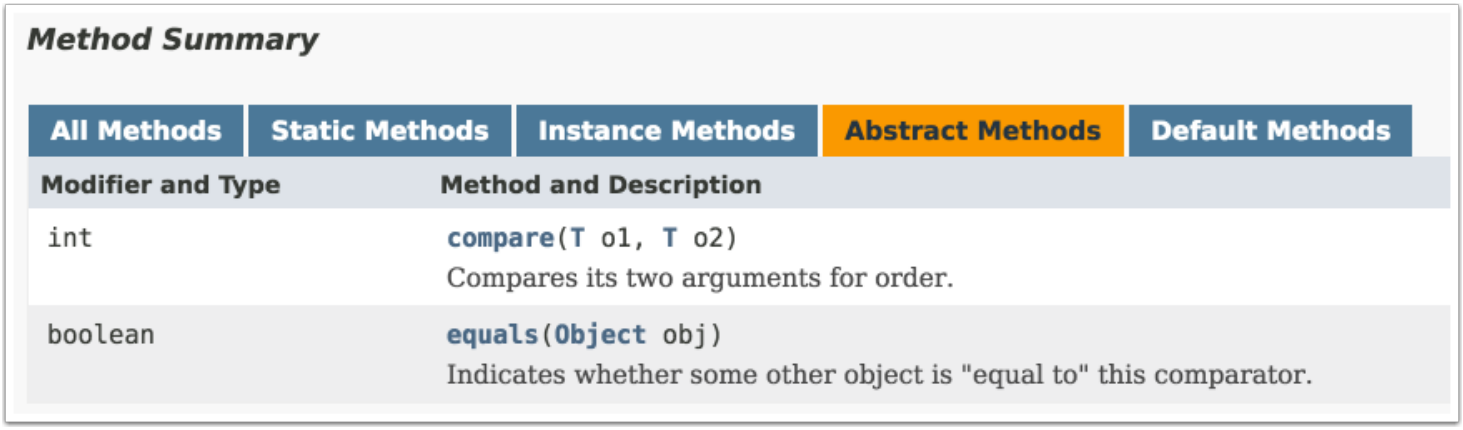
```
@Test
public void isPalidromeUsingMethodRef() throws Exception {
    assertTrue(
        palindromes.stream()
            .allMatch(PalindromeChecker::checkPalindrome));

    assertFalse(
        PalindromeChecker.checkPalindrome("This is NOT a palindrome"));
}
```

The `allMatch` method on `Stream` takes a `Predicate`, another of the functional interfaces in the `java.util.function` package. A `Predicate` takes a single argument and returns a boolean. The `checkPalindrome` method satisfies this requirement, and here is accessed using a method reference.

The `allMatch` method returns true only if every element of the stream satisfies the predicate. Just to make sure the tested implementation doesn't simply return `true` for all cases, the `assertFalse` test checks a string that isn't a palindrome.

One edge case should also be noted. The `Comparator` interface is used for sorting, which is discussed in other recipes. If you look at the JavaDocs for that interface and select the `Abstract Methods` tab, you see the methods shown in Abstract methods in the Comparator class.



Method Summary

All Methods | Static Methods | Instance Methods | Abstract Methods | Default Methods

Modifier and Type	Method and Description
int	**compare**(T o1, T o2) Compares its two arguments for order.
boolean	**equals**(Object obj) Indicates whether some other object is "equal to" this comparator.

Figure 1. Abstract methods in the Comparator class

How can this be a functional interface if there are two abstract methods, especially if one of them is actually implemented in `java.lang.Object` ?

As it turns out, this has always been legal. You can declare methods in `Object` as abstract in an interface, but that doesn't make them abstract. Usually the reason for doing so is to add documentation that explains the contract of the interface. In the case of `Comparator` , the contract is that if two elements return `true` from the `equals` method, the `compare` method should return zero. Adding the `equals` method to `Comparator` allows the associated JavaDocs to explain that.

From a Java 8 perspective, this fortunately means that methods from `Object` don't count against the single abstract method limit, and `Comparator` is still a functional interface.

5. Default and Static Methods in Interfaces

The traditional reason Java never supported multiple inheritance is the so-called *diamond problem*. Say you have an inheritance hierarchy as shown in the (vaguely UML-like) Animal Inheritance.

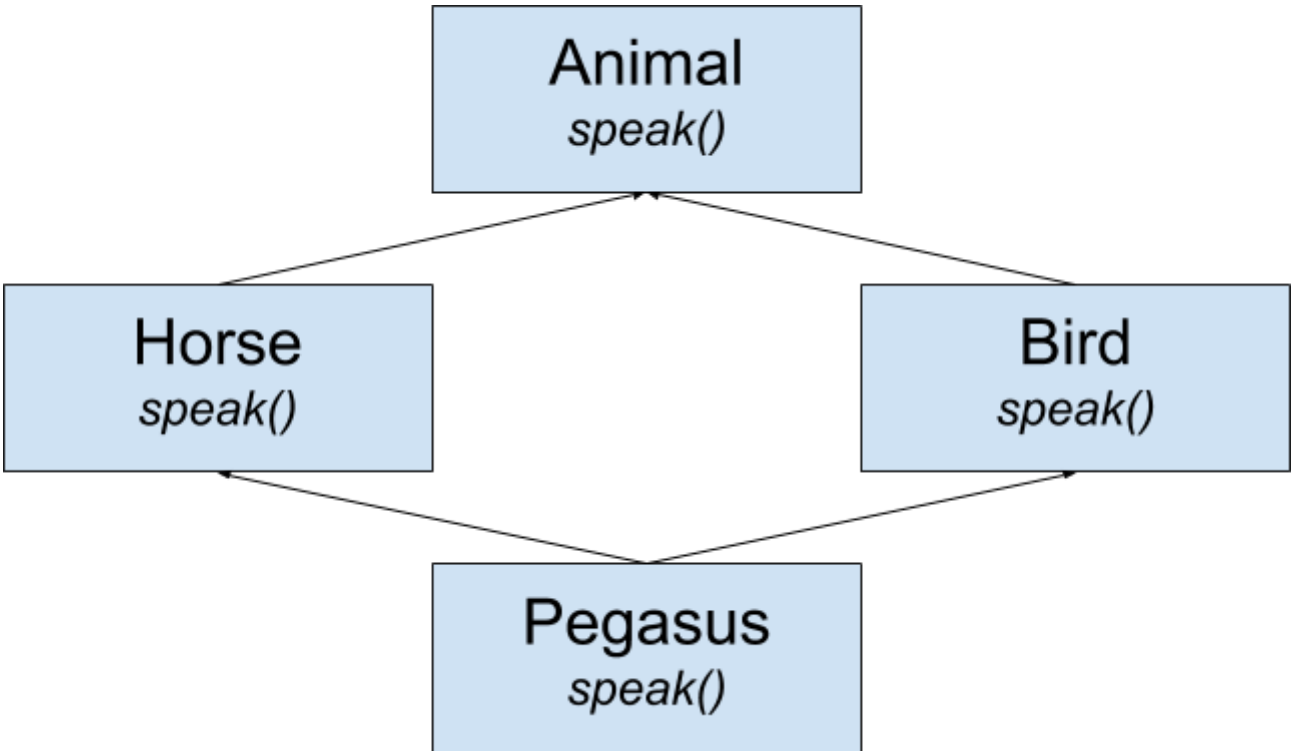


Figure 2. Animal Inheritance

Class `Animal` has two child classes, `Bird` and `Horse`, each of which override the `speak` method, in `Horse` to say "whinny" and in `Bird` to say "chirp". What, then, does `Pegasus` (who multiply inherits from both `Horse` and `Bird`)[2] say? What if you have a reference of type `Animal` assigned to an instance of `Pegasus`? What then should the `speak` method return?

JAVA

```
Animal animal = new Pegaus();
animal.speak(); // whinny, chirp, or other?
```

Different languages take different approaches to this problem. In C++, for example, multiple inheritance is allowed, but if a class inherits conflicting implementations, it won't compile. In Eiffel[3], the compiler allows you to choose which implementation you want.

Java's approach is to prohibit multiple inheritance, and interfaces are introduced as a work-around. Since interfaces have only abstract methods, there are no implementations to conflict. Multiple inheritance is even allowed with interfaces, though not very common.

The problem is, if you can never implement a method in an interface, you wind up with some awkward issues. For example, among the methods in the `java.util.Collection` interface are:

```
boolean isEmpty()
int     size()
```
JAVA

The `isEmpty` method returns true if there are no elements in the collection, and false otherwise. The `size` method returns the number of elements in the collections. Regardless of the underlying implementation, you can immediately implement the `isEmpty` method in terms of `size`, as in Implementation of isEmpty in terms of size.

Example 21. Implementation of isEmpty in terms of size

```
public boolean isEmpty() {
    return size() == 0;
}
```
JAVA

Since `Collection` is an interface, you can't do this in the interface itself. Instead, the abstract class `java.util.AbstractCollection` includes, among other code, exactly the implementation of `isEmpty` shown here. If you are creating your own collection implementation and you don't already have a superclass, you can extend `AbstractCollection` and you get the `isEmpty` method for free. If you already have a superclass, you have to implement the `Collection` interface instead and remember to provide your own implementation of `isEmpty` as well as `size`.

All of this is quite familiar to experienced Java developers, but as of Java 8 the situation changes. Now you can add implementations to interface methods. All you have to do is add the keyword `default` to a method and provide an implementation. The example in The `Employee` interface with a default method illustrates a `default` method.

Example 22. The `Employee` interface with a default method

```java
public interface Employee {
    String getFirst();

    String getLast();

    void convertCaffeineToCodeForMoney();

    default String getName() {
        return String.format("%s %s", getFirst(), getLast());
    }
}
```

The `getName` method has the keyword `default`, and its implementation is in terms of the other, abstract, methods in the interface, `getFirst` and `getLast`.

Many of the existing interfaces in Java have been enhanced with default methods. For example, `Collection` now contains the following default methods:

```java
default boolean        removeIf(Predicate<? super E> filter)
default Stream<E>             stream()
default Stream<E>             parallelStream()
default Spliterator<E> spliterator()
```

The `removeIf` method removes all elements from the collection that satisfy the `Predicate` argument, returning `true` if any elements were removed. The `stream` and `parallel` methods are factory methods for creating streams, and are discussed elsewhere in these materials. The `spliterator` method returns an object from a class that implements the `Spliterator` interface, which is an object for traversing and partitioning elements from a source.

Default methods are used the same way any other methods are used, as Using default methods shows.

Example 23. Using default methods

```java
List<Integer> nums = Arrays.asList(3, 1, 4, 1, 5, 9);
boolean removed = nums.removeIf(n -> n <= 0);   1
System.out.println("Elements were " + (removed ? "" : "NOT") + " removed");

// Iterator has a default forEach method
nums.forEach(System.out::println);
```

```
1 Calls the default method in Collection
```

What happens when a class implements two interfaces with the same default method? The short answer is that if the class implements the method itself everything is fine, because in any conflict between a class and an interface, the class always wins.

Turning now to `static` methods, the idea that that all static members of Java classes are class-level, meaning they are associated with the class as a whole rather than with a particular instance. That makes their use in interfaces odd from a philosophical point of view. After all, what does a class-level member mean when the interface is implemented by many different classes?

You access a static attribute or method using the class name. Again, what does that imply when a class implements an interface? Should the static member be accessible via the class name rather than the interface name?

Even more, if interfaces supported static members, does a class even need to implement the interface in order to use those elements?

The designers of Java could have decided these questions in several different ways. Prior to Java 8, the decision was not to allow static members in interfaces at all.

The down side of that decision is that developers created utility classes: classes that contained only static methods. A typical example is `java.util.Collections`, which contains methods for sorting and searching, wrapping collections in synchronized or unmodifiable types, and more. In the NIO package, `java.nio.file.Paths` is another example, which contains only static methods that parse `Path` instances from strings or URIs.

Now, in Java 8, you can add static methods to interfaces whenever you like. The mechanism is:

- Add the `static` keyword to the method.
- Provide an implementation (which cannot be overridden). In this they are like `default` methods, and are included in the default tab in the JavaDocs.
- Access the method using the interface name. Classes do not need to implement an interface to use its static methods.

A very common example of a static method in an interface is the `comparing` method in `java.util.Comparator`, along with its primitive variants `comparingInt`, `comparingLong`, and `comparingDouble`. The `Comparator` interface also has static methods `naturalOrder` and `reverseOrder`. Sorting strings shows how they are used.

Example 24. Sorting strings

JAVA

```
List<String> bonds = Arrays.asList("Connery", "Lazenby", "Moore", "Dalton",
        "Brosnan", "Craig");

// Sorted in natural order
List<String> sorted = bonds.stream()
    .sorted(Comparator.naturalOrder())  // same as "sorted()"
    .collect(Collectors.toList());
// [Brosnan, Connery, Craig, Dalton, Lazenby, Moore]

// Sorted in the reverse of the natural order
sorted = bonds.stream()
    .sorted(Comparator.reverseOrder())
    .collect(Collectors.toList());
// [Moore, Lazenby, Dalton, Craig, Connery, Brosnan]

// Sorted by name, all lowercase
sorted = bonds.stream()
    .sorted(Comparator.comparing(String::toLowerCase))
    .collect(Collectors.toList());
// [Brosnan, Connery, Craig, Dalton, Lazenby, Moore]

// Sorted by length
sorted = bonds.stream()
    .sorted(Comparator.comparingInt(String::length))
    .collect(Collectors.toList());
// [Moore, Craig, Dalton, Connery, Lazenby, Brosnan]

// Sorted by length then natural order
sorted = bonds.stream()
    .sorted(Comparator.comparingInt(String::length)
        .thenComparing(Comparator.naturalOrder()))
    .collect(Collectors.toList());
// [Craig, Moore, Dalton, Brosnan, Connery, Lazenby]
```

Static methods in interfaces remove the need to create separate utility classes, though that option is still available if a design calls for it.

The key points are:

- static methods must have an implementation
- you can not override a static method
- call static methods using the interface name
- you do not need to implement an interface to use its static methods

6. Streams

Java 8 introduced a new streaming metaphor to support functional programming. A stream is a sequence of elements that does not save the elements and does not modify the original source. Functional programming in Java often involves generating a stream from some source of data, passing the data through a series of intermediate operations (called a *pipeline*), and completing the process with a *terminal expression*.

Streams can only be used once. After a stream has passed through zero or more intermediate operations and reached a terminal operation, it is finished. To process the values again, you need to make a new stream.

The new `java.util.stream.Stream` interface in Java 8 provides several static methods for creating streams. Specifically, you can use the static methods `Stream.of`, `Stream.iterate`, and `Stream.generate`.

The `Stream.of` method takes a variable argument list of elements:

```
static <T> Stream<T> of(T... values)
```
JAVA

The implementation of the `of` method in the standard library actually delegates to the `stream` method in the `Arrays` class, shown in Reference implementation of Stream.of.

Example 25. Reference implementation of Stream.of

```
@SafeVarargs
public static<T> Stream<T> of(T... values) {
    return Arrays.stream(values);
}
```
JAVA

The `@SafeVarargs` annotation is part of Java generics. It comes up when you have an array as an argument, because it is possible to assign a typed array to an `Object` array and then violate type safety with an added element. The `@SafeVarargs` annotation tells the compiler that the developer promises not to do that.

As a trivial example, see Creating a stream using Stream.of.

Since streams do not process any data until a terminal expression is reached, each of the examples in this section will add the `collect` method at the end.

Example 26. Creating a stream using Stream.of

```java
String names = Stream.of("Gomez", "Morticia", "Wednesday", "Pugsley")
    .collect(Collectors.joining(","));
System.out.println(names);
// prints Gomez,Morticia,Wednesday,Pugsley
```

The API also includes an overloaded `of` method that takes a single element `T t`. This method returns a singleton sequential stream containing a single element.

Speaking of the `Arrays.stream` method, Creating a stream using Arrays.stream shows an example.

Example 27. Creating a stream using Arrays.stream

```java
String[] munsters = { "Herman", "Lily", "Eddie", "Marilyn", "Grandpa" };
names = Arrays.stream(munsters)
    .collect(Collectors.joining(","));
System.out.println(names);
// prints Herman,Lily,Eddie,Marilyn,Grandpa
```

Since you have to create an array ahead of time, this approach is less convenient, but works well for variable argument lists. The API includes overloads of `Arrays.stream` for arrays of `int`, `long`, and `double`, as well as the generic type used here.

Another static factory method in the `Stream` interface is `iterate`. The signature of the `iterate` method is:

```java
static <T> Stream<T> iterate(T seed, UnaryOperator<T> f)
```

According to the JavaDocs, this method "returns an *infinite* (emphasis added) sequential, ordered `Stream` produced by iterative application of a function `f` to an initial element seed". A `UnaryOperator` is a `Function` whose single, generic input and output types are the same type. This is useful when you have a way to produce the next value of the stream from the current value, as in Creating a stream using Stream.iterate.

Example 28. Creating a stream using Stream.iterate

```
JAVA
List<BigDecimal> nums =
    Stream.iterate(BigDecimal.ONE, n -> n.add(BigDecimal.ONE) )
        .limit(10)
        .collect(Collectors.toList());
System.out.println(nums);
// prints [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
```

This example counts from one using `BigDecimal` instances. Since the resulting stream is unbounded, the intermediate operation `limit` is needed here.

The other factory method in the `Stream` class is `generate`, whose signature is:

```
JAVA
static <T> Stream<T> generate(Supplier<T> s)
```

This method produces a sequential, unordered stream by repeatedly invoking the `Supplier`. A simple example of a `Supplier` in the standard library (a method that takes no arguments but produces a return value) is the `Math.random` method, which is used in Creating a stream using Stream.generate.

Example 29. Creating a stream using Stream.generate

```
JAVA
long count = Stream.generate(Math::random)
        .limit(10)
        .count();
System.out.println(count);
// prints 10, the number of times the Supplier was invoked
```

If you already have a collection, you can take advantage of the default method `stream` that has been added to the `Collection` interface, as in Creating a stream from a collection.[4]

Example 30. Creating a stream from a collection

```java
List<String> bradyBunch = Arrays.asList("Greg", "Marcia", "Peter",
    "Jan", "Bobby", "Cindy");
names = bradyBunch.stream()
        .collect(Collectors.joining(","));
System.out.println(names);
// prints Greg,Marcia,Peter,Jan,Bobby,Cindy
```

There are three child interfaces of `Stream` specifically for working with primitives: `IntStream`, `LongStream`, and `DoubleStream`. `IntStream` and `LongStream` each has two additional factory methods for creating streams, `range` and `rangeClosed`. Their method signatures from `IntStream` are (`LongStream` is similar):

```java
static IntStream  range(int startInclusive, int endExclusive)
static IntStream  rangeClosed(int startInclusive, int endInclusive)
static LongStream range(long startInclusive, long endExclusive)
static LongStream rangeClosed(long startInclusive, long endInclusive)
```

The arguments show the difference between the two: `rangeClosed` includes the end value, and `range` doesn't. Each returns a sequential, ordered stream that starts with the first argument and increments by one after that. An example of each is shown in The range and rangeClosed methods.

Example 31. The range and rangeClosed methods

```java
List<Integer> ints = IntStream.range(10, 15)
    .boxed()   1
    .collect(Collectors.toList());
System.out.println(ints);
// prints [10, 11, 12, 13, 14]

List<Long> longs = LongStream.rangeClosed(10, 15)
    .boxed()   1
    .collect(Collectors.toList());
System.out.println(longs);
// prints [10, 11, 12, 13, 14, 15]
```

1 Necessary for Collectors to convert to generic List

The only quirk in that example is the use of the `boxed` method to convert the `int` values to `Integer` instances.

To summarize, here are the methods to create streams:

- `Stream.of(T… values)` and `Stream.of(T t)`
- `Arrays.stream(T[] array)`, with overloads for `int[]`, `double[]`, and `long[]`
- `Stream.iterate(T seed, UnaryOperator<T> f)`
- `Stream.generate(Supplier<T> s)`
- `Collection.stream()`
- Using `range` and `rangeClosed`:
  - `IntStream.range(int startInclusive, int endExclusive)`
  - `IntStream.rangeClosed(int startInclusive, int endInclusive)`
  - `LongStream.range(long startInclusive, long endExclusive)`
  - `LongStream.rangeClosed(long startInclusive, long endInclusive)`

7. Sorting

The `sorted` method on `Stream` produces a new, sorted stream using the natural ordering for the class. The natural ordering is specified by implementing the `java.util.Comparable` interface.

For example, consider sorting a collection of strings, as shown in Sorting strings lexicographically..

Example 32. Sorting strings lexicographically.

JAVA

```
private List<String> sampleStrings =
    Arrays.asList("this", "is", "a", "list", "of", "strings");

// Default sort from Java 7-
public List<String> defaultSort() {
    Collections.sort(sampleStrings);
    return sampleStrings;
}

// Default sort from Java 8+
public List<String> defaultSortUsingStreams() {
    return sampleStrings.stream()
        .sorted()
        .collect(Collectors.toList());
}
```

Java has included a utility class called `Collections` ever since the collections framework was added back in version 1.2. The static `sort` method on `Collections` takes a `List` as an argument, but returns `void`. The sort is destructive, modifying the supplied collection. This approach does not follow the functional principles supported by Java 8, which emphasize immutability.

Java 8 uses the `sorted` method on streams to do the same sorting, but produces a new stream rather than modifying the original collection. In this example, after sorting the collection, the returned list is sorted according to the natural ordering of the class. For strings, the natural ordering is lexicographical, which reduces to alphabetical when all the strings are lowercase, as in this example.

If you want to sort the strings in a different way, then there is an overloaded `sorted` method that takes a `Comparator` as an argument.

Sorting strings by length shows a length sort for strings in two different ways.

Example 33. Sorting strings by length

JAVA

```
// Sort by length with sorted
public List<String> lengthSortUsingSorted() {
    return sampleStrings.stream()
        .sorted((s1, s2) -> s1.length() - s2.length())  1
        .collect(toList());
}

// Length sort with comparingInt
public List<String> lengthSortUsingComparator() {
    return sampleStrings.stream()
        .sorted(Comparator.comparingInt(String::length))  2
        .collect(toList());
}
```

1 Using a lambda for the Comparator

2 Generating a Comparator using the comparingInt method

The argument to the `sorted` method is a `java.util.Comparator`, which is a functional interface. In `lengthSortUsingSorted`, a lambda expression is provided to implement the `compare` method in `Comparator`. In Java 7 and earlier, the implementation could be provided by an anonymous inner class, but here a lambda expression is all that is required.

The second method, `lengthSortUsingComparator`, takes advantage of one of the static methods added to the `Comparator` interface. The `comparingInt` method takes an argument of type `ToIntFunction` that transforms the string into an int, called a *keyExtractor* in the docs, and generates a `Comparator` that sorts the collection using that key.

The added default methods in `Comparator` are extremely useful. While you can write a `Comparator` that sorts by length pretty easily, when you want to sort by more than one field that can get complicated. Consider sorting the strings by length, then equal length strings alphabetically. Using the default and static methods in `Comparator`, that becomes almost trivial, as shown in Sorting by length, then equal lengths lexicographically.

Example 34. Sorting by length, then equal lengths lexicographically

```java
import static java.util.Comparator.comparing;
import static java.util.Comparator.naturalOrder;
import static java.util.Comparator.reverseOrder;
import static java.util.stream.Collectors.toList;

// class definition...

// Sort by length then alpha using sorted
public List<String> lengthSortThenAlphaSort() {
    return sampleStrings.stream()
        .sorted(comparing(String::length)
            .thenComparing(naturalOrder()))
        .collect(toList());
}

// Sort by length then reverse alpha using sorted
public List<String> lengthSortThenReverseAlphaSort() {
    return sampleStrings.stream()
        .sorted(comparing(String::length)
            .thenComparing(reverseOrder()))
        .collect(toList());
}
```

`Comparator` provides a default method called `thenComparing`. Just like `comparing`, it also takes a `Function` as an argument, known a key extractor. Chaining this to the `comparing` method returns a `Comparator` that compares by the first quantity, then equal first by the second, and so on.

Notice the static imports in this case that make the code easier to read. Once you get used to the static methods in both `Comparator` and `Collectors`, this becomes an easy way to simplify the code.

This approach works on any class, even if it does not implement `Comparable`. Consider the `Golfer` class shown in A class for golfers.

Example 35. A class for golfers

```java
public class Golfer {
    private String first;
    private String last;
    private int score;

    // constructors ...

    // getters and setters ...

    /// toString, equals, hashCode ...
}
```

To create a leader board at a tournament, it makes sense to sort by score, then by last name, and then by first name. Sorting golfers shows how to do that.

Example 36. Sorting golfers

```java
private List<Golfer> golfers = Arrays.asList(
    new Golfer("Jack", "Nicklaus", 68),
    new Golfer("Tiger", "Woods", 70),
    new Golfer("Tom", "Watson", 70),
    new Golfer("Ty", "Webb", 68),
    new Golfer("Bubba", "Watson", 70)
);

public List<Golfer> sortByScoreThenLastThenFirst() {
    golfers.stream()
        .sorted(comparingInt(Golfer::getScore)
            .thenComparing(Golfer::getLast)
            .thenComparing(Golfer::getFirst))
        .collect(toList());
}
```

The output from calling `sortByScoreThenLastThenFirst` is shown in Sorted golfers.

Example 37. Sorted golfers

```java
Golfer{first='Jack', last='Nicklaus', score=68}
Golfer{first='Ty', last='Webb', score=68}
Golfer{first='Bubba', last='Watson', score=70}
Golfer{first='Tom', last='Watson', score=70}
Golfer{first='Tiger', last='Woods', score=70}
```

The golfers are sorted by score, so Nicklaus and Webb[5] come before Woods and both Watsons. Then equal scores are sorted by last name, putting Nicklaus before Webb and Watson before Woods. Finally, equal scores and last names are sorted by first name, putting Bubba Watson before Tom Watson.

The default and static methods in `Comparator`, along with the new `sorted` method on `Stream`, makes generating complex sorts easy.

8. Partitions and Groups

Say you have a collection of strings. If you want to split them into those that have even lengths and those that have odd lengths, you can use `Collectors.partitioningBy`, as in Partitioning strings by even or odd lengths.

Example 38. Partitioning strings by even or odd lengths

JAVA

```
List<String> strings = Arrays.asList("this", "is", "a", "long", "list", "of",
        "strings", "to", "use", "as", "a", "demo");

Map<Boolean, List<String>> lengthMap = strings.stream()
        .collect(Collectors.partitioningBy(s -> s.length() % 2 == 0));

lengthMap.forEach((key,value) -> System.out.printf("%5s: %s%n", key, value));
//
// false: [a, strings, use, a]
//  true: [this, is, long, list, of, to, as, demo]
```

The signature of the two `partitioningBy` methods are:

JAVA

```
static <T> Collector<T,?,Map<Boolean,List<T>>> partitioningBy(
    Predicate<? super T> predicate)
static <T,D,A> Collector<T,?,Map<Boolean,D>>   partitioningBy(
    Predicate<? super T> predicate, Collector<? super T,A,D> downstream)
```

The first `partitioningBy` method takes a `Predicate` as an argument. It divides the elements into those that satisfy the `Predicate` and those that don't. You always get a `Map` as a result with exactly two entries: one for the values that satisfy the `Predicate`, and one for the elements that do not.

The overloaded version of the method takes a second argument of type `Collector`, called a *downstream collector*. This allows you to post-process the lists returned by the partition, and is discussed in [downstream_collectors].

The `groupingBy` method performs an operation like a "group by" statement in SQL. It returns a map where the keys are the groups and the values are lists of elements in each group. The signature for the `groupingBy` method is:

```java
static <T,K> Collector<T,?,Map<K,List<T>>> groupingBy(
    Function<? super T,? extends K> classifier)
```

The `Function` argument takes each element of the stream and extracts a property to group by. This time, rather than simply partition the strings into two categories, consider separating them by length, as in Grouping strings by length.

Example 39. Grouping strings by length

```java
List<String> strings = Arrays.asList("this", "is", "a", "long", "list", "of",
        "strings", "to", "use", "as", "a", "demo");

Map<Integer, List<String>> lengthMap = strings.stream()
        .collect(Collectors.groupingBy(String::length));

lengthMap.forEach((k,v) -> System.out.printf("%d: %s%n", k, v));
//
// 1: [a, a]
// 2: [is, of, to, as]
// 3: [use]
// 4: [this, long, list, demo]
// 7: [strings]
```

The keys in the resulting maps are the lengths of the strings (1, 2, 3, 4, and 7) and the values are lists of strings of each length.

Rather than the actual lists, you may be interested in how many fall into each category. In other words, instead of producing a `Map` whose values are `List<String>`, you might want just the numbers of element in each of the lists. The `partitioningBy` method has an overloaded version whose second argument is of type `Collector`:

```java
static <T,D,A> Collector<T,?,Map<Boolean,D>> partitioningBy(
    Predicate<? super T> predicate, Collector<? super T,A,D> downstream)
```

This is where the static `Collectors.counting` method becomes useful. Counting the partitioned strings shows how it works.

Example 40. Counting the partitioned strings

```java
Map<Boolean, Long> numberLengthMap = strings.stream()
        .collect(Collectors.partitioningBy(s -> s.length() % 2 == 0,
                 Collectors.counting()));   1

numberLengthMap.forEach((k,v) -> System.out.printf("%5s: %d%n", k, v));
//
// false: 4
//  true: 8
```

1 downstream collector

This is called a *downstream collector*, because it is post-processing the resulting lists downstream, i.e., after the partitioning operation is completed.

The `groupingBy` method also has an overload that takes a downstream collector.

```java
static <T,K,A,D> Collector<T,?,Map<K,D>>        groupingBy(Function<? super T,? extends K>
classifier, Collector<? super T,A,D> downstream)
```

Several methods in `Stream` have analogs in the `Collectors` class. Collectors methods similar to Stream methods shows how they align.

Table 1. Collectors methods similar to Stream methods

Stream	Collectors
`count`	`counting`
`map`	`mapping`
`min`	`minBy`
`max`	`maxBy`
`IntStream.sum`	`summingInt`
`DoubleStream.sum`	`summingDouble`
`LongStream.sum`	`summingLong`

Stream	Collectors
`IntStream.summarizing`	`summarizingInt`
`DoubleStream.summarizing`	`summarizingDouble`
`LongStream.summarizing`	`summarizingLong`

9. The java.time Package

The standard edition library includes two classes for handling dates and times that have been in Java from the beginning: `java.util.Date` and `java.util.Calendar`. The former is a classic example of how *not* to design a class. If you check the public API, practically all the methods are deprecated, and have been since Java 1.1 (roughly 1997). The deprecations recommend using `Calendar` instead, which isn't much fun either.

Both pre-date the addition of enums into the language, and therefore use integer constants for field like months. Both are mutable, and therefore not thread safe. To handle some issues, the library later added the `java.sql.Date` class as a subclass of the version in `java.util`, but that didn't really address the fundamental problems.

Finally, in Java SE 8, a completely new package was added that addressed everything. The `java.time` package is based on the Joda-Time library (http://www.joda.org/joda-time/), which has been used as a free, open source alternative for years. In fact, the designers of Joda-Time helped design and build the new package, and recommend that future development use it.

The new package was developed under JSR-310: Date and Time API, and supports the ISO 8601 standard. It correctly adjusts for leap years and daylight savings rules in individual regions.

This chapter contains a few recipes that illustrate the usefulness of the `java.time` package. Hopefully they will address basic questions you may have, and point you to further information wherever needed.

The classes in Date-Time all produce immutable instances, so they are thread safe. They also do not have public constructors, so each is instantiated using factory methods.

Two static, factory methods are of particular note: `now` and `of`. The `now` method is used to create an instance based on the current date or time. The `now` factory method shows an example.

Example 41. The `now` factory method

```java
import java.time.*;

public class NowFactoryMethod {
    public static void main(String[] args) {
        System.out.println("Instant.now():       " + Instant.now());
        System.out.println("LocalDate.now():     " + LocalDate.now());
        System.out.println("LocalTime.now():     " + LocalTime.now());
        System.out.println("LocalDateTime.now(): " + LocalDateTime.now());
        System.out.println("ZonedDateTime.now(): " + ZonedDateTime.now());
    }
}
```

A sample set of results are shown in The results of calling the `now` method.

Example 42. The results of calling the `now` method

```
Instant.now():       2016-08-10T04:47:50.039Z
LocalDate.now():     2016-08-10
LocalTime.now():     00:47:50.116
LocalDateTime.now(): 2016-08-10T00:47:50.116
ZonedDateTime.now(): 2016-08-10T00:47:50.117-04:00[America/New_York]
```

All output values are using the ISO 8601 standard formatting. For dates, the basic format is `yyyy-MM-dd`. For times, the format is `hh:mm:ss.sss`. The format for `LocalDateTime` combines the two, using a capital `T` as a separator. Date/times with a time zone append a numerical offset (here, `-04:00`) using UTC as a base, as well as a so-called "region id" (here, America/New_York). The output of the `toString` method in `Instant` shows the time to nanosecond precision, in "Zulu" time.

The `now` method also appears in the classes `Year`, `YearMonth`, and `ZoneId`.

The static `of` factory method is used to produce new values. For `LocalDate`, the arguments are the year, month (either the enum or an int) and the day of month. For `LocalTime`, there are several overloads, depending on how many values of the set of hour, minute, second, and nanosecond are available. The `of` method on `LocalDateTime` combines the others. Some examples are shown in The `of` method for the date/time classes.

Example 43. The `of` method for the date/time classes

```java
import java.time.LocalDate;
import java.time.LocalDateTime;
import java.time.LocalTime;
import java.time.Month;

public class OfFactoryMethod {
    public static void main(String[] args) {
        System.out.println("First landing on the Moon:");
        LocalDate moonLandingDate = LocalDate.of(1969, Month.JULY, 20);
        LocalTime moonLandingTime = LocalTime.of(20, 18);
        System.out.println("Date: " + moonLandingDate);
        System.out.println("Time: " + moonLandingTime);

        System.out.println("Neal Armstrong steps onto the surface: ");
        LocalTime walkTime = LocalTime.of(20, 2, 56, 150_000_000);
        LocalDateTime walk = LocalDateTime.of(moonLandingDate, walkTime);
        System.out.println(walk);
    }
}
```

The output of the demo in The `of` method for the date/time classes is in Output from the `of` demo.

Example 44. Output from the `of` demo

```java
First landing on the Moon:
Date: 1969-07-20
Time: 20:18
Neal Armstrong steps onto the surface:
1969-07-20T20:02:56.150
```

The last argument to the `LocalTime.of` method is nanoseconds, so this example used a feature from Java 7 where you can insert an underscore inside a numerical value for readability.

The `Instant` class models a single, instantaneous point along the time line.

The `ZonedDateTime` class combines dates and times with time zone information from the `ZoneId` class. Time zones are expressed relative to UTC.

There are two enums in the package: `Month` and `DayOfWeek`. `Month` has constants for each month in the standard calendar (`JANUARY` through `DECEMBER`), whose integer values start at 1.[6] The API recommends that you use the the enum constants rather than the int value if at all possible. `Month` also has many convenient methods, as shown in Some methods in the `Month` enum.

Example 45. Some methods in the `Month` enum

```java
import java.time.Month;

public class MonthMethods {
    public static void main(String[] args) {
        System.out.println("Days in Feb in a leap year: " +
                Month.FEBRUARY.length(true));
        System.out.println("Day of year for first day of Aug (leap year): " +
                Month.AUGUST.firstDayOfYear(true));
        System.out.println("Month.of(1): " + Month.of(1));
        System.out.println("Adding two months: " + Month.JANUARY.plus(2));
        System.out.println("Subtracting a month: " + Month.MARCH.minus(1));
    }
}
```

The output of Some methods in the `Month` enum is shown in Output of `Month` methods demo.

Example 46. Output of `Month` methods demo

```
Days in Feb in a leap year: 29
Day of year for first day of Aug (leap year): 214
Month.of(1): JANUARY
Adding two months: MARCH
Subtracting a month: FEBRUARY
```

The last two examples, which use the `plus` and `minus` methods, create new instances.

Because the `java.time` classes are immutable, any instance method that seems to modify one, like `plus`, `minus`, or `with`, produces a new instance.

The `DayOfWeek` enum has constants representing the seven weekdays, from `MONDAY` through `SUNDAY`. Again the int value for each follows the ISO standard, so that `MONDAY` is 1 and `SUNDAY` is 7.

1. Plain Old Java Object
2. "A magnificent horse, with the brain of a bird." (Disney's *Hercules* movie, which is fun if you pretend you know nothing about Greek mythology and never heard of Hercules)
3. There's an obscure reference for you, but Eiffel was one of the foundational languages in Object-Oriented Programming.
4. Hopefully it doesn't destroy my credibility entirely to admit that I was able to recall the names of all six Brady Bunch kids without looking them up. Believe me, I'm as horrified as you are.
5. Ty Webb, of course, is from the movie *Caddyshack*, who preferred to sort golfers by height (Chevy Chase being 6 ft 5 in tall). Adding a sort by height is left as an easy exercise to the reader.
6. This is in contrast to the integer constants in the `Calendar` class, which sadly start at zero.

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