

# Core Technologies

Version 5.0.3.RELEASE

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This part of the reference documentation covers all of those technologies that are absolutely integral to the Spring Framework.

Foremost amongst these is the Spring Framework's Inversion of Control (IoC) container. A thorough treatment of the Spring Framework's IoC container is closely followed by comprehensive coverage of Spring's Aspect-Oriented Programming (AOP) technologies. The Spring Framework has its own AOP framework, which is conceptually easy to understand, and which successfully addresses the 80% sweet spot of AOP requirements in Java enterprise programming.

Coverage of Spring's integration with AspectJ (currently the richest - in terms of features - and certainly most mature AOP implementation in the Java enterprise space) is also provided.

# Chapter 1. The IoC container

## 1.1. Introduction to the Spring IoC container and beans

This chapter covers the Spring Framework implementation of the Inversion of Control (IoC) [1: See [Inversion of Control](#)] principle. IoC is also known as *dependency injection* (DI). It is a process whereby objects define their dependencies, that is, the other objects they work with, only through constructor arguments, arguments to a factory method, or properties that are set on the object instance after it is constructed or returned from a factory method. The container then *injects* those dependencies when it creates the bean. This process is fundamentally the inverse, hence the name *Inversion of Control* (IoC), of the bean itself controlling the instantiation or location of its dependencies by using direct construction of classes, or a mechanism such as the *Service Locator* pattern.

The `org.springframework.beans` and `org.springframework.context` packages are the basis for Spring Framework's IoC container. The `BeanFactory` interface provides an advanced configuration mechanism capable of managing any type of object. `ApplicationContext` is a sub-interface of `BeanFactory`. It adds easier integration with Spring's AOP features; message resource handling (for use in internationalization), event publication; and application-layer specific contexts such as the `WebApplicationContext` for use in web applications.

In short, the `BeanFactory` provides the configuration framework and basic functionality, and the `ApplicationContext` adds more enterprise-specific functionality. The `ApplicationContext` is a complete superset of the `BeanFactory`, and is used exclusively in this chapter in descriptions of Spring's IoC container. For more information on using the `BeanFactory` instead of the `ApplicationContext`, refer to [The BeanFactory](#).

In Spring, the objects that form the backbone of your application and that are managed by the Spring IoC *container* are called *beans*. A bean is an object that is instantiated, assembled, and otherwise managed by a Spring IoC container. Otherwise, a bean is simply one of many objects in your application. Beans, and the *dependencies* among them, are reflected in the *configuration metadata* used by a container.

## 1.2. Container overview

The interface `org.springframework.context.ApplicationContext` represents the Spring IoC container and is responsible for instantiating, configuring, and assembling the aforementioned beans. The container gets its instructions on what objects to instantiate, configure, and assemble by reading configuration metadata. The configuration metadata is represented in XML, Java annotations, or Java code. It allows you to express the objects that compose your application and the rich interdependencies between such objects.

Several implementations of the `ApplicationContext` interface are supplied out-of-the-box with Spring. In standalone applications it is common to create an instance of `ClassPathXmlApplicationContext` or `FileSystemXmlApplicationContext`. While XML has been the traditional format for defining configuration metadata you can instruct the container to use Java

annotations or code as the metadata format by providing a small amount of XML configuration to declaratively enable support for these additional metadata formats.

In most application scenarios, explicit user code is not required to instantiate one or more instances of a Spring IoC container. For example, in a web application scenario, a simple eight (or so) lines of boilerplate web descriptor XML in the `web.xml` file of the application will typically suffice (see [Convenient ApplicationContext instantiation for web applications](#)). If you are using the [Spring Tool Suite](#) Eclipse-powered development environment this boilerplate configuration can be easily created with few mouse clicks or keystrokes.

The following diagram is a high-level view of how Spring works. Your application classes are combined with configuration metadata so that after the `ApplicationContext` is created and initialized, you have a fully configured and executable system or application.

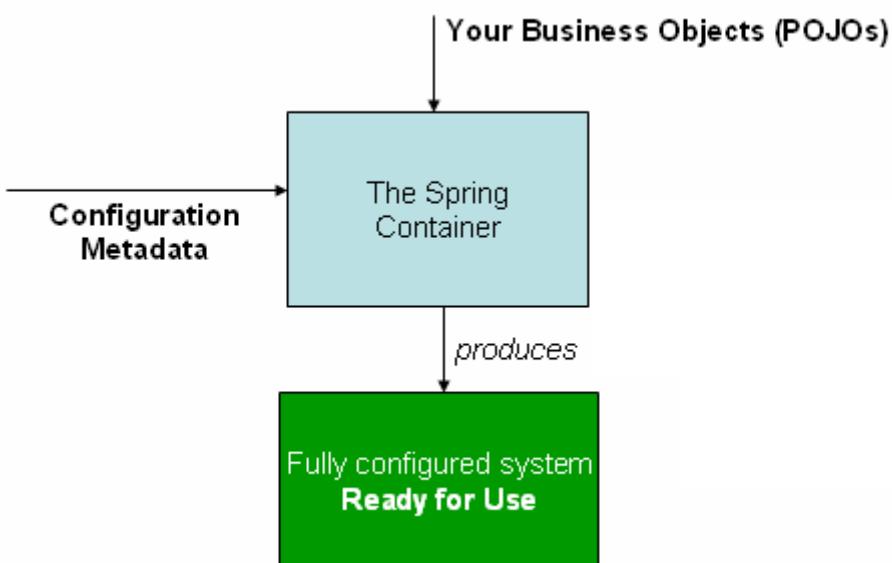


Figure 1. The Spring IoC container

### 1.2.1. Configuration metadata

As the preceding diagram shows, the Spring IoC container consumes a form of *configuration metadata*; this configuration metadata represents how you as an application developer tell the Spring container to instantiate, configure, and assemble the objects in your application.

Configuration metadata is traditionally supplied in a simple and intuitive XML format, which is what most of this chapter uses to convey key concepts and features of the Spring IoC container.



XML-based metadata is *not* the only allowed form of configuration metadata. The Spring IoC container itself is *totally* decoupled from the format in which this configuration metadata is actually written. These days many developers choose [Java-based configuration](#) for their Spring applications.

For information about using other forms of metadata with the Spring container, see:

- [Annotation-based configuration](#): Spring 2.5 introduced support for annotation-based configuration metadata.

- **Java-based configuration:** Starting with Spring 3.0, many features provided by the Spring JavaConfig project became part of the core Spring Framework. Thus you can define beans external to your application classes by using Java rather than XML files. To use these new features, see the `@Configuration`, `@Bean`, `@Import` and `@DependsOn` annotations.

Spring configuration consists of at least one and typically more than one bean definition that the container must manage. XML-based configuration metadata shows these beans configured as `<bean/>` elements inside a top-level `<beans/>` element. Java configuration typically uses `@Bean` annotated methods within a `@Configuration` class.

These bean definitions correspond to the actual objects that make up your application. Typically you define service layer objects, data access objects (DAOs), presentation objects such as Struts `Action` instances, infrastructure objects such as Hibernate `SessionFactories`, JMS `Queues`, and so forth. Typically one does not configure fine-grained domain objects in the container, because it is usually the responsibility of DAOs and business logic to create and load domain objects. However, you can use Spring's integration with AspectJ to configure objects that have been created outside the control of an IoC container. See [Using AspectJ to dependency-inject domain objects with Spring](#).

The following example shows the basic structure of XML-based configuration metadata:

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
                           http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="..." class="...">
        <!-- collaborators and configuration for this bean go here -->
    </bean>

    <bean id="..." class="...">
        <!-- collaborators and configuration for this bean go here -->
    </bean>

    <!-- more bean definitions go here -->

</beans>

```

The `id` attribute is a string that you use to identify the individual bean definition. The `class` attribute defines the type of the bean and uses the fully qualified classname. The value of the `id` attribute refers to collaborating objects. The XML for referring to collaborating objects is not shown in this example; see [Dependencies](#) for more information.

### 1.2.2. Instantiating a container

Instantiating a Spring IoC container is straightforward. The location path or paths supplied to an `ApplicationContext` constructor are actually resource strings that allow the container to load configuration metadata from a variety of external resources such as the local file system, from the Java `CLASSPATH`, and so on.

```
ApplicationContext context = new ClassPathXmlApplicationContext("services.xml",  
"daos.xml");
```



After you learn about Spring's IoC container, you may want to know more about Spring's `Resource` abstraction, as described in [Resources](#), which provides a convenient mechanism for reading an `InputStream` from locations defined in a URI syntax. In particular, `Resource` paths are used to construct applications contexts as described in [Application contexts and Resource paths](#).

The following example shows the service layer objects (`services.xml`) configuration file:

```
<?xml version="1.0" encoding="UTF-8"?>  
<beans xmlns="http://www.springframework.org/schema/beans"  
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"  
       xsi:schemaLocation="http://www.springframework.org/schema/beans  
                           http://www.springframework.org/schema/beans/spring-beans.xsd">  
  
    <!-- services -->  
  
    <bean id="petStore" class=  
          "org.springframework.samples.jpetstore.services.PetStoreServiceImpl">  
        <property name="accountDao" ref="accountDao"/>  
        <property name="itemDao" ref="itemDao"/>  
        <!-- additional collaborators and configuration for this bean go here -->  
    </bean>  
  
    <!-- more bean definitions for services go here -->  
  
</beans>
```

The following example shows the data access objects `daos.xml` file:

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="accountDao"
        class="org.springframework.samples.jpetstore.dao.jpa.JpaAccountDao">
        <!-- additional collaborators and configuration for this bean go here -->
    </bean>

    <bean id="itemDao" class=
        org.springframework.samples.jpetstore.dao.jpa.JpaItemDao">
        <!-- additional collaborators and configuration for this bean go here -->
    </bean>

    <!-- more bean definitions for data access objects go here -->
</beans>

```

In the preceding example, the service layer consists of the class `PetStoreServiceImpl`, and two data access objects of the type `JpaAccountDao` and `JpaItemDao` (based on the JPA Object/Relational mapping standard). The `property name` element refers to the name of the JavaBean property, and the `ref` element refers to the name of another bean definition. This linkage between `id` and `ref` elements expresses the dependency between collaborating objects. For details of configuring an object's dependencies, see [Dependencies](#).

## Composing XML-based configuration metadata

It can be useful to have bean definitions span multiple XML files. Often each individual XML configuration file represents a logical layer or module in your architecture.

You can use the application context constructor to load bean definitions from all these XML fragments. This constructor takes multiple `Resource` locations, as was shown in the previous section. Alternatively, use one or more occurrences of the `<import/>` element to load bean definitions from another file or files. For example:

```

<beans>
    <import resource="services.xml"/>
    <import resource="resources/messageSource.xml"/>
    <import resource="/resources/themeSource.xml"/>

    <bean id="bean1" class="..."/>
    <bean id="bean2" class="..."/>
</beans>

```

In the preceding example, external bean definitions are loaded from three files: `services.xml`, `messageSource.xml`, and `themeSource.xml`. All location paths are relative to the definition file doing

the importing, so `services.xml` must be in the same directory or classpath location as the file doing the importing, while `messageSource.xml` and `themeSource.xml` must be in a `resources` location below the location of the importing file. As you can see, a leading slash is ignored, but given that these paths are relative, it is better form not to use the slash at all. The contents of the files being imported, including the top level `<beans/>` element, must be valid XML bean definitions according to the Spring Schema.

It is possible, but not recommended, to reference files in parent directories using a relative `../"` path. Doing so creates a dependency on a file that is outside the current application. In particular, this reference is not recommended for "classpath:" URLs (for example, "classpath:../services.xml"), where the runtime resolution process chooses the "nearest" classpath root and then looks into its parent directory. Classpath configuration changes may lead to the choice of a different, incorrect directory.



You can always use fully qualified resource locations instead of relative paths: for example, "file:C:/config/services.xml" or "classpath:/config/services.xml". However, be aware that you are coupling your application's configuration to specific absolute locations. It is generally preferable to keep an indirection for such absolute locations, for example, through "\${...}" placeholders that are resolved against JVM system properties at runtime.

The import directive is a feature provided by the beans namespace itself. Further configuration features beyond plain bean definitions are available in a selection of XML namespaces provided by Spring, e.g. the "context" and the "util" namespace.

## The Groovy Bean Definition DSL

As a further example for externalized configuration metadata, bean definitions can also be expressed in Spring's Groovy Bean Definition DSL, as known from the Grails framework. Typically, such configuration will live in a ".groovy" file with a structure as follows:

```

beans {
    dataSource(BasicDataSource) {
        driverClassName = "org.hsqldb.jdbcDriver"
        url = "jdbc:hsqldb:mem:grailsDB"
        username = "sa"
        password = ""
        settings = [mynew:"setting"]
    }
    sessionFactory(SessionFactory) {
        dataSource = dataSource
    }
    myService(MyService) {
        nestedBean = { AnotherBean bean ->
            dataSource = dataSource
        }
    }
}

```

This configuration style is largely equivalent to XML bean definitions and even supports Spring's XML configuration namespaces. It also allows for importing XML bean definition files through an "importBeans" directive.

### 1.2.3. Using the container

The `ApplicationContext` is the interface for an advanced factory capable of maintaining a registry of different beans and their dependencies. Using the method `T getBean(String name, Class<T> requiredType)` you can retrieve instances of your beans.

The `ApplicationContext` enables you to read bean definitions and access them as follows:

```

// create and configure beans
ApplicationContext context = new ClassPathXmlApplicationContext("services.xml",
    "daos.xml");

// retrieve configured instance
PetStoreService service = context.getBean("petStore", PetStoreService.class);

// use configured instance
List<String> userList = service.getUsernameList();

```

With Groovy configuration, bootstrapping looks very similar, just a different context implementation class which is Groovy-aware (but also understands XML bean definitions):

```

ApplicationContext context = new GenericGroovyApplicationContext("services.groovy",
    "daos.groovy");

```

The most flexible variant is `GenericApplicationContext` in combination with reader delegates, e.g.

with `XmlBeanDefinitionReader` for XML files:

```
GenericApplicationContext context = new GenericApplicationContext();
new XmlBeanDefinitionReader(context).loadBeanDefinitions("services.xml", "daos.xml");
context.refresh();
```

Or with `GroovyBeanDefinitionReader` for Groovy files:

```
GenericApplicationContext context = new GenericApplicationContext();
new GroovyBeanDefinitionReader(context).loadBeanDefinitions("services.groovy",
"daos.groovy");
context.refresh();
```

Such reader delegates can be mixed and matched on the same `ApplicationContext`, reading bean definitions from diverse configuration sources, if desired.

You can then use `getBean` to retrieve instances of your beans. The `ApplicationContext` interface has a few other methods for retrieving beans, but ideally your application code should never use them. Indeed, your application code should have no calls to the `getBean()` method at all, and thus no dependency on Spring APIs at all. For example, Spring's integration with web frameworks provides dependency injection for various web framework components such as controllers and JSF-managed beans, allowing you to declare a dependency on a specific bean through metadata (e.g. an autowiring annotation).

## 1.3. Bean overview

A Spring IoC container manages one or more *beans*. These beans are created with the configuration metadata that you supply to the container, for example, in the form of XML `<bean/>` definitions.

Within the container itself, these bean definitions are represented as `BeanDefinition` objects, which contain (among other information) the following metadata:

- A *package-qualified class name*: typically the actual implementation class of the bean being defined.
- Bean behavioral configuration elements, which state how the bean should behave in the container (scope, lifecycle callbacks, and so forth).
- References to other beans that are needed for the bean to do its work; these references are also called *collaborators* or *dependencies*.
- Other configuration settings to set in the newly created object, for example, the number of connections to use in a bean that manages a connection pool, or the size limit of the pool.

This metadata translates to a set of properties that make up each bean definition.

Table 1. The bean definition

Property	Explained in...
class	Instantiating beans
name	Naming beans
scope	Bean scopes
constructor arguments	Dependency Injection
properties	Dependency Injection
autowiring mode	Autowiring collaborators
lazy-initialization mode	Lazy-initialized beans
initialization method	Initialization callbacks
destruction method	Destruction callbacks

In addition to bean definitions that contain information on how to create a specific bean, the `ApplicationContext` implementations also permit the registration of existing objects that are created outside the container, by users. This is done by accessing the `ApplicationContext`'s `BeanFactory` via the method `getBeanFactory()` which returns the `BeanFactory` implementation `DefaultListableBeanFactory`. `DefaultListableBeanFactory` supports this registration through the methods `registerSingleton(..)` and `registerBeanDefinition(..)`. However, typical applications work solely with beans defined through metadata bean definitions.



Bean metadata and manually supplied singleton instances need to be registered as early as possible, in order for the container to properly reason about them during autowiring and other introspection steps. While overriding of existing metadata and existing singleton instances is supported to some degree, the registration of new beans at runtime (concurrently with live access to factory) is not officially supported and may lead to concurrent access exceptions and/or inconsistent state in the bean container.

### 1.3.1. Naming beans

Every bean has one or more identifiers. These identifiers must be unique within the container that hosts the bean. A bean usually has only one identifier, but if it requires more than one, the extra ones can be considered aliases.

In XML-based configuration metadata, you use the `id` and/or `name` attributes to specify the bean identifier(s). The `id` attribute allows you to specify exactly one id. Conventionally these names are alphanumeric ('myBean', 'fooService', etc.), but may contain special characters as well. If you want to introduce other aliases to the bean, you can also specify them in the `name` attribute, separated by a comma (,), semicolon (;), or white space. As a historical note, in versions prior to Spring 3.1, the `id` attribute was defined as an `xsd:ID` type, which constrained possible characters. As of 3.1, it is defined as an `xsd:string` type. Note that bean `id` uniqueness is still enforced by the container, though no longer by XML parsers.

You are not required to supply a name or id for a bean. If no name or id is supplied explicitly, the container generates a unique name for that bean. However, if you want to refer to that bean by name, through the use of the `ref` element or `Service Locator` style lookup, you must provide a name.

Motivations for not supplying a name are related to using [inner beans](#) and [autowiring collaborators](#).

## Bean Naming Conventions

The convention is to use the standard Java convention for instance field names when naming beans. That is, bean names start with a lowercase letter, and are camel-cased from then on. Examples of such names would be (without quotes) '`accountManager`', '`accountService`', '`userDao`', '`loginController`', and so forth.

Naming beans consistently makes your configuration easier to read and understand, and if you are using Spring AOP it helps a lot when applying advice to a set of beans related by name.



With component scanning in the classpath, Spring generates bean names for unnamed components, following the rules above: essentially, taking the simple class name and turning its initial character to lower-case. However, in the (unusual) special case when there is more than one character and both the first and second characters are upper case, the original casing gets preserved. These are the same rules as defined by `java.beans.Introspector.decapitalize` (which Spring is using here).

### Aliasing a bean outside the bean definition

In a bean definition itself, you can supply more than one name for the bean, by using a combination of up to one name specified by the `id` attribute, and any number of other names in the `name` attribute. These names can be equivalent aliases to the same bean, and are useful for some situations, such as allowing each component in an application to refer to a common dependency by using a bean name that is specific to that component itself.

Specifying all aliases where the bean is actually defined is not always adequate, however. It is sometimes desirable to introduce an alias for a bean that is defined elsewhere. This is commonly the case in large systems where configuration is split amongst each subsystem, each subsystem having its own set of object definitions. In XML-based configuration metadata, you can use the `<alias>` element to accomplish this.

```
<alias name="fromName" alias="toName"/>
```

In this case, a bean in the same container which is named `fromName`, may also, after the use of this alias definition, be referred to as `toName`.

For example, the configuration metadata for subsystem A may refer to a `DataSource` via the name `subsystemA-dataSource`. The configuration metadata for subsystem B may refer to a `DataSource` via the name `subsystemB-dataSource`. When composing the main application that uses both these subsystems the main application refers to the `DataSource` via the name `myApp-dataSource`. To have all three names refer to the same object you add to the `MyApp` configuration metadata the

following aliases definitions:

```
<alias name="subsystemA-dataSource" alias="subsystemB-dataSource"/>
<alias name="subsystemA-dataSource" alias="myApp-dataSource" />
```

Now each component and the main application can refer to the dataSource through a name that is unique and guaranteed not to clash with any other definition (effectively creating a namespace), yet they refer to the same bean.

## Java-configuration

If you are using Java-configuration, the `@Bean` annotation can be used to provide aliases see [Using the @Bean annotation](#) for details.

### 1.3.2. Instantiating beans

A bean definition essentially is a recipe for creating one or more objects. The container looks at the recipe for a named bean when asked, and uses the configuration metadata encapsulated by that bean definition to create (or acquire) an actual object.

If you use XML-based configuration metadata, you specify the type (or class) of object that is to be instantiated in the `class` attribute of the `<bean/>` element. This `class` attribute, which internally is a `Class` property on a `BeanDefinition` instance, is usually mandatory. (For exceptions, see [Instantiation using an instance factory method](#) and [Bean definition inheritance](#).) You use the `Class` property in one of two ways:

- Typically, to specify the bean class to be constructed in the case where the container itself directly creates the bean by calling its constructor reflectively, somewhat equivalent to Java code using the `new` operator.
- To specify the actual class containing the `static` factory method that will be invoked to create the object, in the less common case where the container invokes a `static factory` method on a class to create the bean. The object type returned from the invocation of the `static` factory method may be the same class or another class entirely.

### *Inner class names*

If you want to configure a bean definition for a `static` nested class, you have to use the *binary* name of the nested class.

For example, if you have a class called `Foo` in the `com.example` package, and this `Foo` class has a `static` nested class called `Bar`, the value of the '`class`' attribute on a bean definition would be...

```
com.example.Foo$Bar
```

Notice the use of the `$` character in the name to separate the nested class name from the outer class name.

## Instantiation with a constructor

When you create a bean by the constructor approach, all normal classes are usable by and compatible with Spring. That is, the class being developed does not need to implement any specific interfaces or to be coded in a specific fashion. Simply specifying the bean class should suffice. However, depending on what type of IoC you use for that specific bean, you may need a default (empty) constructor.

The Spring IoC container can manage virtually *any* class you want it to manage; it is not limited to managing true JavaBeans. Most Spring users prefer actual JavaBeans with only a default (no-argument) constructor and appropriate setters and getters modeled after the properties in the container. You can also have more exotic non-bean-style classes in your container. If, for example, you need to use a legacy connection pool that absolutely does not adhere to the JavaBean specification, Spring can manage it as well.

With XML-based configuration metadata you can specify your bean class as follows:

```
<bean id="exampleBean" class="examples.ExampleBean"/>  
  
<bean name="anotherExample" class="examples.ExampleBeanTwo"/>
```

For details about the mechanism for supplying arguments to the constructor (if required) and setting object instance properties after the object is constructed, see [Injecting Dependencies](#).

## Instantiation with a static factory method

When defining a bean that you create with a static factory method, you use the `class` attribute to specify the class containing the `static` factory method and an attribute named `factory-method` to specify the name of the factory method itself. You should be able to call this method (with optional arguments as described later) and return a live object, which subsequently is treated as if it had been created through a constructor. One use for such a bean definition is to call `static` factories in legacy code.

The following bean definition specifies that the bean will be created by calling a factory-method.

The definition does not specify the type (class) of the returned object, only the class containing the factory method. In this example, the `createInstance()` method must be a *static* method.

```
<bean id="clientService"
      class="examples.ClientService"
      factory-method="createInstance"/>
```

```
public class ClientService {
    private static ClientService clientService = new ClientService();
    private ClientService() {}

    public static ClientService createInstance() {
        return clientService;
    }
}
```

For details about the mechanism for supplying (optional) arguments to the factory method and setting object instance properties after the object is returned from the factory, see [Dependencies and configuration in detail](#).

### Instantiation using an instance factory method

Similar to instantiation through a [static factory method](#), instantiation with an instance factory method invokes a non-static method of an existing bean from the container to create a new bean. To use this mechanism, leave the `class` attribute empty, and in the `factory-bean` attribute, specify the name of a bean in the current (or parent/ancestor) container that contains the instance method that is to be invoked to create the object. Set the name of the factory method itself with the `factory-method` attribute.

```
<!-- the factory bean, which contains a method called createInstance() -->
<bean id="serviceLocator" class="examples.DefaultServiceLocator">
    <!-- inject any dependencies required by this locator bean -->
</bean>

<!-- the bean to be created via the factory bean -->
<bean id="clientService"
      factory-bean="serviceLocator"
      factory-method="createClientServiceInstance"/>
```

```

public class DefaultServiceLocator {

    private static ClientService clientService = new ClientServiceImpl();

    public ClientService createClientServiceInstance() {
        return clientService;
    }
}

```

One factory class can also hold more than one factory method as shown here:

```

<bean id="serviceLocator" class="examples.DefaultServiceLocator">
    <!-- inject any dependencies required by this locator bean -->
</bean>

<bean id="clientService"
      factory-bean="serviceLocator"
      factory-method="createClientServiceInstance"/>

<bean id="accountService"
      factory-bean="serviceLocator"
      factory-method="createAccountServiceInstance"/>

```

```

public class DefaultServiceLocator {

    private static ClientService clientService = new ClientServiceImpl();

    private static AccountService accountService = new AccountServiceImpl();

    public ClientService createClientServiceInstance() {
        return clientService;
    }

    public AccountService createAccountServiceInstance() {
        return accountService;
    }
}

```

This approach shows that the factory bean itself can be managed and configured through dependency injection (DI). See [Dependencies and configuration in detail](#).



In Spring documentation, *factory bean* refers to a bean that is configured in the Spring container that will create objects through an `instance` or `static` factory method. By contrast, `FactoryBean` (notice the capitalization) refers to a Spring-specific `FactoryBean`.

## 1.4. Dependencies

A typical enterprise application does not consist of a single object (or bean in the Spring parlance). Even the simplest application has a few objects that work together to present what the end-user sees as a coherent application. This next section explains how you go from defining a number of bean definitions that stand alone to a fully realized application where objects collaborate to achieve a goal.

### 1.4.1. Dependency Injection

*Dependency injection* (DI) is a process whereby objects define their dependencies, that is, the other objects they work with, only through constructor arguments, arguments to a factory method, or properties that are set on the object instance after it is constructed or returned from a factory method. The container then *injects* those dependencies when it creates the bean. This process is fundamentally the inverse, hence the name *Inversion of Control* (IoC), of the bean itself controlling the instantiation or location of its dependencies on its own by using direct construction of classes, or the *Service Locator* pattern.

Code is cleaner with the DI principle and decoupling is more effective when objects are provided with their dependencies. The object does not look up its dependencies, and does not know the location or class of the dependencies. As such, your classes become easier to test, in particular when the dependencies are on interfaces or abstract base classes, which allow for stub or mock implementations to be used in unit tests.

DI exists in two major variants, [Constructor-based dependency injection](#) and [Setter-based dependency injection](#).

#### Constructor-based dependency injection

*Constructor-based* DI is accomplished by the container invoking a constructor with a number of arguments, each representing a dependency. Calling a `static` factory method with specific arguments to construct the bean is nearly equivalent, and this discussion treats arguments to a constructor and to a `static` factory method similarly. The following example shows a class that can only be dependency-injected with constructor injection. Notice that there is nothing *special* about this class, it is a POJO that has no dependencies on container specific interfaces, base classes or annotations.

```

public class SimpleMovieLister {

    // the SimpleMovieLister has a dependency on a MovieFinder
    private MovieFinder movieFinder;

    // a constructor so that the Spring container can inject a MovieFinder
    public SimpleMovieLister(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // business logic that actually uses the injected MovieFinder is omitted...
}

```

### Constructor argument resolution

Constructor argument resolution matching occurs using the argument's type. If no potential ambiguity exists in the constructor arguments of a bean definition, then the order in which the constructor arguments are defined in a bean definition is the order in which those arguments are supplied to the appropriate constructor when the bean is being instantiated. Consider the following class:

```

package x.y;

public class Foo {

    public Foo(Bar bar, Baz baz) {
        // ...
    }
}

```

No potential ambiguity exists, assuming that `Bar` and `Baz` classes are not related by inheritance. Thus the following configuration works fine, and you do not need to specify the constructor argument indexes and/or types explicitly in the `<constructor-arg>` element.

```

<beans>
    <bean id="foo" class="x.y.Foo">
        <constructor-arg ref="bar"/>
        <constructor-arg ref="baz"/>
    </bean>

    <bean id="bar" class="x.y.Bar"/>

    <bean id="baz" class="x.y.Baz"/>
</beans>

```

When another bean is referenced, the type is known, and matching can occur (as was the case with the preceding example). When a simple type is used, such as `<value>true</value>`, Spring cannot

determine the type of the value, and so cannot match by type without help. Consider the following class:

```
package examples;

public class ExampleBean {

    // Number of years to calculate the Ultimate Answer
    private int years;

    // The Answer to Life, the Universe, and Everything
    private String ultimateAnswer;

    public ExampleBean(int years, String ultimateAnswer) {
        this.years = years;
        this.ultimateAnswer = ultimateAnswer;
    }
}
```

#### *Constructor argument type matching*

In the preceding scenario, the container *can* use type matching with simple types if you explicitly specify the type of the constructor argument using the `type` attribute. For example:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <constructor-arg type="int" value="7500000"/>
    <constructor-arg type="java.lang.String" value="42"/>
</bean>
```

#### *Constructor argument index*

Use the `index` attribute to specify explicitly the index of constructor arguments. For example:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <constructor-arg index="0" value="7500000"/>
    <constructor-arg index="1" value="42"/>
</bean>
```

In addition to resolving the ambiguity of multiple simple values, specifying an index resolves ambiguity where a constructor has two arguments of the same type. Note that the *index is 0 based*.

#### *Constructor argument name*

You can also use the constructor parameter name for value disambiguation:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <constructor-arg name="years" value="7500000"/>
    <constructor-arg name="ultimateAnswer" value="42"/>
</bean>
```

Keep in mind that to make this work out of the box your code must be compiled with the debug flag enabled so that Spring can look up the parameter name from the constructor. If you can't compile your code with debug flag (or don't want to) you can use [@ConstructorProperties](#) JDK annotation to explicitly name your constructor arguments. The sample class would then have to look as follows:

```
package examples;

public class ExampleBean {

    // Fields omitted

    @ConstructorProperties({"years", "ultimateAnswer"})
    public ExampleBean(int years, String ultimateAnswer) {
        this.years = years;
        this.ultimateAnswer = ultimateAnswer;
    }
}
```

## Setter-based dependency injection

*Setter-based* DI is accomplished by the container calling setter methods on your beans after invoking a no-argument constructor or no-argument `static` factory method to instantiate your bean.

The following example shows a class that can only be dependency-injected using pure setter injection. This class is conventional Java. It is a POJO that has no dependencies on container specific interfaces, base classes or annotations.

```
public class SimpleMovieLister {

    // the SimpleMovieLister has a dependency on the MovieFinder
    private MovieFinder movieFinder;

    // a setter method so that the Spring container can inject a MovieFinder
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // business logic that actually uses the injected MovieFinder is omitted...
}
```

The `ApplicationContext` supports constructor-based and setter-based DI for the beans it manages. It

also supports setter-based DI after some dependencies have already been injected through the constructor approach. You configure the dependencies in the form of a `BeanDefinition`, which you use in conjunction with `PropertyEditor` instances to convert properties from one format to another. However, most Spring users do not work with these classes directly (i.e., programmatically) but rather with XML `bean` definitions, annotated components (i.e., classes annotated with `@Component`, `@Controller`, etc.), or `@Bean` methods in Java-based `@Configuration` classes. These sources are then converted internally into instances of `BeanDefinition` and used to load an entire Spring IoC container instance.

## Constructor-based or setter-based DI?

Since you can mix constructor-based and setter-based DI, it is a good rule of thumb to use constructors for *mandatory dependencies* and setter methods or configuration methods for *optional dependencies*. Note that use of the `@Required` annotation on a setter method can be used to make the property a required dependency.

The Spring team generally advocates constructor injection as it enables one to implement application components as *immutable objects* and to ensure that required dependencies are not `null`. Furthermore constructor-injected components are always returned to client (calling) code in a fully initialized state. As a side note, a large number of constructor arguments is a *bad code smell*, implying that the class likely has too many responsibilities and should be refactored to better address proper separation of concerns.

Setter injection should primarily only be used for optional dependencies that can be assigned reasonable default values within the class. Otherwise, not-null checks must be performed everywhere the code uses the dependency. One benefit of setter injection is that setter methods make objects of that class amenable to reconfiguration or re-injection later. Management through `JMX MBeans` is therefore a compelling use case for setter injection.

Use the DI style that makes the most sense for a particular class. Sometimes, when dealing with third-party classes for which you do not have the source, the choice is made for you. For example, if a third-party class does not expose any setter methods, then constructor injection may be the only available form of DI.

## Dependency resolution process

The container performs bean dependency resolution as follows:

- The `ApplicationContext` is created and initialized with configuration metadata that describes all the beans. Configuration metadata can be specified via XML, Java code, or annotations.
- For each bean, its dependencies are expressed in the form of properties, constructor arguments, or arguments to the static-factory method if you are using that instead of a normal constructor. These dependencies are provided to the bean, *when the bean is actually created*.
- Each property or constructor argument is an actual definition of the value to set, or a reference to another bean in the container.
- Each property or constructor argument which is a value is converted from its specified format to the actual type of that property or constructor argument. By default Spring can convert a

value supplied in string format to all built-in types, such as `int`, `long`, `String`, `boolean`, etc.

The Spring container validates the configuration of each bean as the container is created. However, the bean properties themselves are not set until the bean is *actually created*. Beans that are singleton-scoped and set to be pre-instantiated (the default) are created when the container is created. Scopes are defined in [Bean scopes](#). Otherwise, the bean is created only when it is requested. Creation of a bean potentially causes a graph of beans to be created, as the bean's dependencies and its dependencies' dependencies (and so on) are created and assigned. Note that resolution mismatches among those dependencies may show up late, i.e. on first creation of the affected bean.

## Circular dependencies

If you use predominantly constructor injection, it is possible to create an unresolvable circular dependency scenario.

For example: Class A requires an instance of class B through constructor injection, and class B requires an instance of class A through constructor injection. If you configure beans for classes A and B to be injected into each other, the Spring IoC container detects this circular reference at runtime, and throws a [BeanCurrentlyInCreationException](#).

One possible solution is to edit the source code of some classes to be configured by setters rather than constructors. Alternatively, avoid constructor injection and use setter injection only. In other words, although it is not recommended, you can configure circular dependencies with setter injection.

Unlike the *typical* case (with no circular dependencies), a circular dependency between bean A and bean B forces one of the beans to be injected into the other prior to being fully initialized itself (a classic chicken/egg scenario).

You can generally trust Spring to do the right thing. It detects configuration problems, such as references to non-existent beans and circular dependencies, at container load-time. Spring sets properties and resolves dependencies as late as possible, when the bean is actually created. This means that a Spring container which has loaded correctly can later generate an exception when you request an object if there is a problem creating that object or one of its dependencies. For example, the bean throws an exception as a result of a missing or invalid property. This potentially delayed visibility of some configuration issues is why [ApplicationContext](#) implementations by default pre-instantiate singleton beans. At the cost of some upfront time and memory to create these beans before they are actually needed, you discover configuration issues when the [ApplicationContext](#) is created, not later. You can still override this default behavior so that singleton beans will lazy-initialize, rather than be pre-instantiated.

If no circular dependencies exist, when one or more collaborating beans are being injected into a dependent bean, each collaborating bean is *totally* configured prior to being injected into the dependent bean. This means that if bean A has a dependency on bean B, the Spring IoC container completely configures bean B prior to invoking the setter method on bean A. In other words, the bean is instantiated (if not a pre-instantiated singleton), its dependencies are set, and the relevant lifecycle methods (such as a [configured init method](#) or the [InitializingBean callback method](#)) are

invoked.

## Examples of dependency injection

The following example uses XML-based configuration metadata for setter-based DI. A small part of a Spring XML configuration file specifies some bean definitions:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <!-- setter injection using the nested ref element -->
    <property name="beanOne">
        <ref bean="anotherExampleBean"/>
    </property>

    <!-- setter injection using the neater ref attribute -->
    <property name="beanTwo" ref="yetAnotherBean"/>
    <property name="integerProperty" value="1"/>
</bean>

<bean id="anotherExampleBean" class="examples.AnotherBean"/>
<bean id="yetAnotherBean" class="examples.YetAnotherBean"/>
```

```
public class ExampleBean {

    private AnotherBean beanOne;

    private YetAnotherBean beanTwo;

    private int i;

    public void setBeanOne(AnotherBean beanOne) {
        this.beanOne = beanOne;
    }

    public void setBeanTwo(YetAnotherBean beanTwo) {
        this.beanTwo = beanTwo;
    }

    public void setIntegerProperty(int i) {
        this.i = i;
    }
}
```

In the preceding example, setters are declared to match against the properties specified in the XML file. The following example uses constructor-based DI:

```

<bean id="exampleBean" class="examples.ExampleBean">
    <!-- constructor injection using the nested ref element -->
    <constructor-arg>
        <ref bean="anotherExampleBean"/>
    </constructor-arg>

    <!-- constructor injection using the neater ref attribute -->
    <constructor-arg ref="yetAnotherBean"/>

    <constructor-arg type="int" value="1"/>
</bean>

<bean id="anotherExampleBean" class="examples.AnotherBean"/>
<bean id="yetAnotherBean" class="examples.YetAnotherBean"/>

```

```

public class ExampleBean {

    private AnotherBean beanOne;

    private YetAnotherBean beanTwo;

    private int i;

    public ExampleBean(
        AnotherBean anotherBean, YetAnotherBean yetAnotherBean, int i) {
        this.beanOne = anotherBean;
        this.beanTwo = yetAnotherBean;
        this.i = i;
    }
}

```

The constructor arguments specified in the bean definition will be used as arguments to the constructor of the `ExampleBean`.

Now consider a variant of this example, where instead of using a constructor, Spring is told to call a `static` factory method to return an instance of the object:

```

<bean id="exampleBean" class="examples.ExampleBean" factory-method="createInstance">
    <constructor-arg ref="anotherExampleBean"/>
    <constructor-arg ref="yetAnotherBean"/>
    <constructor-arg value="1"/>
</bean>

<bean id="anotherExampleBean" class="examples.AnotherBean"/>
<bean id="yetAnotherBean" class="examples.YetAnotherBean"/>

```

```

public class ExampleBean {

    // a private constructor
    private ExampleBean(...) {
        ...
    }

    // a static factory method; the arguments to this method can be
    // considered the dependencies of the bean that is returned,
    // regardless of how those arguments are actually used.
    public static ExampleBean createInstance (
        AnotherBean anotherBean, YetAnotherBean yetAnotherBean, int i) {

        ExampleBean eb = new ExampleBean (...);
        // some other operations...
        return eb;
    }
}

```

Arguments to the `static` factory method are supplied via `<constructor-arg/>` elements, exactly the same as if a constructor had actually been used. The type of the class being returned by the factory method does not have to be of the same type as the class that contains the `static` factory method, although in this example it is. An instance (non-static) factory method would be used in an essentially identical fashion (aside from the use of the `factory-bean` attribute instead of the `class` attribute), so details will not be discussed here.

## 1.4.2. Dependencies and configuration in detail

As mentioned in the previous section, you can define bean properties and constructor arguments as references to other managed beans (collaborators), or as values defined inline. Spring's XML-based configuration metadata supports sub-element types within its `<property/>` and `<constructor-arg/>` elements for this purpose.

### Straight values (primitives, Strings, and so on)

The `value` attribute of the `<property/>` element specifies a property or constructor argument as a human-readable string representation. Spring's `conversion service` is used to convert these values from a `String` to the actual type of the property or argument.

```

<bean id="myDataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-
method="close">
    <!-- results in a setDriverClassName(String) call -->
    <property name="driverClassName" value="com.mysql.jdbc.Driver"/>
    <property name="url" value="jdbc:mysql://localhost:3306/mydb"/>
    <property name="username" value="root"/>
    <property name="password" value="masterkaoli"/>
</bean>

```

The following example uses the [p-namespace](#) for even more succinct XML configuration.

```
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:p="http://www.springframework.org/schema/p"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
                           http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="myDataSource" class="org.apache.commons.dbcp.BasicDataSource"
          destroy-method="close"
          p:driverClassName="com.mysql.jdbc.Driver"
          p:url="jdbc:mysql://localhost:3306/mydb"
          p:username="root"
          p:password="masterkaoli"/>

</beans>
```

The preceding XML is more succinct; however, typos are discovered at runtime rather than design time, unless you use an IDE such as [IntelliJ IDEA](#) or the [Spring Tool Suite](#) (STS) that support automatic property completion when you create bean definitions. Such IDE assistance is highly recommended.

You can also configure a [java.util.Properties](#) instance as:

```
<bean id="mappings"
      class="org.springframework.beans.factory.config.PropertyPlaceholderConfigurer">

    <!-- typed as a java.util.Properties -->
    <property name="properties">
        <value>
            jdbc.driver.className=com.mysql.jdbc.Driver
            jdbc.url=jdbc:mysql://localhost:3306/mydb
        </value>
    </property>
</bean>
```

The Spring container converts the text inside the `<value>` element into a [java.util.Properties](#) instance by using the JavaBeans [PropertyEditor](#) mechanism. This is a nice shortcut, and is one of a few places where the Spring team do favor the use of the nested `<value>` element over the `value` attribute style.

### The `idref` element

The `idref` element is simply an error-proof way to pass the `id` (string value - not a reference) of another bean in the container to a `<constructor-arg/>` or `<property/>` element.

```

<bean id="theTargetBean" class="..."/>

<bean id="theClientBean" class="...">
    <property name="targetName">
        <idref bean="theTargetBean"/>
    </property>
</bean>

```

The above bean definition snippet is *exactly* equivalent (at runtime) to the following snippet:

```

<bean id="theTargetBean" class="..."/>

<bean id="client" class="...">
    <property name="targetName" value="theTargetBean"/>
</bean>

```

The first form is preferable to the second, because using the `idref` tag allows the container to validate *at deployment time* that the referenced, named bean actually exists. In the second variation, no validation is performed on the value that is passed to the `targetName` property of the `client` bean. Typos are only discovered (with most likely fatal results) when the `client` bean is actually instantiated. If the `client` bean is a `prototype` bean, this typo and the resulting exception may only be discovered long after the container is deployed.



The `local` attribute on the `idref` element is no longer supported in the 4.0 beans xsd since it does not provide value over a regular `bean` reference anymore. Simply change your existing `idref local` references to `idref bean` when upgrading to the 4.0 schema.

A common place (at least in versions earlier than Spring 2.0) where the `<idref/>` element brings value is in the configuration of `AOP interceptors` in a `ProxyFactoryBean` bean definition. Using `<idref/>` elements when you specify the interceptor names prevents you from misspelling an interceptor id.

## References to other beans (collaborators)

The `ref` element is the final element inside a `<constructor-arg/>` or `<property/>` definition element. Here you set the value of the specified property of a bean to be a reference to another bean (a collaborator) managed by the container. The referenced bean is a dependency of the bean whose property will be set, and it is initialized on demand as needed before the property is set. (If the collaborator is a singleton bean, it may be initialized already by the container.) All references are ultimately a reference to another object. Scoping and validation depend on whether you specify the id/name of the other object through the `bean`, `local`, or `parent` attributes.

Specifying the target bean through the `bean` attribute of the `<ref/>` tag is the most general form, and allows creation of a reference to any bean in the same container or parent container, regardless of whether it is in the same XML file. The value of the `bean` attribute may be the same as the `id` attribute of the target bean, or as one of the values in the `name` attribute of the target bean.

```
<ref bean="someBean"/>
```

Specifying the target bean through the `parent` attribute creates a reference to a bean that is in a parent container of the current container. The value of the `parent` attribute may be the same as either the `id` attribute of the target bean, or one of the values in the `name` attribute of the target bean, and the target bean must be in a parent container of the current one. You use this bean reference variant mainly when you have a hierarchy of containers and you want to wrap an existing bean in a parent container with a proxy that will have the same name as the parent bean.

```
<!-- in the parent context -->
<bean id="accountService" class="com.foo.SimpleAccountService">
    <!-- insert dependencies as required as here -->
</bean>
```

```
<!-- in the child (descendant) context -->
<bean id="accountService" <!-- bean name is the same as the parent bean -->
    class="org.springframework.aop.framework.ProxyFactoryBean">
        <property name="target">
            <ref parent="accountService"/> <!-- notice how we refer to the parent bean -->
        </property>
        <!-- insert other configuration and dependencies as required here -->
</bean>
```



The `local` attribute on the `ref` element is no longer supported in the 4.0 beans xsd since it does not provide value over a regular `bean` reference anymore. Simply change your existing `ref local` references to `ref bean` when upgrading to the 4.0 schema.

## Inner beans

A `<bean/>` element inside the `<property/>` or `<constructor-arg/>` elements defines a so-called *inner bean*.

```
<bean id="outer" class="...">
    <!-- instead of using a reference to a target bean, simply define the target bean
    inline -->
        <property name="target">
            <bean class="com.example.Person"> <!-- this is the inner bean -->
                <property name="name" value="Fiona Apple"/>
                <property name="age" value="25"/>
            </bean>
        </property>
    </bean>
```

An inner bean definition does not require a defined id or name; if specified, the container does not

use such a value as an identifier. The container also ignores the `scope` flag on creation: Inner beans are *always* anonymous and they are *always* created with the outer bean. It is *not* possible to inject inner beans into collaborating beans other than into the enclosing bean or to access them independently.

As a corner case, it is possible to receive destruction callbacks from a custom scope, e.g. for a request-scoped inner bean contained within a singleton bean: The creation of the inner bean instance will be tied to its containing bean, but destruction callbacks allow it to participate in the request scope's lifecycle. This is not a common scenario; inner beans typically simply share their containing bean's scope.

## Collections

In the `<list/>`, `<set/>`, `<map/>`, and `<props/>` elements, you set the properties and arguments of the Java Collection types `List`, `Set`, `Map`, and `Properties`, respectively.

```
<bean id="moreComplexObject" class="example.ComplexObject">
    <!-- results in a setAdminEmails(java.util.Properties) call -->
    <property name="adminEmails">
        <props>
            <prop key="administrator">administrator@example.org</prop>
            <prop key="support">support@example.org</prop>
            <prop key="development">development@example.org</prop>
        </props>
    </property>
    <!-- results in a setSomeList(java.util.List) call -->
    <property name="someList">
        <list>
            <value>a list element followed by a reference</value>
            <ref bean="myDataSource" />
        </list>
    </property>
    <!-- results in a setSomeMap(java.util.Map) call -->
    <property name="someMap">
        <map>
            <entry key="an entry" value="just some string"/>
            <entry key="a ref" value-ref="myDataSource"/>
        </map>
    </property>
    <!-- results in a setSomeSet(java.util.Set) call -->
    <property name="someSet">
        <set>
            <value>just some string</value>
            <ref bean="myDataSource" />
        </set>
    </property>
</bean>
```

The value of a map key or value, or a set value, can also again be any of the following elements:

```
bean | ref | idref | list | set | map | props | value | null
```

## Collection merging

The Spring container also supports the *merging* of collections. An application developer can define a parent-style `<list/>`, `<map/>`, `<set/>` or `<props/>` element, and have child-style `<list/>`, `<map/>`, `<set/>` or `<props/>` elements inherit and override values from the parent collection. That is, the child collection's values are the result of merging the elements of the parent and child collections, with the child's collection elements overriding values specified in the parent collection.

*This section on merging discusses the parent-child bean mechanism. Readers unfamiliar with parent and child bean definitions may wish to read the [relevant section](#) before continuing.*

The following example demonstrates collection merging:

```
<beans>
    <bean id="parent" abstract="true" class="example.ComplexObject">
        <property name="adminEmails">
            <props>
                <prop key="administrator">administrator@example.com</prop>
                <prop key="support">support@example.com</prop>
            </props>
        </property>
    </bean>
    <bean id="child" parent="parent">
        <property name="adminEmails">
            <!-- the merge is specified on the child collection definition -->
            <props merge="true">
                <prop key="sales">sales@example.com</prop>
                <prop key="support">support@example.co.uk</prop>
            </props>
        </property>
    </bean>
</beans>
```

Notice the use of the `merge=true` attribute on the `<props/>` element of the `adminEmails` property of the `child` bean definition. When the `child` bean is resolved and instantiated by the container, the resulting instance has an `adminEmails Properties` collection that contains the result of the merging of the child's `adminEmails` collection with the parent's `adminEmails` collection.

```
administrator=administrator@example.com
sales=sales@example.com
support=support@example.co.uk
```

The child `Properties` collection's value set inherits all property elements from the parent `<props/>`, and the child's value for the `support` value overrides the value in the parent collection.

This merging behavior applies similarly to the `<list/>`, `<map/>`, and `<set/>` collection types. In the specific case of the `<list/>` element, the semantics associated with the `List` collection type, that is, the notion of an `ordered` collection of values, is maintained; the parent's values precede all of the child list's values. In the case of the `Map`, `Set`, and `Properties` collection types, no ordering exists. Hence no ordering semantics are in effect for the collection types that underlie the associated `Map`, `Set`, and `Properties` implementation types that the container uses internally.

### Limitations of collection merging

You cannot merge different collection types (such as a `Map` and a `List`), and if you do attempt to do so an appropriate `Exception` is thrown. The `merge` attribute must be specified on the lower, inherited, child definition; specifying the `merge` attribute on a parent collection definition is redundant and will not result in the desired merging.

### Strongly-typed collection

With the introduction of generic types in Java 5, you can use strongly typed collections. That is, it is possible to declare a `Collection` type such that it can only contain `String` elements (for example). If you are using Spring to dependency-inject a strongly-typed `Collection` into a bean, you can take advantage of Spring's type-conversion support such that the elements of your strongly-typed `Collection` instances are converted to the appropriate type prior to being added to the `Collection`.

```
public class Foo {  
  
    private Map<String, Float> accounts;  
  
    public void setAccounts(Map<String, Float> accounts) {  
        this.accounts = accounts;  
    }  
}
```

```
<beans>  
    <bean id="foo" class="x.y.Foo">  
        <property name="accounts">  
            <map>  
                <entry key="one" value="9.99"/>  
                <entry key="two" value="2.75"/>  
                <entry key="six" value="3.99"/>  
            </map>  
        </property>  
    </bean>  
</beans>
```

When the `accounts` property of the `foo` bean is prepared for injection, the generics information about the element type of the strongly-typed `Map<String, Float>` is available by reflection. Thus Spring's type conversion infrastructure recognizes the various value elements as being of type `Float`, and the string values `9.99`, `2.75`, and `3.99` are converted into an actual `Float` type.

## Null and empty string values

Spring treats empty arguments for properties and the like as empty **Strings**. The following XML-based configuration metadata snippet sets the email property to the empty **String** value ("").

```
<bean class="ExampleBean">
    <property name="email" value="" />
</bean>
```

The preceding example is equivalent to the following Java code:

```
exampleBean.setEmail("");
```

The **<null/>** element handles **null** values. For example:

```
<bean class="ExampleBean">
    <property name="email">
        <null/>
    </property>
</bean>
```

The above configuration is equivalent to the following Java code:

```
exampleBean.setEmail(null);
```

## XML shortcut with the p-namespace

The p-namespace enables you to use the **bean** element's attributes, instead of nested **<property/>** elements, to describe your property values and/or collaborating beans.

Spring supports extensible configuration formats [with namespaces](#), which are based on an XML Schema definition. The **beans** configuration format discussed in this chapter is defined in an XML Schema document. However, the p-namespace is not defined in an XSD file and exists only in the core of Spring.

The following example shows two XML snippets that resolve to the same result: The first uses standard XML format and the second uses the p-namespace.

```

<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:p="http://www.springframework.org/schema/p"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
                           http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean name="classic" class="com.example.ExampleBean">
        <property name="email" value="foo@bar.com"/>
    </bean>

    <bean name="p-namespace" class="com.example.ExampleBean"
          p:email="foo@bar.com"/>
</beans>

```

The example shows an attribute in the p-namespace called email in the bean definition. This tells Spring to include a property declaration. As previously mentioned, the p-namespace does not have a schema definition, so you can set the name of the attribute to the property name.

This next example includes two more bean definitions that both have a reference to another bean:

```

<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:p="http://www.springframework.org/schema/p"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
                           http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean name="john-classic" class="com.example.Person">
        <property name="name" value="John Doe"/>
        <property name="spouse" ref="jane"/>
    </bean>

    <bean name="john-modern"
          class="com.example.Person"
          p:name="John Doe"
          p:spouse-ref="jane"/>

    <bean name="jane" class="com.example.Person">
        <property name="name" value="Jane Doe"/>
    </bean>
</beans>

```

As you can see, this example includes not only a property value using the p-namespace, but also uses a special format to declare property references. Whereas the first bean definition uses `<property name="spouse" ref="jane"/>` to create a reference from bean `john` to bean `jane`, the second bean definition uses `p:spouse-ref="jane"` as an attribute to do the exact same thing. In this case `spouse` is the property name, whereas the `-ref` part indicates that this is not a straight value but rather a reference to another bean.



The p-namespace is not as flexible as the standard XML format. For example, the format for declaring property references clashes with properties that end in Ref, whereas the standard XML format does not. We recommend that you choose your approach carefully and communicate this to your team members, to avoid producing XML documents that use all three approaches at the same time.

## XML shortcut with the c-namespace

Similar to the [XML shortcut with the p-namespace](#), the *c-namespace*, newly introduced in Spring 3.1, allows usage of inlined attributes for configuring the constructor arguments rather than nested `constructor-arg` elements.

Let's review the examples from [Constructor-based dependency injection](#) with the `c:` namespace:

```
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:c="http://www.springframework.org/schema/c"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
                           http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="bar" class="x.y.Bar"/>
    <bean id="baz" class="x.y.Baz"/>

    <!-- traditional declaration -->
    <bean id="foo" class="x.y.Foo">
        <constructor-arg ref="bar"/>
        <constructor-arg ref="baz"/>
        <constructor-arg value="foo@bar.com"/>
    </bean>

    <!-- c-namespace declaration -->
    <bean id="foo" class="x.y.Foo" c:bar-ref="bar" c:baz-ref="baz" c:email=
        "foo@bar.com"/>

</beans>
```

The `c:` namespace uses the same conventions as the `p:` one (trailing `-ref` for bean references) for setting the constructor arguments by their names. And just as well, it needs to be declared even though it is not defined in an XSD schema (but it exists inside the Spring core).

For the rare cases where the constructor argument names are not available (usually if the bytecode was compiled without debugging information), one can use fallback to the argument indexes:

```
<!-- c-namespace index declaration -->
<bean id="foo" class="x.y.Foo" c:_0-ref="bar" c:_1-ref="baz"/>
```



Due to the XML grammar, the index notation requires the presence of the leading `_` as XML attribute names cannot start with a number (even though some IDE allow it).

In practice, the constructor resolution **mechanism** is quite efficient in matching arguments so unless one really needs to, we recommend using the name notation through-out your configuration.

### Compound property names

You can use compound or nested property names when you set bean properties, as long as all components of the path except the final property name are not `null`. Consider the following bean definition.

```
<bean id="foo" class="foo.Bar">
    <property name="fred.bob.sammy" value="123" />
</bean>
```

The `foo` bean has a `fred` property, which has a `bob` property, which has a `sammy` property, and that final `sammy` property is being set to the value `123`. In order for this to work, the `fred` property of `foo`, and the `bob` property of `fred` must not be `null` after the bean is constructed, or a `NullPointerException` is thrown.

### 1.4.3. Using depends-on

If a bean is a dependency of another that usually means that one bean is set as a property of another. Typically you accomplish this with the `<ref/>` element in XML-based configuration metadata. However, sometimes dependencies between beans are less direct; for example, a static initializer in a class needs to be triggered, such as database driver registration. The `depends-on` attribute can explicitly force one or more beans to be initialized before the bean using this element is initialized. The following example uses the `depends-on` attribute to express a dependency on a single bean:

```
<bean id="beanOne" class="ExampleBean" depends-on="manager"/>
<bean id="manager" class="ManagerBean" />
```

To express a dependency on multiple beans, supply a list of bean names as the value of the `depends-on` attribute, with commas, whitespace and semicolons, used as valid delimiters:

```
<bean id="beanOne" class="ExampleBean" depends-on="manager,accountDao">
    <property name="manager" ref="manager" />
</bean>

<bean id="manager" class="ManagerBean" />
<bean id="accountDao" class="x.y.jdbc.JdbcAccountDao" />
```



The `depends-on` attribute in the bean definition can specify both an initialization time dependency and, in the case of `singleton` beans only, a corresponding destroy time dependency. Dependent beans that define a `depends-on` relationship with a given bean are destroyed first, prior to the given bean itself being destroyed. Thus `depends-on` can also control shutdown order.

#### 1.4.4. Lazy-initialized beans

By default, `ApplicationContext` implementations eagerly create and configure all `singleton` beans as part of the initialization process. Generally, this pre-instantiation is desirable, because errors in the configuration or surrounding environment are discovered immediately, as opposed to hours or even days later. When this behavior is *not* desirable, you can prevent pre-instantiation of a singleton bean by marking the bean definition as lazy-initialized. A lazy-initialized bean tells the IoC container to create a bean instance when it is first requested, rather than at startup.

In XML, this behavior is controlled by the `lazy-init` attribute on the `<bean/>` element; for example:

```
<bean id="lazy" class="com.foo.ExpensiveToCreateBean" lazy-init="true"/>
<bean name="not.lazy" class="com.foo.AnotherBean"/>
```

When the preceding configuration is consumed by an `ApplicationContext`, the bean named `lazy` is not eagerly pre-instantiated when the `ApplicationContext` is starting up, whereas the `not.lazy` bean is eagerly pre-instantiated.

However, when a lazy-initialized bean is a dependency of a singleton bean that is *not* lazy-initialized, the `ApplicationContext` creates the lazy-initialized bean at startup, because it must satisfy the singleton's dependencies. The lazy-initialized bean is injected into a singleton bean elsewhere that is not lazy-initialized.

You can also control lazy-initialization at the container level by using the `default-lazy-init` attribute on the `<beans/>` element; for example:

```
<beans default-lazy-init="true">
    <!-- no beans will be pre-instantiated... -->
</beans>
```

#### 1.4.5. Autowiring collaborators

The Spring container can *autowire* relationships between collaborating beans. You can allow Spring to resolve collaborators (other beans) automatically for your bean by inspecting the contents of the `ApplicationContext`. Autowiring has the following advantages:

- Autowiring can significantly reduce the need to specify properties or constructor arguments. (Other mechanisms such as a bean template [discussed elsewhere in this chapter](#) are also valuable in this regard.)
- Autowiring can update a configuration as your objects evolve. For example, if you need to add a

dependency to a class, that dependency can be satisfied automatically without you needing to modify the configuration. Thus autowiring can be especially useful during development, without negating the option of switching to explicit wiring when the code base becomes more stable.

When using XML-based configuration metadata [2: See [Dependency Injection](#)], you specify autowire mode for a bean definition with the `autowire` attribute of the `<bean/>` element. The autowiring functionality has four modes. You specify autowiring *per* bean and thus can choose which ones to autowire.

*Table 2. Autowiring modes*

Mode	Explanation
no	(Default) No autowiring. Bean references must be defined via a <code>ref</code> element. Changing the default setting is not recommended for larger deployments, because specifying collaborators explicitly gives greater control and clarity. To some extent, it documents the structure of a system.
byName	Autowiring by property name. Spring looks for a bean with the same name as the property that needs to be autowired. For example, if a bean definition is set to autowire by name, and it contains a <i>master</i> property (that is, it has a <code>setMaster(..)</code> method), Spring looks for a bean definition named <code>master</code> , and uses it to set the property.
byType	Allows a property to be autowired if exactly one bean of the property type exists in the container. If more than one exists, a fatal exception is thrown, which indicates that you may not use <i>byType</i> autowiring for that bean. If there are no matching beans, nothing happens; the property is not set.
constructor	Analogous to <i>byType</i> , but applies to constructor arguments. If there is not exactly one bean of the constructor argument type in the container, a fatal error is raised.

With *byType* or *constructor* autowiring mode, you can wire arrays and typed-collections. In such cases *all* autowire candidates within the container that match the expected type are provided to satisfy the dependency. You can autowire strongly-typed Maps if the expected key type is `String`. An autowired Maps values will consist of all bean instances that match the expected type, and the Maps keys will contain the corresponding bean names.

You can combine autowire behavior with dependency checking, which is performed after autowiring completes.

## Limitations and disadvantages of autowiring

Autowiring works best when it is used consistently across a project. If autowiring is not used in general, it might be confusing to developers to use it to wire only one or two bean definitions.

Consider the limitations and disadvantages of autowiring:

- Explicit dependencies in `property` and `constructor-arg` settings always override autowiring. You cannot autowire so-called *simple* properties such as primitives, `Strings`, and `Classes` (and arrays of such simple properties). This limitation is by-design.
- Autowiring is less exact than explicit wiring. Although, as noted in the above table, Spring is careful to avoid guessing in case of ambiguity that might have unexpected results, the relationships between your Spring-managed objects are no longer documented explicitly.
- Wiring information may not be available to tools that may generate documentation from a Spring container.
- Multiple bean definitions within the container may match the type specified by the setter method or constructor argument to be autowired. For arrays, collections, or Maps, this is not necessarily a problem. However for dependencies that expect a single value, this ambiguity is not arbitrarily resolved. If no unique bean definition is available, an exception is thrown.

In the latter scenario, you have several options:

- Abandon autowiring in favor of explicit wiring.
- Avoid autowiring for a bean definition by setting its `autowire-candidate` attributes to `false` as described in the next section.
- Designate a single bean definition as the *primary* candidate by setting the `primary` attribute of its `<bean/>` element to `true`.
- Implement the more fine-grained control available with annotation-based configuration, as described in [Annotation-based container configuration](#).

## Excluding a bean from autowiring

On a per-bean basis, you can exclude a bean from autowiring. In Spring's XML format, set the `autowire-candidate` attribute of the `<bean/>` element to `false`; the container makes that specific bean definition unavailable to the autowiring infrastructure (including annotation style configurations such as `@Autowired`).



The `autowire-candidate` attribute is designed to only affect type-based autowiring. It does not affect explicit references by name, which will get resolved even if the specified bean is not marked as an autowire candidate. As a consequence, autowiring by name will nevertheless inject a bean if the name matches.

You can also limit autowire candidates based on pattern-matching against bean names. The top-level `<beans/>` element accepts one or more patterns within its `default-autowire-candidates` attribute. For example, to limit autowire candidate status to any bean whose name ends with `Repository`, provide a value of `*Repository`. To provide multiple patterns, define them in a comma-separated list. An explicit value of `true` or `false` for a bean definitions `autowire-candidate` attribute

always takes precedence, and for such beans, the pattern matching rules do not apply.

These techniques are useful for beans that you never want to be injected into other beans by autowiring. It does not mean that an excluded bean cannot itself be configured using autowiring. Rather, the bean itself is not a candidate for autowiring other beans.

### 1.4.6. Method injection

In most application scenarios, most beans in the container are [singletons](#). When a singleton bean needs to collaborate with another singleton bean, or a non-singleton bean needs to collaborate with another non-singleton bean, you typically handle the dependency by defining one bean as a property of the other. A problem arises when the bean lifecycles are different. Suppose singleton bean A needs to use non-singleton (prototype) bean B, perhaps on each method invocation on A. The container only creates the singleton bean A once, and thus only gets one opportunity to set the properties. The container cannot provide bean A with a new instance of bean B every time one is needed.

A solution is to forego some inversion of control. You can [make bean A aware of the container](#) by implementing the [ApplicationContextAware](#) interface, and by [making a getBean\("B"\) call to the container](#) ask for (a typically new) bean B instance every time bean A needs it. The following is an example of this approach:

```

// a class that uses a stateful Command-style class to perform some processing
package fiona.apple;

// Spring-API imports
import org.springframework.beans.BeansException;
import org.springframework.context.ApplicationContext;
import org.springframework.context.ApplicationContextAware;

public class CommandManager implements ApplicationContextAware {

    private ApplicationContext applicationContext;

    public Object process(Map commandState) {
        // grab a new instance of the appropriate Command
        Command command = createCommand();
        // set the state on the (hopefully brand new) Command instance
        command.setState(commandState);
        return command.execute();
    }

    protected Command createCommand() {
        // notice the Spring API dependency!
        return this.applicationContext.getBean("command", Command.class);
    }

    public void setApplicationContext(
        ApplicationContext applicationContext) throws BeansException {
        this.applicationContext = applicationContext;
    }
}

```

The preceding is not desirable, because the business code is aware of and coupled to the Spring Framework. Method Injection, a somewhat advanced feature of the Spring IoC container, allows this use case to be handled in a clean fashion.

You can read more about the motivation for Method Injection in [this blog entry](#).

## Lookup method injection

Lookup method injection is the ability of the container to override methods on *container managed beans*, to return the lookup result for another named bean in the container. The lookup typically involves a prototype bean as in the scenario described in the preceding section. The Spring Framework implements this method injection by using bytecode generation from the CGLIB library to generate dynamically a subclass that overrides the method.



- For this dynamic subclassing to work, the class that the Spring bean container will subclass cannot be **final**, and the method to be overridden cannot be **final** either.
- Unit-testing a class that has an **abstract** method requires you to subclass the class yourself and to supply a stub implementation of the **abstract** method.
- Concrete methods are also necessary for component scanning which requires concrete classes to pick up.
- A further key limitation is that lookup methods won't work with factory methods and in particular not with **@Bean** methods in configuration classes, since the container is not in charge of creating the instance in that case and therefore cannot create a runtime-generated subclass on the fly.

Looking at the **CommandManager** class in the previous code snippet, you see that the Spring container will dynamically override the implementation of the **createCommand()** method. Your **CommandManager** class will not have any Spring dependencies, as can be seen in the reworked example:

```
package fiona.apple;

// no more Spring imports!

public abstract class CommandManager {

    public Object process(Object commandState) {
        // grab a new instance of the appropriate Command interface
        Command command = createCommand();
        // set the state on the (hopefully brand new) Command instance
        command.setState(commandState);
        return command.execute();
    }

    // okay... but where is the implementation of this method?
    protected abstract Command createCommand();
}
```

In the client class containing the method to be injected (the **CommandManager** in this case), the method to be injected requires a signature of the following form:

```
<public|protected> [abstract] <return-type> theMethodName(no-arguments);
```

If the method is **abstract**, the dynamically-generated subclass implements the method. Otherwise, the dynamically-generated subclass overrides the concrete method defined in the original class. For example:

```

<!-- a stateful bean deployed as a prototype (non-singleton) -->
<bean id="myCommand" class="fiona.apple.AsyncCommand" scope="prototype">
    <!-- inject dependencies here as required -->
</bean>

<!-- commandProcessor uses statefulCommandHelper -->
<bean id="commandManager" class="fiona.apple.CommandManager">
    <lookup-method name="createCommand" bean="myCommand"/>
</bean>

```

The bean identified as *commandManager* calls its own method `createCommand()` whenever it needs a new instance of the *myCommand* bean. You must be careful to deploy the *myCommand* bean as a prototype, if that is actually what is needed. If it is as a *singleton*, the same instance of the *myCommand* bean is returned each time.

Alternatively, within the annotation-based component model, you may declare a lookup method through the `@Lookup` annotation:

```

public abstract class CommandManager {

    public Object process(Object commandState) {
        Command command = createCommand();
        command.setState(commandState);
        return command.execute();
    }

    @Lookup("myCommand")
    protected abstract Command createCommand();
}

```

Or, more idiomatically, you may rely on the target bean getting resolved against the declared return type of the lookup method:

```

public abstract class CommandManager {

    public Object process(Object commandState) {
        MyCommand command = createCommand();
        command.setState(commandState);
        return command.execute();
    }

    @Lookup
    protected abstract MyCommand createCommand();
}

```

Note that you will typically declare such annotated lookup methods with a concrete stub implementation, in order for them to be compatible with Spring's component scanning rules where

abstract classes get ignored by default. This limitation does not apply in case of explicitly registered or explicitly imported bean classes.



Another way of accessing differently scoped target beans is an `ObjectFactory/Provider` injection point. Check out [Scoped beans as dependencies](#).

The interested reader may also find the `ServiceLocatorFactoryBean` (in the `org.springframework.beans.factory.config` package) to be of use.

## Arbitrary method replacement

A less useful form of method injection than lookup method injection is the ability to replace arbitrary methods in a managed bean with another method implementation. Users may safely skip the rest of this section until the functionality is actually needed.

With XML-based configuration metadata, you can use the `replaced-method` element to replace an existing method implementation with another, for a deployed bean. Consider the following class, with a method `computeValue`, which we want to override:

```
public class MyValueCalculator {  
  
    public String computeValue(String input) {  
        // some real code...  
    }  
  
    // some other methods...  
}
```

A class implementing the `org.springframework.beans.factory.support.MethodReplacer` interface provides the new method definition.

```
/**  
 * meant to be used to override the existing computeValue(String)  
 * implementation in MyValueCalculator  
 */  
public class ReplacementComputeValue implements MethodReplacer {  
  
    public Object reimplement(Object o, Method m, Object[] args) throws Throwable {  
        // get the input value, work with it, and return a computed result  
        String input = (String) args[0];  
        ...  
        return ...;  
    }  
}
```

The bean definition to deploy the original class and specify the method override would look like this:

```

<bean id="myValueCalculator" class="x.y.z.MyValueCalculator">
    <!-- arbitrary method replacement -->
    <replaced-method name="computeValue" replacer="replacementComputeValue">
        <arg-type>String</arg-type>
    </replaced-method>
</bean>

<bean id="replacementComputeValue" class="a.b.c.ReplacementComputeValue"/>

```

You can use one or more contained `<arg-type/>` elements within the `<replaced-method/>` element to indicate the method signature of the method being overridden. The signature for the arguments is necessary only if the method is overloaded and multiple variants exist within the class. For convenience, the type string for an argument may be a substring of the fully qualified type name. For example, the following all match `java.lang.String`:

```

java.lang.String
String
Str

```

Because the number of arguments is often enough to distinguish between each possible choice, this shortcut can save a lot of typing, by allowing you to type only the shortest string that will match an argument type.

## 1.5. Bean scopes

When you create a bean definition, you create a *recipe* for creating actual instances of the class defined by that bean definition. The idea that a bean definition is a recipe is important, because it means that, as with a class, you can create many object instances from a single recipe.

You can control not only the various dependencies and configuration values that are to be plugged into an object that is created from a particular bean definition, but also the *scope* of the objects created from a particular bean definition. This approach is powerful and flexible in that you can choose the scope of the objects you create through configuration instead of having to bake in the scope of an object at the Java class level. Beans can be defined to be deployed in one of a number of scopes: out of the box, the Spring Framework supports six scopes, four of which are available only if you use a web-aware `ApplicationContext`.

The following scopes are supported out of the box. You can also create a [custom scope](#).

*Table 3. Bean scopes*

Scope	Description
<code>singleton</code>	(Default) Scopes a single bean definition to a single object instance per Spring IoC container.
<code>prototype</code>	Scopes a single bean definition to any number of object instances.

Scope	Description
request	Scopes a single bean definition to the lifecycle of a single HTTP request; that is, each HTTP request has its own instance of a bean created off the back of a single bean definition. Only valid in the context of a web-aware Spring <a href="#">ApplicationContext</a> .
session	Scopes a single bean definition to the lifecycle of an HTTP <a href="#">Session</a> . Only valid in the context of a web-aware Spring <a href="#">ApplicationContext</a> .
application	Scopes a single bean definition to the lifecycle of a <a href="#">ServletContext</a> . Only valid in the context of a web-aware Spring <a href="#">ApplicationContext</a> .
websocket	Scopes a single bean definition to the lifecycle of a <a href="#">WebSocket</a> . Only valid in the context of a web-aware Spring <a href="#">ApplicationContext</a> .

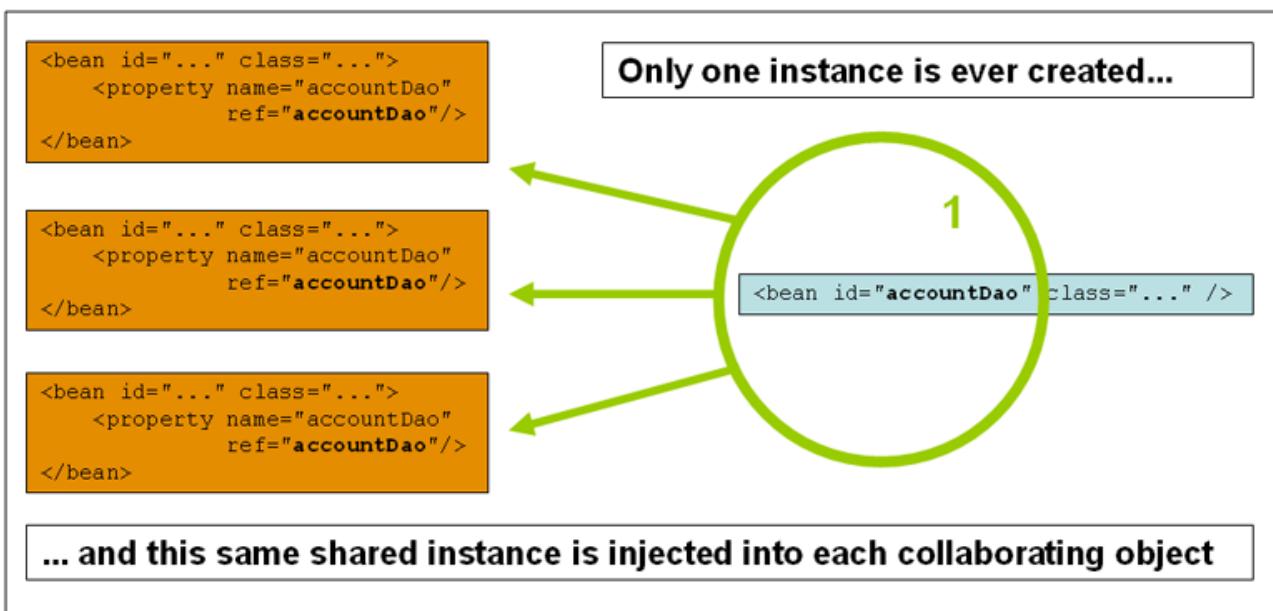


As of Spring 3.0, a *thread scope* is available, but is not registered by default. For more information, see the documentation for [SimpleThreadScope](#). For instructions on how to register this or any other custom scope, see [Using a custom scope](#).

### 1.5.1. The singleton scope

Only one *shared* instance of a singleton bean is managed, and all requests for beans with an id or ids matching that bean definition result in that one specific bean instance being returned by the Spring container.

To put it another way, when you define a bean definition and it is scoped as a singleton, the Spring IoC container creates *exactly one* instance of the object defined by that bean definition. This single instance is stored in a cache of such singleton beans, and *all subsequent requests and references* for that named bean return the cached object.



Spring's concept of a singleton bean differs from the Singleton pattern as defined in the Gang of Four (GoF) patterns book. The GoF Singleton hard-codes the scope of an object such that one *and only one* instance of a particular class is created *per ClassLoader*. The scope of the Spring singleton is best described as *per container and per bean*. This means that if you define one bean for a particular class in a single Spring container, then the Spring container creates one *and only one* instance of the class defined by that bean definition. *The singleton scope is the default scope in Spring*. To define a bean as a singleton in XML, you would write, for example:

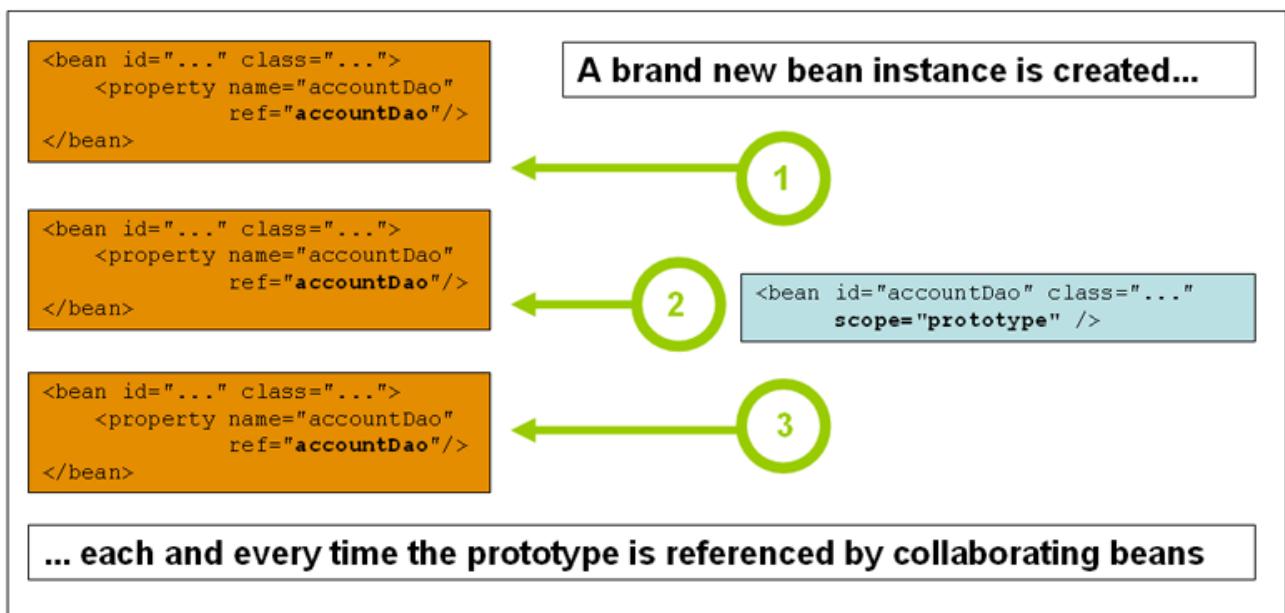
```
<bean id="accountService" class="com.foo.DefaultAccountService"/>

<!-- the following is equivalent, though redundant (singleton scope is the default)
-->
<bean id="accountService" class="com.foo.DefaultAccountService" scope="singleton"/>
```

### 1.5.2. The prototype scope

The non-singleton, prototype scope of bean deployment results in the *creation of a new bean instance* every time a request for that specific bean is made. That is, the bean is injected into another bean or you request it through a `getBean()` method call on the container. As a rule, use the prototype scope for all stateful beans and the singleton scope for stateless beans.

The following diagram illustrates the Spring prototype scope. A *data access object (DAO)* is not typically configured as a prototype, because a typical DAO does not hold any conversational state; it was just easier for this author to reuse the core of the singleton diagram.



The following example defines a bean as a prototype in XML:

```
<bean id="accountService" class="com.foo.DefaultAccountService" scope="prototype"/>
```

In contrast to the other scopes, Spring does not manage the complete lifecycle of a prototype bean:

the container instantiates, configures, and otherwise assembles a prototype object, and hands it to the client, with no further record of that prototype instance. Thus, although *initialization* lifecycle callback methods are called on all objects regardless of scope, in the case of prototypes, configured *destruction* lifecycle callbacks are *not* called. The client code must clean up prototype-scoped objects and release expensive resources that the prototype bean(s) are holding. To get the Spring container to release resources held by prototype-scoped beans, try using a custom [bean post-processor](#), which holds a reference to beans that need to be cleaned up.

In some respects, the Spring container's role in regard to a prototype-scoped bean is a replacement for the Java `new` operator. All lifecycle management past that point must be handled by the client. (For details on the lifecycle of a bean in the Spring container, see [Lifecycle callbacks](#).)

### 1.5.3. Singleton beans with prototype-bean dependencies

When you use singleton-scoped beans with dependencies on prototype beans, be aware that *dependencies are resolved at instantiation time*. Thus if you dependency-inject a prototype-scoped bean into a singleton-scoped bean, a new prototype bean is instantiated and then dependency-injected into the singleton bean. The prototype instance is the sole instance that is ever supplied to the singleton-scoped bean.

However, suppose you want the singleton-scoped bean to acquire a new instance of the prototype-scoped bean repeatedly at runtime. You cannot dependency-inject a prototype-scoped bean into your singleton bean, because that injection occurs only *once*, when the Spring container is instantiating the singleton bean and resolving and injecting its dependencies. If you need a new instance of a prototype bean at runtime more than once, see [Method injection](#)

### 1.5.4. Request, session, application, and WebSocket scopes

The `request`, `session`, `application`, and `websocket` scopes are *only* available if you use a web-aware Spring `ApplicationContext` implementation (such as `XmlWebApplicationContext`). If you use these scopes with regular Spring IoC containers such as the `ClassPathXmlApplicationContext`, an `IllegalStateException` will be thrown complaining about an unknown bean scope.

#### Initial web configuration

To support the scoping of beans at the `request`, `session`, `application`, and `websocket` levels (web-scoped beans), some minor initial configuration is required before you define your beans. (This initial setup is *not* required for the standard scopes, `singleton` and `prototype`.)

How you accomplish this initial setup depends on your particular Servlet environment.

If you access scoped beans within Spring Web MVC, in effect, within a request that is processed by the Spring `DispatcherServlet`, then no special setup is necessary: `DispatcherServlet` already exposes all relevant state.

If you use a Servlet 2.5 web container, with requests processed outside of Spring's `DispatcherServlet` (for example, when using JSF or Struts), you need to register the `org.springframework.web.context.request.RequestContextListener` `ServletRequestListener`. For Servlet 3.0+, this can be done programmatically via the `WebApplicationInitializer` interface.

Alternatively, or for older containers, add the following declaration to your web application's `web.xml` file:

```
<web-app>
  ...
  <listener>
    <listener-class>
      org.springframework.web.context.request.RequestContextListener
    </listener-class>
  </listener>
  ...
</web-app>
```

Alternatively, if there are issues with your listener setup, consider using Spring's `RequestContextFilter`. The filter mapping depends on the surrounding web application configuration, so you have to change it as appropriate.

```
<web-app>
  ...
  <filter>
    <filter-name>requestContextFilter</filter-name>
    <filter-class>org.springframework.web.filter.RequestContextFilter</filter-
class>
  </filter>
  <filter-mapping>
    <filter-name>requestContextFilter</filter-name>
    <url-pattern>/*</url-pattern>
  </filter-mapping>
  ...
</web-app>
```

`DispatcherServlet`, `RequestContextListener`, and `RequestContextFilter` all do exactly the same thing, namely bind the HTTP request object to the `Thread` that is servicing that request. This makes beans that are request- and session-scoped available further down the call chain.

## Request scope

Consider the following XML configuration for a bean definition:

```
<bean id="loginAction" class="com.foo.LoginAction" scope="request"/>
```

The Spring container creates a new instance of the `LoginAction` bean by using the `loginAction` bean definition for each and every HTTP request. That is, the `loginAction` bean is scoped at the HTTP request level. You can change the internal state of the instance that is created as much as you want, because other instances created from the same `loginAction` bean definition will not see these changes in state; they are particular to an individual request. When the request completes processing, the bean that is scoped to the request is discarded.

When using annotation-driven components or Java Config, the `@RequestScope` annotation can be used to assign a component to the `request` scope.

```
<strong>@RequestScope</strong>
@Component
public class LoginAction {
    // ...
}
```

## Session scope

Consider the following XML configuration for a bean definition:

```
<bean id="userPreferences" class="com.foo.UserPreferences" scope="session"/>
```

The Spring container creates a new instance of the `UserPreferences` bean by using the `userPreferences` bean definition for the lifetime of a single HTTP `Session`. In other words, the `userPreferences` bean is effectively scoped at the HTTP `Session` level. As with `request-scoped` beans, you can change the internal state of the instance that is created as much as you want, knowing that other HTTP `Session` instances that are also using instances created from the same `userPreferences` bean definition do not see these changes in state, because they are particular to an individual HTTP `Session`. When the HTTP `Session` is eventually discarded, the bean that is scoped to that particular HTTP `Session` is also discarded.

When using annotation-driven components or Java Config, the `@SessionScope` annotation can be used to assign a component to the `session` scope.

```
<strong>@SessionScope</strong>
@Component
public class UserPreferences {
    // ...
}
```

## Application scope

Consider the following XML configuration for a bean definition:

```
<bean id="appPreferences" class="com.foo.AppPreferences" scope="application"/>
```

The Spring container creates a new instance of the `AppPreferences` bean by using the `appPreferences` bean definition once for the entire web application. That is, the `appPreferences` bean is scoped at the `ServletContext` level, stored as a regular `ServletContext` attribute. This is somewhat similar to a Spring singleton bean but differs in two important ways: It is a singleton per `ServletContext`, not per Spring 'ApplicationContext' (for which there may be several in any given web application), and it is actually exposed and therefore visible as a `ServletContext` attribute.

When using annotation-driven components or Java Config, the `@ApplicationScope` annotation can be used to assign a component to the `application` scope.

```
<strong>@ApplicationScope</strong>
@Component
public class AppPreferences {
    // ...
}
```

## Scoped beans as dependencies

The Spring IoC container manages not only the instantiation of your objects (beans), but also the wiring up of collaborators (or dependencies). If you want to inject (for example) an HTTP request scoped bean into another bean of a longer-lived scope, you may choose to inject an AOP proxy in place of the scoped bean. That is, you need to inject a proxy object that exposes the same public interface as the scoped object but that can also retrieve the real target object from the relevant scope (such as an HTTP request) and delegate method calls onto the real object.

You may also use `<aop:scoped-proxy/>` between beans that are scoped as `singleton`, with the reference then going through an intermediate proxy that is serializable and therefore able to re-obtain the target singleton bean on deserialization.

When declaring `<aop:scoped-proxy/>` against a bean of scope `prototype`, every method call on the shared proxy will lead to the creation of a new target instance which the call is then being forwarded to.

Also, scoped proxies are not the only way to access beans from shorter scopes in a lifecycle-safe fashion. You may also simply declare your injection point (i.e. the constructor/setter argument or autowired field) as `ObjectFactory<MyTargetBean>`, allowing for a `get0bject()` call to retrieve the current instance on demand every time it is needed - without holding on to the instance or storing it separately.

As an extended variant, you may declare `ObjectProvider<MyTargetBean>` which delivers several additional access variants, including `getIfAvailable` and `getIfUnique`.

The JSR-330 variant of this is called `Provider`, used with a `Provider<MyTargetBean>` declaration and a corresponding `get()` call for every retrieval attempt. See [here](#) for more details on JSR-330 overall.

The configuration in the following example is only one line, but it is important to understand the "why" as well as the "how" behind it.



```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <!-- an HTTP Session-scoped bean exposed as a proxy -->
    <bean id="userPreferences" class="com.foo.UserPreferences" scope="session">
        <!-- instructs the container to proxy the surrounding bean -->
        <aop:scoped-proxy/>
    </bean>

    <!-- a singleton-scoped bean injected with a proxy to the above bean -->
    <bean id="userService" class="com.foo.SimpleUserService">
        <!-- a reference to the proxied userPreferences bean -->
        <property name="userPreferences" ref="userPreferences"/>
    </bean>
</beans>

```

To create such a proxy, you insert a child `<aop:scoped-proxy/>` element into a scoped bean definition (see [Choosing the type of proxy to create](#) and [XML Schema-based configuration](#)). Why do definitions of beans scoped at the `request`, `session` and custom-scope levels require the `<aop:scoped-proxy/>` element? Let's examine the following singleton bean definition and contrast it with what you need to define for the aforementioned scopes (note that the following `userPreferences` bean definition as it stands is *incomplete*).

```

<bean id="userPreferences" class="com.foo.UserPreferences" scope="session"/>

<bean id="userManager" class="com.foo.UserManager">
    <property name="userPreferences" ref="userPreferences"/>
</bean>

```

In the preceding example, the singleton bean `userManager` is injected with a reference to the HTTP Session-scoped bean `userPreferences`. The salient point here is that the `userManager` bean is a singleton: it will be instantiated *exactly once* per container, and its dependencies (in this case only one, the `userPreferences` bean) are also injected only once. This means that the `userManager` bean will only operate on the exact same `userPreferences` object, that is, the one that it was originally injected with.

This is *not* the behavior you want when injecting a shorter-lived scoped bean into a longer-lived scoped bean, for example injecting an HTTP `Session`-scoped collaborating bean as a dependency into singleton bean. Rather, you need a single `userManager` object, and for the lifetime of an HTTP `Session`, you need a `userPreferences` object that is specific to said HTTP `Session`. Thus the container creates an object that exposes the exact same public interface as the `UserPreferences` class (ideally

an object that is a `UserPreferences` instance) which can fetch the real `UserPreferences` object from the scoping mechanism (HTTP request, `Session`, etc.). The container injects this proxy object into the `userManager` bean, which is unaware that this `UserPreferences` reference is a proxy. In this example, when a `UserManager` instance invokes a method on the dependency-injected `UserPreferences` object, it actually is invoking a method on the proxy. The proxy then fetches the real `UserPreferences` object from (in this case) the HTTP `Session`, and delegates the method invocation onto the retrieved real `UserPreferences` object.

Thus you need the following, correct and complete, configuration when injecting `request-` and `session-scoped` beans into collaborating objects:

```
<bean id="userPreferences" class="com.foo.UserPreferences" scope="session">
    <aop:scoped-proxy/>
</bean>

<bean id="userManager" class="com.foo.UserManager">
    <property name="userPreferences" ref="userPreferences"/>
</bean>
```

#### Choosing the type of proxy to create

By default, when the Spring container creates a proxy for a bean that is marked up with the `<aop:scoped-proxy/>` element, a *CGLIB-based class proxy is created*.



CGLIB proxies only intercept public method calls! Do not call non-public methods on such a proxy; they will not be delegated to the actual scoped target object.

Alternatively, you can configure the Spring container to create standard JDK interface-based proxies for such scoped beans, by specifying `false` for the value of the `proxy-target-class` attribute of the `<aop:scoped-proxy/>` element. Using JDK interface-based proxies means that you do not need additional libraries in your application classpath to effect such proxying. However, it also means that the class of the scoped bean must implement at least one interface, and *that all* collaborators into which the scoped bean is injected must reference the bean through one of its interfaces.

```
<!-- DefaultUserPreferences implements the UserPreferences interface -->
<bean id="userPreferences" class="com.foo.DefaultUserPreferences" scope="session">
    <aop:scoped-proxy proxy-target-class="false"/>
</bean>

<bean id="userManager" class="com.foo.UserManager">
    <property name="userPreferences" ref="userPreferences"/>
</bean>
```

For more detailed information about choosing class-based or interface-based proxying, see [Proxying mechanisms](#).

## 1.5.5. Custom scopes

The bean scoping mechanism is extensible; You can define your own scopes, or even redefine existing scopes, although the latter is considered bad practice and you *cannot* override the built-in `singleton` and `prototype` scopes.

### Creating a custom scope

To integrate your custom scope(s) into the Spring container, you need to implement the `org.springframework.beans.factory.config.Scope` interface, which is described in this section. For an idea of how to implement your own scopes, see the `Scope` implementations that are supplied with the Spring Framework itself and the [Scope javadocs](#), which explains the methods you need to implement in more detail.

The `Scope` interface has four methods to get objects from the scope, remove them from the scope, and allow them to be destroyed.

The following method returns the object from the underlying scope. The session scope implementation, for example, returns the session-scoped bean (and if it does not exist, the method returns a new instance of the bean, after having bound it to the session for future reference).

```
Object get(String name, ObjectFactory objectFactory)
```

The following method removes the object from the underlying scope. The session scope implementation for example, removes the session-scoped bean from the underlying session. The object should be returned, but you can return null if the object with the specified name is not found.

```
Object remove(String name)
```

The following method registers the callbacks the scope should execute when it is destroyed or when the specified object in the scope is destroyed. Refer to the javadocs or a Spring scope implementation for more information on destruction callbacks.

```
void registerDestructionCallback(String name, Runnable destructionCallback)
```

The following method obtains the conversation identifier for the underlying scope. This identifier is different for each scope. For a session scoped implementation, this identifier can be the session identifier.

```
String getConversationId()
```

### Using a custom scope

After you write and test one or more custom `Scope` implementations, you need to make the Spring

container aware of your new scope(s). The following method is the central method to register a new `Scope` with the Spring container:

```
void registerScope(String scopeName, Scope scope);
```

This method is declared on the `ConfigurableBeanFactory` interface, which is available on most of the concrete `ApplicationContext` implementations that ship with Spring via the `BeanFactory` property.

The first argument to the `registerScope(..)` method is the unique name associated with a scope; examples of such names in the Spring container itself are `singleton` and `prototype`. The second argument to the `registerScope(..)` method is an actual instance of the custom `Scope` implementation that you wish to register and use.

Suppose that you write your custom `Scope` implementation, and then register it as below.



The example below uses `SimpleThreadScope` which is included with Spring, but not registered by default. The instructions would be the same for your own custom `Scope` implementations.

```
Scope threadScope = new SimpleThreadScope();
beanFactory.registerScope("thread", threadScope);
```

You then create bean definitions that adhere to the scoping rules of your custom `Scope`:

```
<bean id="..." class="..." scope="thread">
```

With a custom `Scope` implementation, you are not limited to programmatic registration of the scope. You can also do the `Scope` registration declaratively, using the `CustomScopeConfigurer` class:

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <bean class="org.springframework.beans.factory.config.CustomScopeConfigurer">
        <property name="scopes">
            <map>
                <entry key="thread">
                    <bean class="
org.springframework.context.support.SimpleThreadScope"/>
                </entry>
            </map>
        </property>
    </bean>

    <bean id="bar" class="x.y.Bar" scope="thread">
        <property name="name" value="Rick"/>
        <aop:scoped-proxy/>
    </bean>

    <bean id="foo" class="x.y.Foo">
        <property name="bar" ref="bar"/>
    </bean>

</beans>

```



When you place `<aop:scoped-proxy/>` in a `FactoryBean` implementation, it is the factory bean itself that is scoped, not the object returned from `getObject()`.

## 1.6. Customizing the nature of a bean

### 1.6.1. Lifecycle callbacks

To interact with the container's management of the bean lifecycle, you can implement the Spring `InitializingBean` and `DisposableBean` interfaces. The container calls `afterPropertiesSet()` for the former and `destroy()` for the latter to allow the bean to perform certain actions upon initialization and destruction of your beans.

The JSR-250 `@PostConstruct` and `@PreDestroy` annotations are generally considered best practice for receiving lifecycle callbacks in a modern Spring application. Using these annotations means that your beans are not coupled to Spring specific interfaces. For details see [@PostConstruct and @PreDestroy](#).



If you don't want to use the JSR-250 annotations but you are still looking to remove coupling consider the use of init-method and destroy-method object definition metadata.

Internally, the Spring Framework uses `BeanPostProcessor` implementations to process any callback interfaces it can find and call the appropriate methods. If you need custom features or other lifecycle behavior Spring does not offer out-of-the-box, you can implement a `BeanPostProcessor` yourself. For more information, see [Container Extension Points](#).

In addition to the initialization and destruction callbacks, Spring-managed objects may also implement the `Lifecycle` interface so that those objects can participate in the startup and shutdown process as driven by the container's own lifecycle.

The lifecycle callback interfaces are described in this section.

## Initialization callbacks

The `org.springframework.beans.factory.InitializingBean` interface allows a bean to perform initialization work after all necessary properties on the bean have been set by the container. The `InitializingBean` interface specifies a single method:

```
void afterPropertiesSet() throws Exception;
```

It is recommended that you do not use the `InitializingBean` interface because it unnecessarily couples the code to Spring. Alternatively, use the `@PostConstruct` annotation or specify a POJO initialization method. In the case of XML-based configuration metadata, you use the `init-method` attribute to specify the name of the method that has a void no-argument signature. With Java config, you use the `initMethod` attribute of `@Bean`, see [Receiving lifecycle callbacks](#). For example, the following:

```
<bean id="exampleInitBean" class="examples.ExampleBean" init-method="init"/>
```

```
public class ExampleBean {  
  
    public void init() {  
        // do some initialization work  
    }  
}
```

...is exactly the same as...

```
<bean id="exampleInitBean" class="examples.AnotherExampleBean"/>
```

```
public class AnotherExampleBean implements InitializingBean {  
  
    public void afterPropertiesSet() {  
        // do some initialization work  
    }  
}
```

but does not couple the code to Spring.

## Destruction callbacks

Implementing the `org.springframework.beans.factory.DisposableBean` interface allows a bean to get a callback when the container containing it is destroyed. The `DisposableBean` interface specifies a single method:

```
void destroy() throws Exception;
```

It is recommended that you do not use the `DisposableBean` callback interface because it unnecessarily couples the code to Spring. Alternatively, use the `@PreDestroy` annotation or specify a generic method that is supported by bean definitions. With XML-based configuration metadata, you use the `destroy-method` attribute on the `<bean/>`. With Java config, you use the `destroyMethod` attribute of `@Bean`, see [Receiving lifecycle callbacks](#). For example, the following definition:

```
<bean id="exampleInitBean" class="examples.ExampleBean" destroy-method="cleanup"/>
```

```
public class ExampleBean {  
  
    public void cleanup() {  
        // do some destruction work (like releasing pooled connections)  
    }  
}
```

is exactly the same as:

```
<bean id="exampleInitBean" class="examples.AnotherExampleBean"/>
```

```
public class AnotherExampleBean implements DisposableBean {  
  
    public void destroy() {  
        // do some destruction work (like releasing pooled connections)  
    }  
}
```

but does not couple the code to Spring.



The `destroy-method` attribute of a `<bean>` element can be assigned a special `(inferred)` value which instructs Spring to automatically detect a public `close` or `shutdown` method on the specific bean class (any class that implements `java.lang.AutoCloseable` or `java.io.Closeable` would therefore match). This special `(inferred)` value can also be set on the `default-destroy-method` attribute of a `<beans>` element to apply this behavior to an entire set of beans (see [Default initialization and destroy methods](#)). Note that this is the default behavior with Java config.

## Default initialization and destroy methods

When you write initialization and destroy method callbacks that do not use the Spring-specific `InitializingBean` and `DisposableBean` callback interfaces, you typically write methods with names such as `init()`, `initialize()`, `dispose()`, and so on. Ideally, the names of such lifecycle callback methods are standardized across a project so that all developers use the same method names and ensure consistency.

You can configure the Spring container to `look` for named initialization and destroy callback method names on *every* bean. This means that you, as an application developer, can write your application classes and use an initialization callback called `init()`, without having to configure an `init-method="init"` attribute with each bean definition. The Spring IoC container calls that method when the bean is created (and in accordance with the standard lifecycle callback contract described previously). This feature also enforces a consistent naming convention for initialization and destroy method callbacks.

Suppose that your initialization callback methods are named `init()` and destroy callback methods are named `destroy()`. Your class will resemble the class in the following example.

```

public class DefaultBlogService implements BlogService {

    private BlogDao blogDao;

    public void setBlogDao(BlogDao blogDao) {
        this.blogDao = blogDao;
    }

    // this is (unsurprisingly) the initialization callback method
    public void init() {
        if (this.blogDao == null) {
            throw new IllegalStateException("The [blogDao] property must be set.");
        }
    }
}

```

```

<beans default-init-method="init">

    <bean id="blogService" class="com.foo.DefaultBlogService">
        <property name="blogDao" ref="blogDao" />
    </bean>

</beans>

```

The presence of the `default-init-method` attribute on the top-level `<beans/>` element attribute causes the Spring IoC container to recognize a method called `init` on beans as the initialization method callback. When a bean is created and assembled, if the bean class has such a method, it is invoked at the appropriate time.

You configure destroy method callbacks similarly (in XML, that is) by using the `default-destroy-method` attribute on the top-level `<beans/>` element.

Where existing bean classes already have callback methods that are named at variance with the convention, you can override the default by specifying (in XML, that is) the method name using the `init-method` and `destroy-method` attributes of the `<bean/>` itself.

The Spring container guarantees that a configured initialization callback is called immediately after a bean is supplied with all dependencies. Thus the initialization callback is called on the raw bean reference, which means that AOP interceptors and so forth are not yet applied to the bean. A target bean is fully created *first, then* an AOP proxy (for example) with its interceptor chain is applied. If the target bean and the proxy are defined separately, your code can even interact with the raw target bean, bypassing the proxy. Hence, it would be inconsistent to apply the interceptors to the `init` method, because doing so would couple the lifecycle of the target bean with its proxy/interceptors and leave strange semantics when your code interacts directly to the raw target bean.

## Combining lifecycle mechanisms

As of Spring 2.5, you have three options for controlling bean lifecycle behavior: the `InitializingBean` and `DisposableBean` callback interfaces; custom `init()` and `destroy()` methods; and the `@PostConstruct` and `@PreDestroy` annotations. You can combine these mechanisms to control a given bean.



If multiple lifecycle mechanisms are configured for a bean, and each mechanism is configured with a different method name, then each configured method is executed in the order listed below. However, if the same method name is configured - for example, `init()` for an initialization method - for more than one of these lifecycle mechanisms, that method is executed once, as explained in the preceding section.

Multiple lifecycle mechanisms configured for the same bean, with different initialization methods, are called as follows:

- Methods annotated with `@PostConstruct`
- `afterPropertiesSet()` as defined by the `InitializingBean` callback interface
- A custom configured `init()` method

Destroy methods are called in the same order:

- Methods annotated with `@PreDestroy`
- `destroy()` as defined by the `DisposableBean` callback interface
- A custom configured `destroy()` method

## Startup and shutdown callbacks

The `Lifecycle` interface defines the essential methods for any object that has its own lifecycle requirements (e.g. starts and stops some background process):

```
public interface Lifecycle {  
  
    void start();  
  
    void stop();  
  
    boolean isRunning();  
}
```

Any Spring-managed object may implement that interface. Then, when the `ApplicationContext` itself receives start and stop signals, e.g. for a stop/restart scenario at runtime, it will cascade those calls to all `Lifecycle` implementations defined within that context. It does this by delegating to a `LifecycleProcessor`:

```
public interface LifecycleProcessor extends Lifecycle {  
  
    void onRefresh();  
  
    void onClose();  
}
```

Notice that the `LifecycleProcessor` is itself an extension of the `Lifecycle` interface. It also adds two other methods for reacting to the context being refreshed and closed.



Note that the regular `org.springframework.context.Lifecycle` interface is just a plain contract for explicit start/stop notifications and does NOT imply auto-startup at context refresh time. Consider implementing `org.springframework.context.SmartLifecycle` instead for fine-grained control over auto-startup of a specific bean (including startup phases). Also, please note that stop notifications are not guaranteed to come before destruction: On regular shutdown, all `Lifecycle` beans will first receive a stop notification before the general destruction callbacks are being propagated; however, on hot refresh during a context's lifetime or on aborted refresh attempts, only destroy methods will be called.

The order of startup and shutdown invocations can be important. If a "depends-on" relationship exists between any two objects, the dependent side will start *after* its dependency, and it will stop *before* its dependency. However, at times the direct dependencies are unknown. You may only know that objects of a certain type should start prior to objects of another type. In those cases, the `SmartLifecycle` interface defines another option, namely the `getPhase()` method as defined on its super-interface, `Phased`.

```
public interface Phased {  
  
    int getPhase();  
}
```

```
public interface SmartLifecycle extends Lifecycle, Phased {  
  
    boolean isAutoStartup();  
  
    void stop(Runnable callback);  
}
```

When starting, the objects with the lowest phase start first, and when stopping, the reverse order is followed. Therefore, an object that implements `SmartLifecycle` and whose `getPhase()` method returns `Integer.MIN_VALUE` would be among the first to start and the last to stop. At the other end of the spectrum, a phase value of `Integer.MAX_VALUE` would indicate that the object should be started last and stopped first (likely because it depends on other processes to be running). When

considering the phase value, it's also important to know that the default phase for any "normal" `Lifecycle` object that does not implement `SmartLifecycle` would be 0. Therefore, any negative phase value would indicate that an object should start before those standard components (and stop after them), and vice versa for any positive phase value.

As you can see the stop method defined by `SmartLifecycle` accepts a callback. Any implementation *must* invoke that callback's `run()` method after that implementation's shutdown process is complete. That enables asynchronous shutdown where necessary since the default implementation of the `LifecycleProcessor` interface, `DefaultLifecycleProcessor`, will wait up to its timeout value for the group of objects within each phase to invoke that callback. The default per-phase timeout is 30 seconds. You can override the default lifecycle processor instance by defining a bean named "lifecycleProcessor" within the context. If you only want to modify the timeout, then defining the following would be sufficient:

```
<bean id="lifecycleProcessor" class="org.springframework.context.support.DefaultLifecycleProcessor">
    <!-- timeout value in milliseconds -->
    <property name="timeoutPerShutdownPhase" value="10000"/>
</bean>
```

As mentioned, the `LifecycleProcessor` interface defines callback methods for the refreshing and closing of the context as well. The latter will simply drive the shutdown process as if `stop()` had been called explicitly, but it will happen when the context is closing. The 'refresh' callback on the other hand enables another feature of `SmartLifecycle` beans. When the context is refreshed (after all objects have been instantiated and initialized), that callback will be invoked, and at that point the default lifecycle processor will check the boolean value returned by each `SmartLifecycle` object's `isAutoStartup()` method. If "true", then that object will be started at that point rather than waiting for an explicit invocation of the context's or its own `start()` method (unlike the context refresh, the context start does not happen automatically for a standard context implementation). The "phase" value as well as any "depends-on" relationships will determine the startup order in the same way as described above.

## Shutting down the Spring IoC container gracefully in non-web applications



This section applies only to non-web applications. Spring's web-based `ApplicationContext` implementations already have code in place to shut down the Spring IoC container gracefully when the relevant web application is shut down.

If you are using Spring's IoC container in a non-web application environment; for example, in a rich client desktop environment; you register a shutdown hook with the JVM. Doing so ensures a graceful shutdown and calls the relevant destroy methods on your singleton beans so that all resources are released. Of course, you must still configure and implement these destroy callbacks correctly.

To register a shutdown hook, you call the `registerShutdownHook()` method that is declared on the `ConfigurableApplicationContext` interface:

```

import org.springframework.context.ConfigurableApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;

public final class Boot {

    public static void main(final String[] args) throws Exception {
        ConfigurableApplicationContext ctx = new ClassPathXmlApplicationContext(
            "beans.xml");

        // add a shutdown hook for the above context...
        ctx.registerShutdownHook();

        // app runs here...

        // main method exits, hook is called prior to the app shutting down...
    }
}

```

## 1.6.2. ApplicationContextAware and BeanNameAware

When an `ApplicationContext` creates an object instance that implements the `org.springframework.context.ApplicationContextAware` interface, the instance is provided with a reference to that `ApplicationContext`.

```

public interface ApplicationContextAware {

    void setApplicationContext(ApplicationContext applicationContext) throws
BeansException;
}

```

Thus beans can manipulate programmatically the `ApplicationContext` that created them, through the `ApplicationContext` interface, or by casting the reference to a known subclass of this interface, such as `ConfigurableApplicationContext`, which exposes additional functionality. One use would be the programmatic retrieval of other beans. Sometimes this capability is useful; however, in general you should avoid it, because it couples the code to Spring and does not follow the Inversion of Control style, where collaborators are provided to beans as properties. Other methods of the `ApplicationContext` provide access to file resources, publishing application events, and accessing a `MessageSource`. These additional features are described in [Additional capabilities of the ApplicationContext](#)

As of Spring 2.5, autowiring is another alternative to obtain reference to the `ApplicationContext`. The "traditional" `constructor` and `byType` autowiring modes (as described in [Autowiring collaborators](#)) can provide a dependency of type `ApplicationContext` for a constructor argument or setter method parameter, respectively. For more flexibility, including the ability to autowire fields and multiple parameter methods, use the new annotation-based autowiring features. If you do, the `ApplicationContext` is autowired into a field, constructor argument, or method parameter that is expecting the `ApplicationContext` type if the field, constructor, or method in question carries the

`@Autowired` annotation. For more information, see [@Autowired](#).

When an `ApplicationContext` creates a class that implements the `org.springframework.beans.factory.BeanNameAware` interface, the class is provided with a reference to the name defined in its associated object definition.

```
public interface BeanNameAware {  
  
    void setBeanName(String name) throws BeansException;  
}
```

The callback is invoked after population of normal bean properties but before an initialization callback such as `InitializingBean.afterPropertiesSet` or a custom init-method.

### 1.6.3. Other Aware interfaces

Besides `ApplicationContextAware` and `BeanNameAware` discussed above, Spring offers a range of `Aware` interfaces that allow beans to indicate to the container that they require a certain *infrastructure* dependency. The most important `Aware` interfaces are summarized below - as a general rule, the name is a good indication of the dependency type:

*Table 4. Aware interfaces*

Name	Injected Dependency	Explained in...
<code>ApplicationContextAware</code>	Declaring <code>ApplicationContext</code>	<code>ApplicationContextAware</code> and <code>BeanNameAware</code>
<code>ApplicationEventPublisherAware</code>	Event publisher of the enclosing <code>ApplicationContext</code>	<a href="#">Additional capabilities of the ApplicationContext</a>
<code>BeanClassLoaderAware</code>	Class loader used to load the bean classes.	<a href="#">Instantiating beans</a>
<code>BeanFactoryAware</code>	Declaring <code>BeanFactory</code>	<code>ApplicationContextAware</code> and <code>BeanNameAware</code>
<code>BeanNameAware</code>	Name of the declaring bean	<code>ApplicationContextAware</code> and <code>BeanNameAware</code>
<code>BootstrapContextAware</code>	Resource adapter <code>BootstrapContext</code> the container runs in. Typically available only in JCA aware <code>ApplicationContexts</code>	<a href="#">JCA CCI</a>
<code>LoadTimeWeaverAware</code>	Defined <i>weaver</i> for processing class definition at load time	<a href="#">Load-time weaving with AspectJ in the Spring Framework</a>
<code>MessageSourceAware</code>	Configured strategy for resolving messages (with support for parametrization and internationalization)	<a href="#">Additional capabilities of the ApplicationContext</a>
<code>NotificationPublisherAware</code>	Spring JMX notification publisher	<a href="#">Notifications</a>

Name	Injected Dependency	Explained in...
ResourceLoaderAware	Configured loader for low-level access to resources	Resources
ServletConfigAware	Current <code>ServletConfig</code> the container runs in. Valid only in a web-aware Spring <code>ApplicationContext</code>	Spring MVC
ServletContextAware	Current <code>ServletContext</code> the container runs in. Valid only in a web-aware Spring <code>ApplicationContext</code>	Spring MVC

Note again that usage of these interfaces ties your code to the Spring API and does not follow the Inversion of Control style. As such, they are recommended for infrastructure beans that require programmatic access to the container.

## 1.7. Bean definition inheritance

A bean definition can contain a lot of configuration information, including constructor arguments, property values, and container-specific information such as initialization method, static factory method name, and so on. A child bean definition inherits configuration data from a parent definition. The child definition can override some values, or add others, as needed. Using parent and child bean definitions can save a lot of typing. Effectively, this is a form of templating.

If you work with an `ApplicationContext` interface programmatically, child bean definitions are represented by the `ChildBeanDefinition` class. Most users do not work with them on this level, instead configuring bean definitions declaratively in something like the `ClassPathXmlApplicationContext`. When you use XML-based configuration metadata, you indicate a child bean definition by using the `parent` attribute, specifying the parent bean as the value of this attribute.

```

<bean id="inheritedTestBean" abstract="true"
      class="org.springframework.beans.TestBean">
    <property name="name" value="parent"/>
    <property name="age" value="1"/>
</bean>

<bean id="inheritsWithDifferentClass"
      class="org.springframework.beans.DerivedTestBean"
      <strong>parent="inheritedTestBean"</strong> init-method="initialize">
    <property name="name" value="override"/>
    <!-- the age property value of 1 will be inherited from parent -->
</bean>
```

A child bean definition uses the bean class from the parent definition if none is specified, but can also override it. In the latter case, the child bean class must be compatible with the parent, that is, it must accept the parent's property values.

A child bean definition inherits scope, constructor argument values, property values, and method overrides from the parent, with the option to add new values. Any scope, initialization method, destroy method, and/or `static` factory method settings that you specify will override the corresponding parent settings.

The remaining settings are *always* taken from the child definition: *depends on*, *autowire mode*, *dependency check*, *singleton*, *lazy init*.

The preceding example explicitly marks the parent bean definition as abstract by using the `abstract` attribute. If the parent definition does not specify a class, explicitly marking the parent bean definition as `abstract` is required, as follows:

```
<bean id="inheritedTestBeanWithoutClass" abstract="true">
    <property name="name" value="parent"/>
    <property name="age" value="1"/>
</bean>

<bean id="inheritsWithClass" class="org.springframework.beans.DerivedTestBean"
      parent="inheritedTestBeanWithoutClass" init-method="initialize">
    <property name="name" value="override"/>
    <!-- age will inherit the value of 1 from the parent bean definition-->
</bean>
```

The parent bean cannot be instantiated on its own because it is incomplete, and it is also explicitly marked as `abstract`. When a definition is `abstract` like this, it is usable only as a pure template bean definition that serves as a parent definition for child definitions. Trying to use such an `abstract` parent bean on its own, by referring to it as a `ref` property of another bean or doing an explicit `getBean()` call with the parent bean id, returns an error. Similarly, the container's internal `preInstantiateSingletons()` method ignores bean definitions that are defined as `abstract`.



`ApplicationContext` pre-instantiates all singletons by default. Therefore, it is important (at least for singleton beans) that if you have a (parent) bean definition which you intend to use only as a template, and this definition specifies a class, you must make sure to set the `abstract` attribute to *true*, otherwise the application context will actually (attempt to) pre-instantiate the `abstract` bean.

## 1.8. Container Extension Points

Typically, an application developer does not need to subclass `ApplicationContext` implementation classes. Instead, the Spring IoC container can be extended by plugging in implementations of special integration interfaces. The next few sections describe these integration interfaces.

### 1.8.1. Customizing beans using a BeanPostProcessor

The `BeanPostProcessor` interface defines *callback methods* that you can implement to provide your own (or override the container's default) instantiation logic, dependency-resolution logic, and so forth. If you want to implement some custom logic after the Spring container finishes instantiating,

configuring, and initializing a bean, you can plug in one or more `BeanPostProcessor` implementations.

You can configure multiple `BeanPostProcessor` instances, and you can control the order in which these `BeanPostProcessors` execute by setting the `order` property. You can set this property only if the `BeanPostProcessor` implements the `Ordered` interface; if you write your own `BeanPostProcessor` you should consider implementing the `Ordered` interface too. For further details, consult the javadocs of the `BeanPostProcessor` and `Ordered` interfaces. See also the note below on [programmatic registration of BeanPostProcessors](#).

`BeanPostProcessors` operate on bean (or object) *instances*; that is to say, the Spring IoC container instantiates a bean instance and *then* `BeanPostProcessors` do their work.



`BeanPostProcessors` are scoped *per-container*. This is only relevant if you are using container hierarchies. If you define a `BeanPostProcessor` in one container, it will *only* post-process the beans in that container. In other words, beans that are defined in one container are not post-processed by a `BeanPostProcessor` defined in another container, even if both containers are part of the same hierarchy.

To change the actual bean definition (i.e., the *blueprint* that defines the bean), you instead need to use a `BeanFactoryPostProcessor` as described in [Customizing configuration metadata with a BeanFactoryPostProcessor](#).

The `org.springframework.beans.factory.config.BeanPostProcessor` interface consists of exactly two callback methods. When such a class is registered as a post-processor with the container, for each bean instance that is created by the container, the post-processor gets a callback from the container both *before* container initialization methods (such as `InitializingBean's afterPropertiesSet()` and any declared init method) are called as well as *after* any bean initialization callbacks. The post-processor can take any action with the bean instance, including ignoring the callback completely. A bean post-processor typically checks for callback interfaces or may wrap a bean with a proxy. Some Spring AOP infrastructure classes are implemented as bean post-processors in order to provide proxy-wrapping logic.

An `ApplicationContext` automatically detects any beans that are defined in the configuration metadata which implement the `BeanPostProcessor` interface. The `ApplicationContext` registers these beans as post-processors so that they can be called later upon bean creation. Bean post-processors can be deployed in the container just like any other beans.

Note that when declaring a `BeanPostProcessor` using an `@Bean` factory method on a configuration class, the return type of the factory method should be the implementation class itself or at least the `org.springframework.beans.factory.config.BeanPostProcessor` interface, clearly indicating the post-processor nature of that bean. Otherwise, the `ApplicationContext` won't be able to autodetect it by type before fully creating it. Since a `BeanPostProcessor` needs to be instantiated early in order to apply to the initialization of other beans in the context, this early type detection is critical.

## *Programmatically registering BeanPostProcessors*

While the recommended approach for `BeanPostProcessor` registration is through `ApplicationContext` auto-detection (as described above), it is also possible to register them *programmatically* against a `ConfigurableBeanFactory` using the `addBeanPostProcessor` method. This can be useful when needing to evaluate conditional logic before registration, or even for copying bean post processors across contexts in a hierarchy. Note however that `BeanPostProcessors` added programmatically *do not respect the `Ordered` interface*. Here it is the *order of registration* that dictates the order of execution. Note also that `BeanPostProcessors` registered programmatically are always processed before those registered through auto-detection, regardless of any explicit ordering.

## *BeanPostProcessors and AOP auto-proxying*

Classes that implement the `BeanPostProcessor` interface are *special* and are treated differently by the container. All `BeanPostProcessors` and beans that they reference directly are instantiated on startup, as part of the special startup phase of the `ApplicationContext`. Next, all `BeanPostProcessors` are registered in a sorted fashion and applied to all further beans in the container. Because AOP auto-proxying is implemented as a `BeanPostProcessor` itself, neither `BeanPostProcessors` nor the beans they reference directly are eligible for auto-proxying, and thus do not have aspects woven into them.

For any such bean, you should see an informational log message: "*Bean foo is not eligible for getting processed by all BeanPostProcessor interfaces (for example: not eligible for auto-proxying)*".

Note that if you have beans wired into your `BeanPostProcessor` using autowiring or `@Resource` (which may fall back to autowiring), Spring might access unexpected beans when searching for type-matching dependency candidates, and therefore make them ineligible for auto-proxying or other kinds of bean post-processing. For example, if you have a dependency annotated with `@Resource` where the field/setter name does not directly correspond to the declared name of a bean and no name attribute is used, then Spring will access other beans for matching them by type.

The following examples show how to write, register, and use `BeanPostProcessors` in an `ApplicationContext`.

### **Example: Hello World, BeanPostProcessor-style**

This first example illustrates basic usage. The example shows a custom `BeanPostProcessor` implementation that invokes the `toString()` method of each bean as it is created by the container and prints the resulting string to the system console.

Find below the custom `BeanPostProcessor` implementation class definition:



```

package scripting;

import org.springframework.beans.factory.config.BeanPostProcessor;

public class InstantiationTracingBeanPostProcessor implements BeanPostProcessor {

    // simply return the instantiated bean as-is
    public Object postProcessBeforeInitialization(Object bean, String beanName) {
        return bean; // we could potentially return any object reference here...
    }

    public Object postProcessAfterInitialization(Object bean, String beanName) {
        System.out.println("Bean '" + beanName + "' created : " + bean.toString());
        return bean;
    }
}

```

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:lang="http://www.springframework.org/schema/lang"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
                           http://www.springframework.org/schema/beans/spring-beans.xsd
                           http://www.springframework.org/schema/lang
                           http://www.springframework.org/schema/lang/spring-lang.xsd">

    <lang:groovy id="messenger"
                 script-source=
"classpath:org/springframework/scripting/groovy/Messenger.groovy">
        <lang:property name="message" value="Fiona Apple Is Just So Dreamy." />
    </lang:groovy>

    <!--
    when the above bean (messenger) is instantiated, this custom
    BeanPostProcessor implementation will output the fact to the system console
    -->
    <bean class="scripting.InstantiationTracingBeanPostProcessor"/>

</beans>

```

Notice how the `InstantiationTracingBeanPostProcessor` is simply defined. It does not even have a name, and because it is a bean it can be dependency-injected just like any other bean. (The preceding configuration also defines a bean that is backed by a Groovy script. The Spring dynamic language support is detailed in the chapter entitled [Dynamic language support](#).)

The following simple Java application executes the preceding code and configuration:

```

import org.springframework.context.ApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;
import org.springframework.scripting.Messenger;

public final class Boot {

    public static void main(final String[] args) throws Exception {
        ApplicationContext ctx = new ClassPathXmlApplicationContext(
"scripting/beans.xml");
        Messenger messenger = (Messenger) ctx.getBean("messenger");
        System.out.println(messenger);
    }

}

```

The output of the preceding application resembles the following:

```

Bean 'messenger' created : org.springframework.scripting.groovy.GroovyMessenger@272961
org.springframework.scripting.groovy.GroovyMessenger@272961

```

### Example: The RequiredAnnotationBeanPostProcessor

Using callback interfaces or annotations in conjunction with a custom `BeanPostProcessor` implementation is a common means of extending the Spring IoC container. An example is Spring's `RequiredAnnotationBeanPostProcessor` - a `BeanPostProcessor` implementation that ships with the Spring distribution which ensures that JavaBean properties on beans that are marked with an (arbitrary) annotation are actually (configured to be) dependency-injected with a value.

### 1.8.2. Customizing configuration metadata with a BeanFactoryPostProcessor

The next extension point that we will look at is the `org.springframework.beans.factory.config.BeanFactoryPostProcessor`. The semantics of this interface are similar to those of the `BeanPostProcessor`, with one major difference: `BeanFactoryPostProcessor` operates on the *bean configuration metadata*; that is, the Spring IoC container allows a `BeanFactoryPostProcessor` to read the configuration metadata and potentially change it *before* the container instantiates any beans other than `BeanFactoryPostProcessors`.

You can configure multiple `BeanFactoryPostProcessors`, and you can control the order in which these `BeanFactoryPostProcessors` execute by setting the `order` property. However, you can only set this property if the `BeanFactoryPostProcessor` implements the `Ordered` interface. If you write your own `BeanFactoryPostProcessor`, you should consider implementing the `Ordered` interface too. Consult the javadocs of the `BeanFactoryPostProcessor` and `Ordered` interfaces for more details.

If you want to change the actual bean *instances* (i.e., the objects that are created from the configuration metadata), then you instead need to use a [BeanPostProcessor](#) (described above in [Customizing beans using a BeanPostProcessor](#)). While it is technically possible to work with bean instances within a [BeanFactoryPostProcessor](#) (e.g., using `BeanFactory.getBean()`), doing so causes premature bean instantiation, violating the standard container lifecycle. This may cause negative side effects such as bypassing bean post processing.



Also, [BeanFactoryPostProcessors](#) are scoped *per-container*. This is only relevant if you are using container hierarchies. If you define a [BeanFactoryPostProcessor](#) in one container, it will *only* be applied to the bean definitions in that container. Bean definitions in one container will not be post-processed by [BeanFactoryPostProcessors](#) in another container, even if both containers are part of the same hierarchy.

A bean factory post-processor is executed automatically when it is declared inside an [ApplicationContext](#), in order to apply changes to the configuration metadata that define the container. Spring includes a number of predefined bean factory post-processors, such as [PropertyOverrideConfigurer](#) and [PropertyPlaceholderConfigurer](#). A custom [BeanFactoryPostProcessor](#) can also be used, for example, to register custom property editors.

An [ApplicationContext](#) automatically detects any beans that are deployed into it that implement the [BeanFactoryPostProcessor](#) interface. It uses these beans as bean factory post-processors, at the appropriate time. You can deploy these post-processor beans as you would any other bean.

As with [BeanPostProcessors](#), you typically do not want to configure [BeanFactoryPostProcessors](#) for lazy initialization. If no other bean references a [Bean\(Factory\)PostProcessor](#), that post-processor will not get instantiated at all. Thus, marking it for lazy initialization will be ignored, and the [Bean\(Factory\)PostProcessor](#) will be instantiated eagerly even if you set the `default-lazy-init` attribute to `true` on the declaration of your `<beans />` element.



### Example: the Class name substitution [PropertyPlaceholderConfigurer](#)

You use the [PropertyPlaceholderConfigurer](#) to externalize property values from a bean definition in a separate file using the standard Java [Properties](#) format. Doing so enables the person deploying an application to customize environment-specific properties such as database URLs and passwords, without the complexity or risk of modifying the main XML definition file or files for the container.

Consider the following XML-based configuration metadata fragment, where a [DataSource](#) with placeholder values is defined. The example shows properties configured from an external [Properties](#) file. At runtime, a [PropertyPlaceholderConfigurer](#) is applied to the metadata that will replace some properties of the [DataSource](#). The values to replace are specified as *placeholders* of the form  `${property-name}` which follows the Ant / log4j / JSP EL style.

```

<bean class="org.springframework.beans.factory.config.PropertyPlaceholderConfigurer">
    <property name="locations" value="classpath:com/foo/jdbc.properties"/>
</bean>

<bean id="dataSource" destroy-method="close"
      class="org.apache.commons.dbcp.BasicDataSource">
    <property name="driverClassName" value="${jdbc.driverClassName}"/>
    <property name="url" value="${jdbc.url}"/>
    <property name="username" value="${jdbc.username}"/>
    <property name="password" value="${jdbc.password}"/>
</bean>

```

The actual values come from another file in the standard Java **Properties** format:

```

jdbc.driverClassName=org.hsqldb.jdbcDriver
jdbc.url=jdbc:hsqldb:hsq://production:9002
jdbc.username=sa
jdbc.password=root

```

Therefore, the string  `${jdbc.username}` is replaced at runtime with the value 'sa', and the same applies for other placeholder values that match keys in the properties file. The **PropertyPlaceholderConfigurer** checks for placeholders in most properties and attributes of a bean definition. Furthermore, the placeholder prefix and suffix can be customized.

With the `context` namespace introduced in Spring 2.5, it is possible to configure property placeholders with a dedicated configuration element. One or more locations can be provided as a comma-separated list in the `location` attribute.

```
<context:property-placeholder location="classpath:com/foo/jdbc.properties"/>
```

The **PropertyPlaceholderConfigurer** not only looks for properties in the **Properties** file you specify. By default it also checks against the Java **System** properties if it cannot find a property in the specified properties files. You can customize this behavior by setting the `systemPropertiesMode` property of the configurer with one of the following three supported integer values:

- *never* (0): Never check system properties
- *fallback* (1): Check system properties if not resolvable in the specified properties files. This is the default.
- *override* (2): Check system properties first, before trying the specified properties files. This allows system properties to override any other property source.

Consult the **PropertyPlaceholderConfigurer** javadocs for more information.

You can use the `PropertyPlaceholderConfigurer` to substitute class names, which is sometimes useful when you have to pick a particular implementation class at runtime. For example:



```
<bean class="org.springframework.beans.factory.config.PropertyPlaceholderConfigurer">
    <property name="locations">
        <value>classpath:com/foo/strategy.properties</value>
    </property>
    <property name="properties">
        <value>custom.strategy.class=com.foo.DefaultStrategy</value>
    </property>
</bean>

<bean id="serviceStrategy" class="${custom.strategy.class}"/>
```

If the class cannot be resolved at runtime to a valid class, resolution of the bean fails when it is about to be created, which is during the `preInstantiateSingletons()` phase of an `ApplicationContext` for a non-lazy-init bean.

### Example: the `PropertyOverrideConfigurer`

The `PropertyOverrideConfigurer`, another bean factory post-processor, resembles the `PropertyPlaceholderConfigurer`, but unlike the latter, the original definitions can have default values or no values at all for bean properties. If an overriding `Properties` file does not have an entry for a certain bean property, the default context definition is used.

Note that the bean definition is *not* aware of being overridden, so it is not immediately obvious from the XML definition file that the override configurer is being used. In case of multiple `PropertyOverrideConfigurer` instances that define different values for the same bean property, the last one wins, due to the overriding mechanism.

Properties file configuration lines take this format:

```
beanName.property=value
```

For example:

```
dataSource.driverClassName=com.mysql.jdbc.Driver
dataSource.url=jdbc:mysql:mydb
```

This example file can be used with a container definition that contains a bean called `dataSource`, which has `driver` and `url` properties.

Compound property names are also supported, as long as every component of the path except the

final property being overridden is already non-null (presumably initialized by the constructors). In this example...

```
foo.fred.bob.sammy=123
```

- i. the `sammy` property of the `bob` property of the `fred` property of the `foo` bean is set to the scalar value `123`.



Specified override values are always *literal* values; they are not translated into bean references. This convention also applies when the original value in the XML bean definition specifies a bean reference.

With the `context` namespace introduced in Spring 2.5, it is possible to configure property overriding with a dedicated configuration element:

```
<context:property-overide location="classpath:override.properties"/>
```

### 1.8.3. Customizing instantiation logic with a FactoryBean

Implement the `org.springframework.beans.factory.FactoryBean` interface for objects that *are themselves factories*.

The `FactoryBean` interface is a point of pluggability into the Spring IoC container's instantiation logic. If you have complex initialization code that is better expressed in Java as opposed to a (potentially) verbose amount of XML, you can create your own `FactoryBean`, write the complex initialization inside that class, and then plug your custom `FactoryBean` into the container.

The `FactoryBean` interface provides three methods:

- `Object getObject()`: returns an instance of the object this factory creates. The instance can possibly be shared, depending on whether this factory returns singletons or prototypes.
- `boolean isSingleton()`: returns `true` if this `FactoryBean` returns singletons, `false` otherwise.
- `Class getObjectType()`: returns the object type returned by the `getObject()` method or `null` if the type is not known in advance.

The `FactoryBean` concept and interface is used in a number of places within the Spring Framework; more than 50 implementations of the `FactoryBean` interface ship with Spring itself.

When you need to ask a container for an actual `FactoryBean` instance itself instead of the bean it produces, preface the bean's id with the ampersand symbol (`&`) when calling the `getBean()` method of the `ApplicationContext`. So for a given `FactoryBean` with an id of `myBean`, invoking `getBean("myBean")` on the container returns the product of the `FactoryBean`; whereas, invoking `getBean("&myBean")` returns the `FactoryBean` instance itself.

## 1.9. Annotation-based container configuration

### Are annotations better than XML for configuring Spring?

The introduction of annotation-based configurations raised the question of whether this approach is 'better' than XML. The short answer is *it depends*. The long answer is that each approach has its pros and cons, and usually it is up to the developer to decide which strategy suits them better. Due to the way they are defined, annotations provide a lot of context in their declaration, leading to shorter and more concise configuration. However, XML excels at wiring up components without touching their source code or recompiling them. Some developers prefer having the wiring close to the source while others argue that annotated classes are no longer POJOs and, furthermore, that the configuration becomes decentralized and harder to control.

No matter the choice, Spring can accommodate both styles and even mix them together. It's worth pointing out that through its [JavaConfig](#) option, Spring allows annotations to be used in a non-invasive way, without touching the target components source code and that in terms of tooling, all configuration styles are supported by the [Spring Tool Suite](#).

An alternative to XML setups is provided by annotation-based configuration which rely on the bytecode metadata for wiring up components instead of angle-bracket declarations. Instead of using XML to describe a bean wiring, the developer moves the configuration into the component class itself by using annotations on the relevant class, method, or field declaration. As mentioned in [Example: The RequiredAnnotationBeanPostProcessor](#), using a [BeanPostProcessor](#) in conjunction with annotations is a common means of extending the Spring IoC container. For example, Spring 2.0 introduced the possibility of enforcing required properties with the [@Required](#) annotation. Spring 2.5 made it possible to follow that same general approach to drive Spring's dependency injection. Essentially, the [@Autowired](#) annotation provides the same capabilities as described in [Autowiring collaborators](#) but with more fine-grained control and wider applicability. Spring 2.5 also added support for JSR-250 annotations such as [@PostConstruct](#), and [@PreDestroy](#). Spring 3.0 added support for JSR-330 (Dependency Injection for Java) annotations contained in the javax.inject package such as [@Inject](#) and [@Named](#). Details about those annotations can be found in the [relevant section](#).



Annotation injection is performed *before* XML injection, thus the latter configuration will override the former for properties wired through both approaches.

As always, you can register them as individual bean definitions, but they can also be implicitly registered by including the following tag in an XML-based Spring configuration (notice the inclusion of the [context](#) namespace):

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

</beans>

```

(The implicitly registered post-processors include `AutowiredAnnotationBeanPostProcessor`, `CommonAnnotationBeanPostProcessor`, `PersistenceAnnotationBeanPostProcessor`, as well as the aforementioned `RequiredAnnotationBeanPostProcessor`.)



`<context:annotation-config/>` only looks for annotations on beans in the same application context in which it is defined. This means that, if you put `<context:annotation-config/>` in a `WebApplicationContext` for a `DispatcherServlet`, it only checks for `@Autowired` beans in your controllers, and not your services. See [The DispatcherServlet](#) for more information.

### 1.9.1. @Required

The `@Required` annotation applies to bean property setter methods, as in the following example:

```

public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Required
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...
}

```

This annotation simply indicates that the affected bean property must be populated at configuration time, through an explicit property value in a bean definition or through autowiring. The container throws an exception if the affected bean property has not been populated; this allows for eager and explicit failure, avoiding `NullPointerExceptions` or the like later on. It is still recommended that you put assertions into the bean class itself, for example, into an init method. Doing so enforces those required references and values even when you use the class outside of a container.

## 1.9.2. @Autowired



JSR 330's `@Inject` annotation can be used in place of Spring's `@Autowired` annotation in the examples below. See [here](#) for more details.

You can apply the `@Autowired` annotation to constructors:

```
public class MovieRecommender {  
  
    private final CustomerPreferenceDao customerPreferenceDao;  
  
    @Autowired  
    public MovieRecommender(CustomerPreferenceDao customerPreferenceDao) {  
        this.customerPreferenceDao = customerPreferenceDao;  
    }  
  
    // ...  
}
```



As of Spring Framework 4.3, an `@Autowired` annotation on such a constructor is no longer necessary if the target bean only defines one constructor to begin with. However, if several constructors are available, at least one must be annotated to teach the container which one to use.

As expected, you can also apply the `@Autowired` annotation to "traditional" setter methods:

```
public class SimpleMovieLister {  
  
    private MovieFinder movieFinder;  
  
    @Autowired  
    public void setMovieFinder(MovieFinder movieFinder) {  
        this.movieFinder = movieFinder;  
    }  
  
    // ...  
}
```

You can also apply the annotation to methods with arbitrary names and/or multiple arguments:

```

public class MovieRecommender {

    private MovieCatalog movieCatalog;

    private CustomerPreferenceDao customerPreferenceDao;

    @Autowired
    public void prepare(MovieCatalog movieCatalog,
        CustomerPreferenceDao customerPreferenceDao) {
        this.movieCatalog = movieCatalog;
        this.customerPreferenceDao = customerPreferenceDao;
    }

    // ...
}

```

You can apply `@Autowired` to fields as well and even mix it with constructors:

```

public class MovieRecommender {

    private final CustomerPreferenceDao customerPreferenceDao;

    @Autowired
    private MovieCatalog movieCatalog;

    @Autowired
    public MovieRecommender(CustomerPreferenceDao customerPreferenceDao) {
        this.customerPreferenceDao = customerPreferenceDao;
    }

    // ...
}

```

Make sure that your target components (e.g. `MovieCatalog`, `CustomerPreferenceDao`) are consistently declared by the type that you are using for your `@Autowired`-annotated injection points. Otherwise injection may fail due to no type match found at runtime.



For XML-defined beans or component classes found through a classpath scan, the container usually knows the concrete type upfront. However, for `@Bean` factory methods, you need to make sure that the declared return type is sufficiently expressive. For components implementing several interfaces or for components potentially referred to by their implementation type, consider declaring the most specific return type on your factory method (at least as specific as required by the injection points referring to your bean).

It is also possible to provide *all* beans of a particular type from the `ApplicationContext` by adding the

annotation to a field or method that expects an array of that type:

```
public class MovieRecommender {  
  
    @Autowired  
    private MovieCatalog[] movieCatalogs;  
  
    // ...  
}
```

The same applies for typed collections:

```
public class MovieRecommender {  
  
    private Set<MovieCatalog> movieCatalogs;  
  
    @Autowired  
    public void setMovieCatalogs(Set<MovieCatalog> movieCatalogs) {  
        this.movieCatalogs = movieCatalogs;  
    }  
  
    // ...  
}
```

Your target beans can implement the `org.springframework.core.Ordered` interface or use the `@Order` or standard `@Priority` annotation if you want items in the array or list to be sorted in a specific order. Otherwise their order will follow the registration order of the corresponding target bean definitions in the container.



The `@Order` annotation may be declared at target class level but also on `@Bean` methods, potentially being very individual per bean definition (in case of multiple definitions with the same bean class). `@Order` values may influence priorities at injection points, but please be aware that they do not influence singleton startup order which is an orthogonal concern determined by dependency relationships and `@DependsOn` declarations.

Note that the standard `javax.annotation.Priority` annotation is not available at the `@Bean` level since it cannot be declared on methods. Its semantics can be modeled through `@Order` values in combination with `@Primary` on a single bean per type.

Even typed Maps can be autowired as long as the expected key type is `String`. The Map values will contain all beans of the expected type, and the keys will contain the corresponding bean names:

```

public class MovieRecommender {

    private Map<String, MovieCatalog> movieCatalogs;

    @Autowired
    public void setMovieCatalogs(Map<String, MovieCatalog> movieCatalogs) {
        this.movieCatalogs = movieCatalogs;
    }

    // ...
}

```

By default, the autowiring fails whenever *zero* candidate beans are available; the default behavior is to treat annotated methods, constructors, and fields as indicating *required* dependencies. This behavior can be changed as demonstrated below.

```

public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Autowired(required = false)
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...
}

```

Only *one annotated constructor per-class* can be marked as *required*, but multiple non-required constructors can be annotated. In that case, each is considered among the candidates and Spring uses the *greediest* constructor whose dependencies can be satisfied, that is the constructor that has the largest number of arguments.



The *required* attribute of `@Autowired` is recommended over the `@Required` annotation. The *required* attribute indicates that the property is not required for autowiring purposes, the property is ignored if it cannot be autowired. `@Required`, on the other hand, is stronger in that it enforces the property that was set by any means supported by the container. If no value is injected, a corresponding exception is raised.

Alternatively, you may express the non-required nature of a particular dependency through Java 8's `java.util.Optional`:

```
public class SimpleMovieLister {  
  
    @Autowired  
    public void setMovieFinder(Optional<MovieFinder> movieFinder) {  
        ...  
    }  
}
```

As of Spring Framework 5.0, you may also use an `@Nullable` annotation (of any kind in any package, e.g. `javax.annotation.Nullable` from JSR-305):

```
public class SimpleMovieLister {  
  
    @Autowired  
    public void setMovieFinder(@Nullable MovieFinder movieFinder) {  
        ...  
    }  
}
```

You can also use `@Autowired` for interfaces that are well-known resolvable dependencies: `BeanFactory`, `ApplicationContext`, `Environment`, `ResourceLoader`, `ApplicationEventPublisher`, and `MessageSource`. These interfaces and their extended interfaces, such as `ConfigurableApplicationContext` or `ResourcePatternResolver`, are automatically resolved, with no special setup necessary.

```
public class MovieRecommender {  
  
    @Autowired  
    private ApplicationContext context;  
  
    public MovieRecommender() {  
    }  
  
    // ...
}
```



`@Autowired`, `@Inject`, `@Resource`, and `@Value` annotations are handled by Spring `BeanPostProcessor` implementations which in turn means that you *cannot* apply these annotations within your own `BeanPostProcessor` or `BeanFactoryPostProcessor` types (if any). These types must be 'wired up' explicitly via XML or using a Spring `@Bean` method.

### 1.9.3. Fine-tuning annotation-based autowiring with `@Primary`

Because autowiring by type may lead to multiple candidates, it is often necessary to have more control over the selection process. One way to accomplish this is with Spring's `@Primary` annotation.

`@Primary` indicates that a particular bean should be given preference when multiple beans are candidates to be autowired to a single-valued dependency. If exactly one 'primary' bean exists among the candidates, it will be the autowired value.

Let's assume we have the following configuration that defines `firstMovieCatalog` as the *primary MovieCatalog*.

```
@Configuration
public class MovieConfiguration {

    @Bean
    <strong>@Primary</strong>
    public MovieCatalog firstMovieCatalog() { ... }

    @Bean
    public MovieCatalog secondMovieCatalog() { ... }

    // ...
}
```

With such configuration, the following `MovieRecommender` will be autowired with the `firstMovieCatalog`.

```
public class MovieRecommender {

    @Autowired
    private MovieCatalog movieCatalog;

    // ...
}
```

The corresponding bean definitions appear as follows.

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

    <bean class="example.SimpleMovieCatalog" <strong>primary="true"</strong>>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean id="movieRecommender" class="example.MovieRecommender"/>

</beans>

```

#### 1.9.4. Fine-tuning annotation-based autowiring with qualifiers

`@Primary` is an effective way to use autowiring by type with several instances when one primary candidate can be determined. When more control over the selection process is required, Spring's `@Qualifier` annotation can be used. You can associate qualifier values with specific arguments, narrowing the set of type matches so that a specific bean is chosen for each argument. In the simplest case, this can be a plain descriptive value:

```

public class MovieRecommender {

    @Autowired
    <strong>@Qualifier("main")</strong>
    private MovieCatalog movieCatalog;

    // ...
}

```

The `@Qualifier` annotation can also be specified on individual constructor arguments or method parameters:

```

public class MovieRecommender {

    private MovieCatalog movieCatalog;

    private CustomerPreferenceDao customerPreferenceDao;

    @Autowired
    public void prepare(@Qualifier("main")MovieCatalog movieCatalog,
        CustomerPreferenceDao customerPreferenceDao) {
        this.movieCatalog = movieCatalog;
        this.customerPreferenceDao = customerPreferenceDao;
    }

    // ...
}

```

The corresponding bean definitions appear as follows. The bean with qualifier value "main" is wired with the constructor argument that is qualified with the same value.

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

    <bean class="example.SimpleMovieCatalog">
        <strong><qualifier value="main"/></strong>

        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <strong><qualifier value="action"/></strong>

        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean id="movieRecommender" class="example.MovieRecommender"/>

</beans>

```

For a fallback match, the bean name is considered a default qualifier value. Thus you can define the bean with an id "main" instead of the nested qualifier element, leading to the same matching result.

However, although you can use this convention to refer to specific beans by name, `@Autowired` is fundamentally about type-driven injection with optional semantic qualifiers. This means that qualifier values, even with the bean name fallback, always have narrowing semantics within the set of type matches; they do not semantically express a reference to a unique bean id. Good qualifier values are "main" or "EMEA" or "persistent", expressing characteristics of a specific component that are independent from the bean `id`, which may be auto-generated in case of an anonymous bean definition like the one in the preceding example.

Qualifiers also apply to typed collections, as discussed above, for example, to `Set<MovieCatalog>`. In this case, all matching beans according to the declared qualifiers are injected as a collection. This implies that qualifiers do not have to be unique; they rather simply constitute filtering criteria. For example, you can define multiple `MovieCatalog` beans with the same qualifier value "action", all of which would be injected into a `Set<MovieCatalog>` annotated with `@Qualifier("action")`.

Letting qualifier values select against target bean names, within the type-matching candidates, doesn't even require a `@Qualifier` annotation at the injection point. If there is no other resolution indicator (e.g. a qualifier or a primary marker), for a non-unique dependency situation, Spring will match the injection point name (i.e. field name or parameter name) against the target bean names and choose the same-named candidate, if any.

That said, if you intend to express annotation-driven injection by name, do not primarily use `@Autowired`, even if it is capable of selecting by bean name among type-matching candidates. Instead, use the JSR-250 `@Resource` annotation, which is semantically defined to identify a specific target component by its unique name, with the declared type being irrelevant for the matching process. `@Autowired` has rather different semantics: After selecting candidate beans by type, the specified String qualifier value will be considered within those type-selected candidates only, e.g. matching an "account" qualifier against beans marked with the same qualifier label.

For beans that are themselves defined as a collection/map or array type, `@Resource` is a fine solution, referring to the specific collection or array bean by unique name. That said, as of 4.3, collection/map and array types can be matched through Spring's `@Autowired` type matching algorithm as well, as long as the element type information is preserved in `@Bean` return type signatures or collection inheritance hierarchies. In this case, qualifier values can be used to select among same-typed collections, as outlined in the previous paragraph.

As of 4.3, `@Autowired` also considers self references for injection, i.e. references back to the bean that is currently injected. Note that self injection is a fallback; regular dependencies on other components always have precedence. In that sense, self references do not participate in regular candidate selection and are therefore in particular never primary; on the contrary, they always end up as lowest precedence. In practice, use self references as a last resort only, e.g. for calling other methods on the same instance through the bean's transactional proxy: Consider factoring out the affected methods to a separate delegate bean in such a scenario. Alternatively, use `@Resource` which may obtain a proxy back to the current bean by its unique name.

`@Autowired` applies to fields, constructors, and multi-argument methods, allowing for narrowing through qualifier annotations at the parameter level. By contrast, `@Resource` is supported only for fields and bean property setter methods with a single argument. As a consequence, stick with qualifiers if your injection target is a constructor or a multi-argument method.

You can create your own custom qualifier annotations. Simply define an annotation and provide the `@Qualifier` annotation within your definition:



```

@Target({ElementType.FIELD, ElementType.PARAMETER})
@Retention(RetentionPolicy.RUNTIME)
<strong>@Qualifier</strong>
public @interface Genre {

    String value();
}

```

Then you can provide the custom qualifier on autowired fields and parameters:

```

public class MovieRecommender {

    @Autowired
    <strong>@Genre("Action")</strong>
    private MovieCatalog actionCatalog;

    private MovieCatalog comedyCatalog;

    @Autowired
    public void setComedyCatalog(<strong>@Genre("Comedy")</strong> MovieCatalog
comedyCatalog) {
        this.comedyCatalog = comedyCatalog;
    }

    // ...
}

```

Next, provide the information for the candidate bean definitions. You can add `<qualifier/>` tags as sub-elements of the `<bean/>` tag and then specify the `type` and `value` to match your custom qualifier annotations. The type is matched against the fully-qualified class name of the annotation. Or, as a convenience if no risk of conflicting names exists, you can use the short class name. Both approaches are demonstrated in the following example.

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

    <bean class="example.SimpleMovieCatalog">
        <strong><qualifier type="Genre" value="Action"/></strong>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <strong><qualifier type="example.Genre" value="Comedy"/></strong>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean id="movieRecommender" class="example.MovieRecommender"/>

</beans>

```

In [Classpath scanning and managed components](#), you will see an annotation-based alternative to providing the qualifier metadata in XML. Specifically, see [Providing qualifier metadata with annotations](#).

In some cases, it may be sufficient to use an annotation without a value. This may be useful when the annotation serves a more generic purpose and can be applied across several different types of dependencies. For example, you may provide an *offline* catalog that would be searched when no Internet connection is available. First define the simple annotation:

```

@Target({ElementType.FIELD, ElementType.PARAMETER})
@Retention(RetentionPolicy.RUNTIME)
@Qualifier
public @interface Offline {
}

```

Then add the annotation to the field or property to be autowired:

```

public class MovieRecommender {

    @Autowired
    <strong>@Offline</strong>
    private MovieCatalog offlineCatalog;

    // ...
}

```

Now the bean definition only needs a qualifier `type`:

```

<bean class="example.SimpleMovieCatalog">
    <strong><qualifier type="Offline"/></strong>
    <!-- inject any dependencies required by this bean -->
</bean>

```

You can also define custom qualifier annotations that accept named attributes in addition to or instead of the simple `value` attribute. If multiple attribute values are then specified on a field or parameter to be autowired, a bean definition must match *all* such attribute values to be considered an autowire candidate. As an example, consider the following annotation definition:

```

@Target({ElementType.FIELD, ElementType.PARAMETER})
@Retention(RetentionPolicy.RUNTIME)
@Qualifier
public @interface MovieQualifier {

    String genre();

    Format format();
}

```

In this case `Format` is an enum:

```

public enum Format {
    VHS, DVD, BLURAY
}

```

The fields to be autowired are annotated with the custom qualifier and include values for both attributes: `genre` and `format`.

```

public class MovieRecommender {

    @Autowired
    @MovieQualifier(format=Format.VHS, genre="Action")
    private MovieCatalog actionVhsCatalog;

    @Autowired
    @MovieQualifier(format=Format.VHS, genre="Comedy")
    private MovieCatalog comedyVhsCatalog;

    @Autowired
    @MovieQualifier(format=Format.DVD, genre="Action")
    private MovieCatalog actionDvdCatalog;

    @Autowired
    @MovieQualifier(format=Format.BLURAY, genre="Comedy")
    private MovieCatalog comedyBluRayCatalog;

    // ...
}

```

Finally, the bean definitions should contain matching qualifier values. This example also demonstrates that bean *meta* attributes may be used instead of the `<qualifier/>` sub-elements. If available, the `<qualifier/>` and its attributes take precedence, but the autowiring mechanism falls back on the values provided within the `<meta/>` tags if no such qualifier is present, as in the last two bean definitions in the following example.

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

    <bean class="example.SimpleMovieCatalog">
        <qualifier type="MovieQualifier">
            <attribute key="format" value="VHS"/>
            <attribute key="genre" value="Action"/>
        </qualifier>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <qualifier type="MovieQualifier">
            <attribute key="format" value="VHS"/>
            <attribute key="genre" value="Comedy"/>
        </qualifier>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <meta key="format" value="DVD"/>
        <meta key="genre" value="Action"/>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <meta key="format" value="BLURAY"/>
        <meta key="genre" value="Comedy"/>
        <!-- inject any dependencies required by this bean -->
    </bean>

</beans>

```

### 1.9.5. Using generics as autowiring qualifiers

In addition to the `@Qualifier` annotation, it is also possible to use Java generic types as an implicit form of qualification. For example, suppose you have the following configuration:

```

@Configuration
public class MyConfiguration {

    @Bean
    public StringStore stringStore() {
        return new StringStore();
    }

    @Bean
    public IntegerStore integerStore() {
        return new IntegerStore();
    }
}

```

Assuming that beans above implement a generic interface, i.e. `Store<String>` and `Store<Integer>`, you can `@Autowire` the `Store` interface and the *generic* will be used as a qualifier:

```

@Autowire
private Store<String> s1; // <String> qualifier, injects the stringStore bean

@Autowire
private Store<Integer> s2; // <Integer> qualifier, injects the integerStore bean

```

Generic qualifiers also apply when autowiring Lists, Maps and Arrays:

```

// Inject all Store beans as long as they have an <Integer> generic
// Store<String> beans will not appear in this list
@Autowired
private List<Store<Integer>> s;

```

## 1.9.6. CustomAutowireConfigurer

The `CustomAutowireConfigurer` is a `BeanFactoryPostProcessor` that enables you to register your own custom qualifier annotation types even if they are not annotated with Spring's `@Qualifier` annotation.

```

<bean id="customAutowireConfigurer"
      class="org.springframework.beans.factory.annotation.CustomAutowireConfigurer">
    <property name="customQualifierTypes">
      <set>
        <value>example.CustomQualifier</value>
      </set>
    </property>
</bean>

```

The `AutowireCandidateResolver` determines autowire candidates by:

- the `autowire-candidate` value of each bean definition
- any `default-autowire-candidates` pattern(s) available on the `<beans/>` element
- the presence of `@Qualifier` annotations and any custom annotations registered with the `CustomAutowireConfigurer`

When multiple beans qualify as autowire candidates, the determination of a "primary" is the following: if exactly one bean definition among the candidates has a `primary` attribute set to `true`, it will be selected.

### 1.9.7. @Resource

Spring also supports injection using the JSR-250 `@Resource` annotation on fields or bean property setter methods. This is a common pattern in Java EE 5 and 6, for example in JSF 1.2 managed beans or JAX-WS 2.0 endpoints. Spring supports this pattern for Spring-managed objects as well.

`@Resource` takes a name attribute, and by default Spring interprets that value as the bean name to be injected. In other words, it follows *by-name* semantics, as demonstrated in this example:

```
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    <strong>@Resource(name="myMovieFinder")</strong>
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }
}
```

If no name is specified explicitly, the default name is derived from the field name or setter method. In case of a field, it takes the field name; in case of a setter method, it takes the bean property name. So the following example is going to have the bean with name "movieFinder" injected into its setter method:

```
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    <strong>@Resource</strong>
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }
}
```

The name provided with the annotation is resolved as a bean name by the `ApplicationContext` of which the `CommonAnnotationBeanPostProcessor` is aware. The names can be resolved through JNDI if you configure Spring's `SimpleJndiBeanFactory` explicitly. However, it is recommended that you rely on the default behavior and simply use Spring's JNDI lookup capabilities to preserve the level of indirection.



In the exclusive case of `@Resource` usage with no explicit name specified, and similar to `@Autowired`, `@Resource` finds a primary type match instead of a specific named bean and resolves well-known resolvable dependencies: the `BeanFactory`, `ApplicationContext`, `ResourceLoader`, `ApplicationEventPublisher`, and `MessageSource` interfaces.

Thus in the following example, the `customerPreferenceDao` field first looks for a bean named `customerPreferenceDao`, then falls back to a primary type match for the type `CustomerPreferenceDao`. The "context" field is injected based on the known resolvable dependency type `ApplicationContext`.

```
public class MovieRecommender {  
  
    @Resource  
    private CustomerPreferenceDao customerPreferenceDao;  
  
    @Resource  
    private ApplicationContext context;  
  
    public MovieRecommender() {  
    }  
  
    // ...  
}
```

### 1.9.8. `@PostConstruct` and `@PreDestroy`

The `CommonAnnotationBeanPostProcessor` not only recognizes the `@Resource` annotation but also the JSR-250 *lifecycle* annotations. Introduced in Spring 2.5, the support for these annotations offers yet another alternative to those described in `initialization callbacks` and `destruction callbacks`. Provided that the `CommonAnnotationBeanPostProcessor` is registered within the Spring `ApplicationContext`, a method carrying one of these annotations is invoked at the same point in the lifecycle as the corresponding Spring lifecycle interface method or explicitly declared callback method. In the example below, the cache will be pre-populated upon initialization and cleared upon destruction.

```

public class CachingMovieLister {

    @PostConstruct
    public void populateMovieCache() {
        // populates the movie cache upon initialization...
    }

    @PreDestroy
    public void clearMovieCache() {
        // clears the movie cache upon destruction...
    }
}

```



For details about the effects of combining various lifecycle mechanisms, see [Combining lifecycle mechanisms](#).

## 1.10. Classpath scanning and managed components

Most examples in this chapter use XML to specify the configuration metadata that produces each `BeanDefinition` within the Spring container. The previous section ([Annotation-based container configuration](#)) demonstrates how to provide a lot of the configuration metadata through source-level annotations. Even in those examples, however, the "base" bean definitions are explicitly defined in the XML file, while the annotations only drive the dependency injection. This section describes an option for implicitly detecting the *candidate components* by scanning the classpath. Candidate components are classes that match against a filter criteria and have a corresponding bean definition registered with the container. This removes the need to use XML to perform bean registration; instead you can use annotations (for example `@Component`), AspectJ type expressions, or your own custom filter criteria to select which classes will have bean definitions registered with the container.



Starting with Spring 3.0, many features provided by the Spring JavaConfig project are part of the core Spring Framework. This allows you to define beans using Java rather than using the traditional XML files. Take a look at the `@Configuration`, `@Bean`, `@Import`, and `@DependsOn` annotations for examples of how to use these new features.

### 1.10.1. `@Component` and further stereotype annotations

The `@Repository` annotation is a marker for any class that fulfills the role or *stereotype* of a repository (also known as Data Access Object or DAO). Among the uses of this marker is the automatic translation of exceptions as described in [Exception translation](#).

Spring provides further stereotype annotations: `@Component`, `@Service`, and `@Controller`. `@Component` is a generic stereotype for any Spring-managed component. `@Repository`, `@Service`, and `@Controller` are specializations of `@Component` for more specific use cases, for example, in the persistence, service, and presentation layers, respectively. Therefore, you can annotate your component classes with

@Component, but by annotating them with @Repository, @Service, or @Controller instead, your classes are more properly suited for processing by tools or associating with aspects. For example, these stereotype annotations make ideal targets for pointcuts. It is also possible that @Repository, @Service, and @Controller may carry additional semantics in future releases of the Spring Framework. Thus, if you are choosing between using @Component or @Service for your service layer, @Service is clearly the better choice. Similarly, as stated above, @Repository is already supported as a marker for automatic exception translation in your persistence layer.

## 1.10.2. Meta-annotations

Many of the annotations provided by Spring can be used as *meta-annotations* in your own code. A meta-annotation is simply an annotation that can be applied to another annotation. For example, the @Service annotation mentioned above is meta-annotated with @Component:

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
@Documented
<strong>@Component</strong> // Spring will see this and treat @Service in the same way
as @Component
public @interface Service {

    // ...
}
```

Meta-annotations can also be combined to create *composed annotations*. For example, the @RestController annotation from Spring MVC is composed of @Controller and @ResponseBody.

In addition, composed annotations may optionally redeclare attributes from meta-annotations to allow user customization. This can be particularly useful when you want to only expose a subset of the meta-annotation's attributes. For example, Spring's @SessionScope annotation hardcodes the scope name to session but still allows customization of the proxyMode.

```
@Target({ElementType.TYPE, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
@Documented
@Scope(WebApplicationContext.SCOPE_SESSION)
public @interface SessionScope {

    /**
     * Alias for {@link Scope#proxyMode}.
     * <p>Defaults to {@link ScopedProxyMode#TARGET_CLASS}.
     */
    @AliasFor(annotation = Scope.class)
    ScopedProxyMode proxyMode() default ScopedProxyMode.TARGET_CLASS;

}
```

@SessionScope can then be used without declaring the proxyMode as follows:

```

@Service
<strong>@SessionScope</strong>
public class SessionScopedService {
    // ...
}

```

Or with an overridden value for the `proxyMode` as follows:

```

@Service
<strong>@SessionScope(proxyMode = ScopedProxyMode.INTERFACES)</strong>
public class SessionScopedUserService implements UserService {
    // ...
}

```

For further details, consult the [Spring Annotation Programming Model](#) wiki page.

### 1.10.3. Automatically detecting classes and registering bean definitions

Spring can automatically detect stereotyped classes and register corresponding `BeanDefinitions` with the `ApplicationContext`. For example, the following two classes are eligible for such autodetection:

```

@Service
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Autowired
    public SimpleMovieLister(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }
}

```

```

@Repository
public class JpaMovieFinder implements MovieFinder {
    // implementation elided for clarity
}

```

To autodetect these classes and register the corresponding beans, you need to add `@ComponentScan` to your `@Configuration` class, where the `basePackages` attribute is a common parent package for the two classes. (Alternatively, you can specify a comma/semicolon/space-separated list that includes the parent package of each class.)

```
@Configuration  
@ComponentScan(basePackages = "org.example")  
public class AppConfig {  
    ...  
}
```



For concision, the above may have used the `value` attribute of the annotation, i.e. `@ComponentScan("org.example")`

The following is an alternative using XML

```
<?xml version="1.0" encoding="UTF-8"?>  
<beans xmlns="http://www.springframework.org/schema/beans"  
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"  
       xmlns:context="http://www.springframework.org/schema/context"  
       xsi:schemaLocation="http://www.springframework.org/schema/beans  
                           http://www.springframework.org/schema/beans/spring-beans.xsd  
                           http://www.springframework.org/schema/context  
                           http://www.springframework.org/schema/context/spring-context.xsd">  
  
    <context:component-scan base-package="org.example"/>  
  
</beans>
```



The use of `<context:component-scan>` implicitly enables the functionality of `<context:annotation-config>`. There is usually no need to include the `<context:annotation-config>` element when using `<context:component-scan>`.



The scanning of classpath packages requires the presence of corresponding directory entries in the classpath. When you build JARs with Ant, make sure that you do *not* activate the files-only switch of the JAR task. Also, classpath directories may not get exposed based on security policies in some environments, e.g. standalone apps on JDK 1.7.0\_45 and higher (which requires 'Trusted-Library' setup in your manifests; see <http://stackoverflow.com/questions/19394570/java-jre-7u45-breaks-classloader-getresources>).

On JDK 9's module path (Jigsaw), Spring's classpath scanning generally works as expected. However, please make sure that your component classes are exported in your `module-info` descriptors; if you expect Spring to invoke non-public members of your classes, make sure that they are 'opened' (i.e. using an `opens` declaration instead of an `exports` declaration in your `module-info` descriptor).

Furthermore, the `AutowiredAnnotationBeanPostProcessor` and `CommonAnnotationBeanPostProcessor` are both included implicitly when you use the `component-scan` element. That means that the two components are autodetected *and* wired together - all without any bean configuration metadata provided in XML.



You can disable the registration of `AutowiredAnnotationBeanPostProcessor` and `CommonAnnotationBeanPostProcessor` by including the `annotation-config` attribute with a value of `false`.

#### 1.10.4. Using filters to customize scanning

By default, classes annotated with `@Component`, `@Repository`, `@Service`, `@Controller`, or a custom annotation that itself is annotated with `@Component` are the only detected candidate components. However, you can modify and extend this behavior simply by applying custom filters. Add them as `includeFilters` or `excludeFilters` parameters of the `@ComponentScan` annotation (or as `include-filter` or `exclude-filter` sub-elements of the `component-scan` element). Each filter element requires the `type` and `expression` attributes. The following table describes the filtering options.

Table 5. Filter Types

Filter Type	Example Expression	Description
annotation (default)	<code>org.example.SomeAnnotation</code>	An annotation to be present at the type level in target components.
assignable	<code>org.example.SomeClass</code>	A class (or interface) that the target components are assignable to (extend/implement).
aspectj	<code>org.example..*Service+</code>	An AspectJ type expression to be matched by the target components.
regex	<code>org\\.example\\.Default.*</code>	A regex expression to be matched by the target components class names.
custom	<code>org.example.MyTypeFilter</code>	A custom implementation of the <code>org.springframework.core.type.TypeFilter</code> interface.

The following example shows the configuration ignoring all `@Repository` annotations and using "stub" repositories instead.

```
@Configuration
@ComponentScan(basePackages = "org.example",
               includeFilters = @Filter(type = FilterType.REGEX, pattern =
".*Stub.*Repository"),
               excludeFilters = @Filter(Repository.class))
public class AppConfig {
    ...
}
```

and the equivalent using XML

```

<beans>
    <context:component-scan base-package="org.example">
        <context:include-filter type="regex"
            expression=".*Stub.*Repository"/>
        <context:exclude-filter type="annotation"
            expression="org.springframework.stereotype.Repository"/>
    </context:component-scan>
</beans>

```

 You can also disable the default filters by setting `useDefaultFilters=false` on the `annotation` or providing `use-default-filters="false"` as an attribute of the `<component-scan/>` element. This will in effect disable automatic detection of classes annotated with `@Component`, `@Repository`, `@Service`, `@Controller`, or `@Configuration`.

### 1.10.5. Defining bean metadata within components

Spring components can also contribute bean definition metadata to the container. You do this with the same `@Bean` annotation used to define bean metadata within `@Configuration` annotated classes. Here is a simple example:

```

@Component
public class FactoryMethodComponent {

    @Bean
    @Qualifier("public")
    public TestBean publicInstance() {
        return new TestBean("publicInstance");
    }

    public void doWork() {
        // Component method implementation omitted
    }
}

```

This class is a Spring component that has application-specific code contained in its `doWork()` method. However, it also contributes a bean definition that has a factory method referring to the method `publicInstance()`. The `@Bean` annotation identifies the factory method and other bean definition properties, such as a qualifier value through the `@Qualifier` annotation. Other method level annotations that can be specified are `@Scope`, `@Lazy`, and custom qualifier annotations.



In addition to its role for component initialization, the `@Lazy` annotation may also be placed on injection points marked with `@Autowired` or `@Inject`. In this context, it leads to the injection of a lazy-resolution proxy.

Autowired fields and methods are supported as previously discussed, with additional support for autowiring of `@Bean` methods:

```

@Component
public class FactoryMethodComponent {

    private static int i;

    @Bean
    @Qualifier("public")
    public TestBean publicInstance() {
        return new TestBean("publicInstance");
    }

    // use of a custom qualifier and autowiring of method parameters
    @Bean
    protected TestBean protectedInstance(
        @Qualifier("public") TestBean spouse,
        @Value("#{privateInstance.age}") String country) {
        TestBean tb = new TestBean("protectedInstance", 1);
        tb.setSpouse(spouse);
        tb.setCountry(country);
        return tb;
    }

    @Bean
    private TestBean privateInstance() {
        return new TestBean("privateInstance", i++);
    }

    @Bean
    @RequestScope
    public TestBean requestScopedInstance() {
        return new TestBean("requestScopedInstance", 3);
    }
}

```

The example autowires the `String` method parameter `country` to the value of the `Age` property on another bean named `privateInstance`. A Spring Expression Language element defines the value of the property through the notation `#{ <expression> }`. For `@Value` annotations, an expression resolver is preconfigured to look for bean names when resolving expression text.

As of Spring Framework 4.3, you may also declare a factory method parameter of type `InjectionPoint` (or its more specific subclass `DependencyDescriptor`) in order to access the requesting injection point that triggers the creation of the current bean. Note that this will only apply to the actual creation of bean instances, not to the injection of existing instances. As a consequence, this feature makes most sense for beans of prototype scope. For other scopes, the factory method will only ever see the injection point which triggered the creation of a new bean instance in the given scope: for example, the dependency that triggered the creation of a lazy singleton bean. Use the provided injection point metadata with semantic care in such scenarios.

```
@Component
public class FactoryMethodComponent {

    @Bean @Scope("prototype")
    public TestBean prototypeInstance(InjectionPoint injectionPoint) {
        return new TestBean("prototypeInstance for " + injectionPoint.getMember());
    }
}
```

The `@Bean` methods in a regular Spring component are processed differently than their counterparts inside a Spring `@Configuration` class. The difference is that `@Component` classes are not enhanced with CGLIB to intercept the invocation of methods and fields. CGLIB proxying is the means by which invoking methods or fields within `@Bean` methods in `@Configuration` classes creates bean metadata references to collaborating objects; such methods are *not* invoked with normal Java semantics but rather go through the container in order to provide the usual lifecycle management and proxying of Spring beans even when referring to other beans via programmatic calls to `@Bean` methods. In contrast, invoking a method or field in an `@Bean` method within a plain `@Component` class *has* standard Java semantics, with no special CGLIB processing or other constraints applying.

You may declare `@Bean` methods as `static`, allowing for them to be called without creating their containing configuration class as an instance. This makes particular sense when defining post-processor beans, e.g. of type `BeanFactoryPostProcessor` or `BeanPostProcessor`, since such beans will get initialized early in the container lifecycle and should avoid triggering other parts of the configuration at that point.

Note that calls to static `@Bean` methods will never get intercepted by the container, not even within `@Configuration` classes (see above). This is due to technical limitations: CGLIB subclassing can only override non-static methods. As a consequence, a direct call to another `@Bean` method will have standard Java semantics, resulting in an independent instance being returned straight from the factory method itself.

The Java language visibility of `@Bean` methods does not have an immediate impact on the resulting bean definition in Spring's container. You may freely declare your factory methods as you see fit in non-`@Configuration` classes and also for static methods anywhere. However, regular `@Bean` methods in `@Configuration` classes need to be overridable, i.e. they must not be declared as `private` or `final`.

`@Bean` methods will also be discovered on base classes of a given component or configuration class, as well as on Java 8 default methods declared in interfaces implemented by the component or configuration class. This allows for a lot of flexibility in composing complex configuration arrangements, with even multiple inheritance being possible through Java 8 default methods as of Spring 4.2.

Finally, note that a single class may hold multiple `@Bean` methods for the same bean, as an arrangement of multiple factory methods to use depending on available dependencies at runtime. This is the same algorithm as for choosing the "greediest" constructor or factory method in other configuration scenarios: The variant with the largest number of satisfiable dependencies will be picked at construction time, analogous to how the container selects between multiple `@Autowired` constructors.

## 1.10.6. Naming autodetected components

When a component is autodetected as part of the scanning process, its bean name is generated by the `BeanNameGenerator` strategy known to that scanner. By default, any Spring stereotype annotation (`@Component`, `@Repository`, `@Service`, and `@Controller`) that contains a `name` value will thereby provide that name to the corresponding bean definition.

If such an annotation contains no `name` value or for any other detected component (such as those discovered by custom filters), the default bean name generator returns the uncapitalized non-qualified class name. For example, if the following two components were detected, the names would be `myMovieLister` and `movieFinderImpl`:

```
@Service("myMovieLister")
public class SimpleMovieLister {
    // ...
}
```

```
@Repository
public class MovieFinderImpl implements MovieFinder {
    // ...
}
```



If you do not want to rely on the default bean-naming strategy, you can provide a custom bean-naming strategy. First, implement the `BeanNameGenerator` interface, and be sure to include a default no-arg constructor. Then, provide the fully-qualified class name when configuring the scanner:

```
@Configuration
@ComponentScan(basePackages = "org.example", nameGenerator = MyNameGenerator.class)
public class AppConfig {
    ...
}
```

```
<beans>
    <context:component-scan base-package="org.example"
        name-generator="org.example.MyNameGenerator" />
</beans>
```

As a general rule, consider specifying the name with the annotation whenever other components may be making explicit references to it. On the other hand, the auto-generated names are adequate whenever the container is responsible for wiring.

### 1.10.7. Providing a scope for autodetected components

As with Spring-managed components in general, the default and most common scope for autodetected components is `singleton`. However, sometimes you need a different scope which can be specified via the `@Scope` annotation. Simply provide the name of the scope within the annotation:

```
@Scope("prototype")
@Repository
public class MovieFinderImpl implements MovieFinder {
    // ...
}
```

For details on web-specific scopes, see [Request, session, application, and WebSocket scopes](#).



To provide a custom strategy for scope resolution rather than relying on the annotation-based approach, implement the `ScopeMetadataResolver` interface, and be sure to include a default no-arg constructor. Then, provide the fully-qualified class name when configuring the scanner:

```
@Configuration  
@ComponentScan(basePackages = "org.example", scopeResolver = MyScopeResolver.class)  
public class AppConfig {  
    ...  
}
```

```
<beans>  
    <context:component-scan base-package="org.example"  
        scope-resolver="org.example.MyScopeResolver" />  
</beans>
```

When using certain non-singleton scopes, it may be necessary to generate proxies for the scoped objects. The reasoning is described in [Scoped beans as dependencies](#). For this purpose, a `scoped-proxy` attribute is available on the component-scan element. The three possible values are: no, interfaces, and targetClass. For example, the following configuration will result in standard JDK dynamic proxies:

```
@Configuration  
@ComponentScan(basePackages = "org.example", scopedProxy = ScopedProxyMode.INTERFACES)  
public class AppConfig {  
    ...  
}
```

```
<beans>  
    <context:component-scan base-package="org.example"  
        scoped-proxy="interfaces" />  
</beans>
```

## 1.10.8. Providing qualifier metadata with annotations

The `@Qualifier` annotation is discussed in [Fine-tuning annotation-based autowiring with qualifiers](#). The examples in that section demonstrate the use of the `@Qualifier` annotation and custom qualifier annotations to provide fine-grained control when you resolve autowire candidates. Because those examples were based on XML bean definitions, the qualifier metadata was provided on the candidate bean definitions using the `qualifier` or `meta` sub-elements of the `bean` element in the XML. When relying upon classpath scanning for autodetection of components, you provide the qualifier metadata with type-level annotations on the candidate class. The following three examples demonstrate this technique:

```
@Component
<strong>@Qualifier("Action")</strong>
public class ActionMovieCatalog implements MovieCatalog {
    // ...
}
```

```
@Component
<strong>@Genre("Action")</strong>
public class ActionMovieCatalog implements MovieCatalog {
    // ...
}
```

```
@Component
<strong>@Offline</strong>
public class CachingMovieCatalog implements MovieCatalog {
    // ...
}
```



As with most annotation-based alternatives, keep in mind that the annotation metadata is bound to the class definition itself, while the use of XML allows for multiple beans *of the same type* to provide variations in their qualifier metadata, because that metadata is provided per-instance rather than per-class.

### 1.10.9. Generating an index of candidate components

While classpath scanning is very fast, it is possible to improve the startup performance of large applications by creating a static list of candidates at compilation time. In this mode, *all modules* of the application must use this mechanism as, when the `ApplicationContext` detects such index, it will automatically use it rather than scanning the classpath.

To generate the index, simply add an additional dependency to each module that contains components that are target for component scan directives:

```
<dependencies>
    <dependency>
        <groupId>org.springframework</groupId>
        <artifactId>spring-context-indexer</artifactId>
        <version>5.0.3.RELEASE</version>
        <optional>true</optional>
    </dependency>
</dependencies>
```

Or, using Gradle:

```
dependencies {  
    compileOnly("org.springframework:spring-context-indexer:5.0.3.RELEASE")  
}
```

That process will generate a `META-INF/spring.components` file that is going to be included in the jar.



When working with this mode in your IDE, the `spring-context-indexer` must be registered as an annotation processor to make sure the index is up to date when candidate components are updated.



The index is enabled automatically when a `META-INF/spring.components` is found on the classpath. If an index is partially available for some libraries (or use cases) but couldn't be built for the whole application, you can fallback to a regular classpath arrangement (i.e. as no index was present at all) by setting `spring.index.ignore` to `true`, either as a system property or in a `spring.properties` file at the root of the classpath.

## 1.11. Using JSR 330 Standard Annotations

Starting with Spring 3.0, Spring offers support for JSR-330 standard annotations (Dependency Injection). Those annotations are scanned in the same way as the Spring annotations. You just need to have the relevant jars in your classpath.

If you are using Maven, the `javax.inject` artifact is available in the standard Maven repository (<http://repo1.maven.org/maven2/javax/inject/javax.inject/1/>). You can add the following dependency to your file pom.xml:



```
<dependency>  
    <groupId>javax.inject</groupId>  
    <artifactId>javax.inject</artifactId>  
    <version>1</version>  
</dependency>
```

### 1.11.1. Dependency Injection with @Inject and @Named

Instead of `@Autowired`, `@javax.inject.Inject` may be used as follows:

```

import javax.inject.Inject;

public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Inject
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    public void listMovies() {
        this.movieFinder.findMovies(...);
        ...
    }
}

```

As with `@Autowired`, it is possible to use `@Inject` at the field level, method level and constructor-argument level. Furthermore, you may declare your injection point as a `Provider`, allowing for on-demand access to beans of shorter scopes or lazy access to other beans through a `Provider.get()` call. As a variant of the example above:

```

import javax.inject.Inject;
import javax.inject.Provider;

public class SimpleMovieLister {

    private Provider<MovieFinder> movieFinder;

    @Inject
    public void setMovieFinder(Provider<MovieFinder> movieFinder) {
        this.movieFinder = movieFinder;
    }

    public void listMovies() {
        this.movieFinder.get().findMovies(...);
        ...
    }
}

```

If you would like to use a qualified name for the dependency that should be injected, you should use the `@Named` annotation as follows:

```

import javax.inject.Inject;
import javax.inject.Named;

public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Inject
    public void setMovieFinder(@Named("main") MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...
}

```

Like `@Autowired`, `@Inject` can also be used with `java.util.Optional` or `@Nullable`. This is even more applicable here since `@Inject` does not have a `required` attribute.

```

public class SimpleMovieLister {

    @Inject
    public void setMovieFinder(Optional<MovieFinder> movieFinder) {
        ...
    }
}

```

```

public class SimpleMovieLister {

    @Inject
    public void setMovieFinder(@Nullable MovieFinder movieFinder) {
        ...
    }
}

```

### 1.11.2. `@Named` and `@ManagedBean`: standard equivalents to the `@Component` annotation

Instead of `@Component`, `@javax.inject.Named` or `javax.annotation.ManagedBean` may be used as follows:

```

import javax.inject.Inject;
import javax.inject.Named;

@Named("movieListener") // @ManagedBean("movieListener") could be used as well
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Inject
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...
}

```

It is very common to use `@Component` without specifying a name for the component. `@Named` can be used in a similar fashion:

```

import javax.inject.Inject;
import javax.inject.Named;

@Named
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Inject
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...
}

```

When using `@Named` or `@ManagedBean`, it is possible to use component scanning in the exact same way as when using Spring annotations:

```

@Configuration
@ComponentScan(basePackages = "org.example")
public class AppConfig {
    ...
}

```



In contrast to `@Component`, the JSR-330 `@Named` and the JSR-250 `ManagedBean` annotations are not composable. Please use Spring's stereotype model for building custom component annotations.

### 1.11.3. Limitations of JSR-330 standard annotations

When working with standard annotations, it is important to know that some significant features are not available as shown in the table below:

Table 6. Spring component model elements vs. JSR-330 variants

Spring	<code>javax.inject.*</code>	<code>javax.inject</code> restrictions / comments
<code>@Autowired</code>	<code>@Inject</code>	<code>@Inject</code> has no 'required' attribute; can be used with Java 8's <code>Optional</code> instead.
<code>@Component</code>	<code>@Named / @ManagedBean</code>	JSR-330 does not provide a composable model, just a way to identify named components.
<code>@Scope("singleton")</code>	<code>@Singleton</code>	The JSR-330 default scope is like Spring's <code>prototype</code> . However, in order to keep it consistent with Spring's general defaults, a JSR-330 bean declared in the Spring container is a <code>singleton</code> by default. In order to use a scope other than <code>singleton</code> , you should use Spring's <code>@Scope</code> annotation. <code>javax.inject</code> also provides a <code>@Scope</code> annotation. Nevertheless, this one is only intended to be used for creating your own annotations.
<code>@Qualifier</code>	<code>@Qualifier / @Named</code>	<code>javax.inject.Qualifier</code> is just a meta-annotation for building custom qualifiers. Concrete String qualifiers (like Spring's <code>@Qualifier</code> with a value) can be associated through <code>javax.inject.Named</code> .
<code>@Value</code>	-	no equivalent
<code>@Required</code>	-	no equivalent
<code>@Lazy</code>	-	no equivalent

Spring	javax.inject.*	javax.inject restrictions / comments
ObjectFactory	Provider	<code>javax.inject.Provider</code> is a direct alternative to Spring's <code>ObjectFactory</code> , just with a shorter <code>get()</code> method name. It can also be used in combination with Spring's <code>@Autowired</code> or with non-annotated constructors and setter methods.

## 1.12. Java-based container configuration

### 1.12.1. Basic concepts: @Bean and @Configuration

The central artifacts in Spring's new Java-configuration support are `@Configuration`-annotated classes and `@Bean`-annotated methods.

The `@Bean` annotation is used to indicate that a method instantiates, configures and initializes a new object to be managed by the Spring IoC container. For those familiar with Spring's `<beans/>` XML configuration the `@Bean` annotation plays the same role as the `<bean/>` element. You can use `@Bean` annotated methods with any Spring `@Component`, however, they are most often used with `@Configuration` beans.

Annotating a class with `@Configuration` indicates that its primary purpose is as a source of bean definitions. Furthermore, `@Configuration` classes allow inter-bean dependencies to be defined by simply calling other `@Bean` methods in the same class. The simplest possible `@Configuration` class would read as follows:

```
@Configuration
public class AppConfig {

    @Bean
    public MyService myService() {
        return new MyServiceImpl();
    }
}
```

The `AppConfig` class above would be equivalent to the following Spring `<beans/>` XML:

```
<beans>
    <bean id="myService" class="com.acme.services.MyServiceImpl"/>
</beans>
```

## Full @Configuration vs 'lite' @Bean mode?

When `@Bean` methods are declared within classes that are *not* annotated with `@Configuration` they are referred to as being processed in a 'lite' mode. Bean methods declared in a `@Component` or even in a *plain old class* will be considered 'lite', with a different primary purpose of the containing class and an `@Bean` method just being a sort of bonus there. For example, service components may expose management views to the container through an additional `@Bean` method on each applicable component class. In such scenarios, `@Bean` methods are a simple general-purpose factory method mechanism.

Unlike full `@Configuration`, lite `@Bean` methods cannot declare inter-bean dependencies. Instead, they operate on their containing component's internal state and optionally on arguments that they may declare. Such an `@Bean` method should therefore not invoke other `@Bean` methods; each such method is literally just a factory method for a particular bean reference, without any special runtime semantics. The positive side-effect here is that no CGLIB subclassing has to be applied at runtime, so there are no limitations in terms of class design (i.e. the containing class may nevertheless be `final` etc).

In common scenarios, `@Bean` methods are to be declared within `@Configuration` classes, ensuring that 'full' mode is always used and that cross-method references will therefore get redirected to the container's lifecycle management. This will prevent the same `@Bean` method from accidentally being invoked through a regular Java call which helps to reduce subtle bugs that can be hard to track down when operating in 'lite' mode.

The `@Bean` and `@Configuration` annotations will be discussed in depth in the sections below. First, however, we'll cover the various ways of creating a Spring container using Java-based configuration.

### 1.12.2. Instantiating the Spring container using `AnnotationConfigApplicationContext`

The sections below document Spring's `AnnotationConfigApplicationContext`, new in Spring 3.0. This versatile `ApplicationContext` implementation is capable of accepting not only `@Configuration` classes as input, but also plain `@Component` classes and classes annotated with JSR-330 metadata.

When `@Configuration` classes are provided as input, the `@Configuration` class itself is registered as a bean definition, and all declared `@Bean` methods within the class are also registered as bean definitions.

When `@Component` and JSR-330 classes are provided, they are registered as bean definitions, and it is assumed that DI metadata such as `@Autowired` or `@Inject` are used within those classes where necessary.

#### Simple construction

In much the same way that Spring XML files are used as input when instantiating a `ClassPathXmlApplicationContext`, `@Configuration` classes may be used as input when instantiating an `AnnotationConfigApplicationContext`. This allows for completely XML-free usage of the Spring

container:

```
public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(AppConfig.class);
    MyService myService = ctx.getBean(MyService.class);
    myService.doStuff();
}
```

As mentioned above, `AnnotationConfigApplicationContext` is not limited to working only with `@Configuration` classes. Any `@Component` or JSR-330 annotated class may be supplied as input to the constructor. For example:

```
public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(MyServiceImpl
.class, Dependency1.class, Dependency2.class);
    MyService myService = ctx.getBean(MyService.class);
    myService.doStuff();
}
```

The above assumes that `MyServiceImpl`, `Dependency1` and `Dependency2` use Spring dependency injection annotations such as `@Autowired`.

### Building the container programmatically using `register(Class<?>...)`

An `AnnotationConfigApplicationContext` may be instantiated using a no-arg constructor and then configured using the `register()` method. This approach is particularly useful when programmatically building an `AnnotationConfigApplicationContext`.

```
public static void main(String[] args) {
    AnnotationConfigApplicationContext ctx = new AnnotationConfigApplicationContext();
    ctx.register(AppConfig.class, OtherConfig.class);
    ctx.register(AdditionalConfig.class);
    ctx.refresh();
    MyService myService = ctx.getBean(MyService.class);
    myService.doStuff();
}
```

### Enabling component scanning with `scan(String...)`

To enable component scanning, just annotate your `@Configuration` class as follows:

```
@Configuration
@ComponentScan(basePackages = "com.acme")
public class AppConfig {
    ...
}
```

Experienced Spring users will be familiar with the XML declaration equivalent from Spring's `context`: namespace



```
<beans>
    <context:component-scan base-package="com.acme"/>
</beans>
```

In the example above, the `com.acme` package will be scanned, looking for any `@Component`-annotated classes, and those classes will be registered as Spring bean definitions within the container. `AnnotationConfigApplicationContext` exposes the `scan(String…)` method to allow for the same component-scanning functionality:

```
public static void main(String[] args) {
    AnnotationConfigApplicationContext ctx = new AnnotationConfigApplicationContext();
    ctx.scan("com.acme");
    ctx.refresh();
    MyService myService = ctx.getBean(MyService.class);
}
```



Remember that `@Configuration` classes are meta-annotated with `@Component`, so they are candidates for component-scanning! In the example above, assuming that `AppConfig` is declared within the `com.acme` package (or any package underneath), it will be picked up during the call to `scan()`, and upon `refresh()` all its `@Bean` methods will be processed and registered as bean definitions within the container.

## Support for web applications with `AnnotationConfigWebApplicationContext`

A `WebApplicationContext` variant of `AnnotationConfigApplicationContext` is available with `AnnotationConfigWebApplicationContext`. This implementation may be used when configuring the Spring `ContextLoaderListener` servlet listener, Spring MVC `DispatcherServlet`, etc. What follows is a `web.xml` snippet that configures a typical Spring MVC web application. Note the use of the `contextClass` context-param and init-param:

```
<web-app>
    <!-- Configure ContextLoaderListener to use AnnotationConfigWebApplicationContext
         instead of the default XmlWebApplicationContext -->
    <context-param>
        <param-name>contextClass</param-name>
        <param-value>
            org.springframework.web.context.support.AnnotationConfigWebApplicationContext
        </param-value>
    </context-param>

    <!-- Configuration locations must consist of one or more comma- or space-delimited
         fully-qualified @Configuration classes. Fully-qualified packages may also be
         specified -->
```

```

specified for component-scanning -->
<context-param>
    <param-name>contextConfigLocation</param-name>
    <param-value>com.acme.AppConfig</param-value>
</context-param>

<!-- Bootstrap the root application context as usual using ContextLoaderListener
-->
<listener>
    <listener-class>
org.springframework.web.context.ContextLoaderListener</listener-class>
    </listener>

<!-- Declare a Spring MVC DispatcherServlet as usual -->
<servlet>
    <servlet-name>dispatcher</servlet-name>
    <servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-
class>
    <!-- Configure DispatcherServlet to use AnnotationConfigWebApplicationContext
        instead of the default XmlWebApplicationContext -->
    <init-param>
        <param-name>contextClass</param-name>
        <param-value>
org.springframework.web.context.support.AnnotationConfigWebApplicationContext
        </param-value>
    </init-param>
    <!-- Again, config locations must consist of one or more comma- or space-
delimited
        and fully-qualified @Configuration classes -->
    <init-param>
        <param-name>contextConfigLocation</param-name>
        <param-value>com.acme.web.MvcConfig</param-value>
    </init-param>
</servlet>

<!-- map all requests for /app/* to the dispatcher servlet -->
<servlet-mapping>
    <servlet-name>dispatcher</servlet-name>
    <url-pattern>/app/*</url-pattern>
</servlet-mapping>
</web-app>

```

### 1.12.3. Using the `@Bean` annotation

`@Bean` is a method-level annotation and a direct analog of the XML `<bean/>` element. The annotation supports some of the attributes offered by `<bean/>`, such as: `init-method`, `destroy-method`, `autowiring` and `name`.

You can use the `@Bean` annotation in a `@Configuration`-annotated or in a `@Component`-annotated class.

## Declaring a bean

To declare a bean, simply annotate a method with the `@Bean` annotation. You use this method to register a bean definition within an `ApplicationContext` of the type specified as the method's return value. By default, the bean name will be the same as the method name. The following is a simple example of a `@Bean` method declaration:

```
@Configuration  
public class AppConfig {  
  
    @Bean  
    public TransferServiceImpl transferService() {  
        return new TransferServiceImpl();  
    }  
}
```

The preceding configuration is exactly equivalent to the following Spring XML:

```
<beans>  
    <bean id="transferService" class="com.acme.TransferServiceImpl"/>  
</beans>
```

Both declarations make a bean named `transferService` available in the `ApplicationContext`, bound to an object instance of type `TransferServiceImpl`:

```
transferService -> com.acme.TransferServiceImpl
```

You may also declare your `@Bean` method with an interface (or base class) return type:

```
@Configuration  
public class AppConfig {  
  
    @Bean  
    public TransferService transferService() {  
        return new TransferServiceImpl();  
    }  
}
```

However, this limits the visibility for advance type prediction to the specified interface type (`TransferService`) then, with the full type (`TransferServiceImpl`) only known to the container once the affected singleton bean has been instantiated. Non-lazy singleton beans get instantiated according to their declaration order, so you may see different type matching results depending on when another component tries to match by a non-declared type (such as `@Autowired TransferServiceImpl` which will only resolve once the "transferService" bean has been instantiated).



If you consistently refer to your types by a declared service interface, your `@Bean` return types may safely join that design decision. However, for components implementing several interfaces or for components potentially referred to by their implementation type, it is safer to declare the most specific return type possible (at least as specific as required by the injection points referring to your bean).

## Bean dependencies

A `@Bean` annotated method can have an arbitrary number of parameters describing the dependencies required to build that bean. For instance if our `TransferService` requires an `AccountRepository` we can materialize that dependency via a method parameter:

```
@Configuration
public class AppConfig {

    @Bean
    public TransferService transferService(AccountRepository accountRepository) {
        return new TransferServiceImpl(accountRepository);
    }
}
```

The resolution mechanism is pretty much identical to constructor-based dependency injection, see [the relevant section](#) for more details.

## Receiving lifecycle callbacks

Any classes defined with the `@Bean` annotation support the regular lifecycle callbacks and can use the `@PostConstruct` and `@PreDestroy` annotations from JSR-250, see [JSR-250 annotations](#) for further details.

The regular Spring `lifecycle` callbacks are fully supported as well. If a bean implements `InitializingBean`, `DisposableBean`, or `Lifecycle`, their respective methods are called by the container.

The standard set of `*Aware` interfaces such as `BeanFactoryAware`, `BeanNameAware`, `MessageSourceAware`, `ApplicationContextAware`, and so on are also fully supported.

The `@Bean` annotation supports specifying arbitrary initialization and destruction callback methods, much like Spring XML's `init-method` and `destroy-method` attributes on the `bean` element:

```
public class Foo {  
  
    public void init() {  
        // initialization logic  
    }  
}  
  
public class Bar {  
  
    public void cleanup() {  
        // destruction logic  
    }  
}  
  
@Configuration  
public class AppConfig {  
  
    @Bean(initMethod = "init")  
    public Foo foo() {  
        return new Foo();  
    }  
  
    @Bean(destroyMethod = "cleanup")  
    public Bar bar() {  
        return new Bar();  
    }  
}
```

By default, beans defined using Java config that have a public `close` or `shutdown` method are automatically enlisted with a destruction callback. If you have a public `close` or `shutdown` method and you do not wish for it to be called when the container shuts down, simply add `@Bean(destroyMethod="")` to your bean definition to disable the default (`inferred`) mode.

You may want to do that by default for a resource that you acquire via JNDI as its lifecycle is managed outside the application. In particular, make sure to always do it for a `DataSource` as it is known to be problematic on Java EE application servers.



```
@Bean(destroyMethod="")
public DataSource dataSource() throws NamingException {
    return (DataSource) jndiTemplate.lookup("MyDS");
}
```

Also, with `@Bean` methods, you will typically choose to use programmatic JNDI lookups: either using Spring's `JndiTemplate/JndiLocatorDelegate` helpers or straight JNDI `InitialContext` usage, but not the `JndiObjectFactoryBean` variant which would force you to declare the return type as the `FactoryBean` type instead of the actual target type, making it harder to use for cross-reference calls in other `@Bean` methods that intend to refer to the provided resource here.

Of course, in the case of `Foo` above, it would be equally as valid to call the `init()` method directly during construction:

```
@Configuration
public class AppConfig {

    @Bean
    public Foo foo() {
        Foo foo = new Foo();
        foo.init();
        return foo;
    }

    // ...
}
```



When you work directly in Java, you can do anything you like with your objects and do not always need to rely on the container lifecycle!

## Specifying bean scope

### Using the `@Scope` annotation

You can specify that your beans defined with the `@Bean` annotation should have a specific scope. You can use any of the standard scopes specified in the [Bean Scopes](#) section.

The default scope is `singleton`, but you can override this with the `@Scope` annotation:

```
@Configuration
public class MyConfiguration {

    @Bean
    <strong>@Scope("prototype")</strong>
    public Encryptor encryptor() {
        // ...
    }
}
```

### @Scope and scoped-proxy

Spring offers a convenient way of working with scoped dependencies through `scoped proxies`. The easiest way to create such a proxy when using the XML configuration is the `<aop:scoped-proxy/>` element. Configuring your beans in Java with a `@Scope` annotation offers equivalent support with the `proxyMode` attribute. The default is no proxy (`ScopedProxyMode.NO`), but you can specify `ScopedProxyMode.TARGET_CLASS` or `ScopedProxyMode.INTERFACES`.

If you port the scoped proxy example from the XML reference documentation (see preceding link) to our `@Bean` using Java, it would look like the following:

```
// an HTTP Session-scoped bean exposed as a proxy
@Bean
<strong>@SessionScope</strong>
public UserPreferences userPreferences() {
    return new UserPreferences();
}

@Bean
public Service userService() {
    UserService service = new SimpleUserService();
    // a reference to the proxied userPreferences bean
    service.setUserPreferences(userPreferences());
    return service;
}
```

### Customizing bean naming

By default, configuration classes use a `@Bean` method's name as the name of the resulting bean. This functionality can be overridden, however, with the `name` attribute.

```

@Configuration
public class AppConfig {

    @Bean(name = "myFoo")
    public Foo foo() {
        return new Foo();
    }
}

```

## Bean aliasing

As discussed in [Naming beans](#), it is sometimes desirable to give a single bean multiple names, otherwise known as *bean aliasing*. The `name` attribute of the `@Bean` annotation accepts a String array for this purpose.

```

@Configuration
public class AppConfig {

    @Bean(name = { "dataSource", "subsystemA-dataSource", "subsystemB-dataSource" })
    public DataSource dataSource() {
        // instantiate, configure and return DataSource bean...
    }
}

```

## Bean description

Sometimes it is helpful to provide a more detailed textual description of a bean. This can be particularly useful when beans are exposed (perhaps via JMX) for monitoring purposes.

To add a description to a `@Bean` the `@Description` annotation can be used:

```

@Configuration
public class AppConfig {

    @Bean
    <strong>@Description("Provides a basic example of a bean")</strong>
    public Foo foo() {
        return new Foo();
    }
}

```

### 1.12.4. Using the `@Configuration` annotation

`@Configuration` is a class-level annotation indicating that an object is a source of bean definitions. `@Configuration` classes declare beans via public `@Bean` annotated methods. Calls to `@Bean` methods on `@Configuration` classes can also be used to define inter-bean dependencies. See [Basic concepts: @Bean and @Configuration](#) for a general introduction.

## Injecting inter-bean dependencies

When `@Beans` have dependencies on one another, expressing that dependency is as simple as having one bean method call another:

```
@Configuration
public class AppConfig {

    @Bean
    public Foo foo() {
        return new Foo(bar());
    }

    @Bean
    public Bar bar() {
        return new Bar();
    }
}
```

In the example above, the `foo` bean receives a reference to `bar` via constructor injection.



This method of declaring inter-bean dependencies only works when the `@Bean` method is declared within a `@Configuration` class. You cannot declare inter-bean dependencies using plain `@Component` classes.

## Lookup method injection

As noted earlier, [lookup method injection](#) is an advanced feature that you should use rarely. It is useful in cases where a singleton-scoped bean has a dependency on a prototype-scoped bean. Using Java for this type of configuration provides a natural means for implementing this pattern.

```
public abstract class CommandManager {
    public Object process(Object commandState) {
        // grab a new instance of the appropriate Command interface
        Command command = createCommand();
        // set the state on the (hopefully brand new) Command instance
        command.setState(commandState);
        return command.execute();
    }

    // okay... but where is the implementation of this method?
    protected abstract Command createCommand();
}
```

Using Java-configuration support , you can create a subclass of `CommandManager` where the abstract `createCommand()` method is overridden in such a way that it looks up a new (prototype) command object:

```

@Bean
@Scope("prototype")
public AsyncCommand asyncCommand() {
    AsyncCommand command = new AsyncCommand();
    // inject dependencies here as required
    return command;
}

@Bean
public CommandManager commandManager() {
    // return new anonymous implementation of CommandManager with command() overridden
    // to return a new prototype Command object
    return new CommandManager() {
        protected Command createCommand() {
            return asyncCommand();
        }
    };
}

```

## Further information about how Java-based configuration works internally

The following example shows a `@Bean` annotated method being called twice:

```

@Configuration
public class AppConfig {

    @Bean
    public ClientService clientService1() {
        ClientServiceImpl clientService = new ClientServiceImpl();
        clientService.setClientDao(clientDao());
        return clientService;
    }

    @Bean
    public ClientService clientService2() {
        ClientServiceImpl clientService = new ClientServiceImpl();
        clientService.setClientDao(clientDao());
        return clientService;
    }

    @Bean
    public ClientDao clientDao() {
        return new ClientDaoImpl();
    }
}

```

`clientDao()` has been called once in `clientService1()` and once in `clientService2()`. Since this method creates a new instance of `ClientDaoImpl` and returns it, you would normally expect having 2

instances (one for each service). That definitely would be problematic: in Spring, instantiated beans have a `singleton` scope by default. This is where the magic comes in: All `@Configuration` classes are subclassed at startup-time with `CGLIB`. In the subclass, the child method checks the container first for any cached (scoped) beans before it calls the parent method and creates a new instance. Note that as of Spring 3.2, it is no longer necessary to add CGLIB to your classpath because CGLIB classes have been repackaged under `org.springframework.cglib` and included directly within the spring-core JAR.



The behavior could be different according to the scope of your bean. We are talking about singletons here.

There are a few restrictions due to the fact that CGLIB dynamically adds features at startup-time, in particular that configuration classes must not be final. However, as of 4.3, any constructors are allowed on configuration classes, including the use of `@Autowired` or a single non-default constructor declaration for default injection.



If you prefer to avoid any CGLIB-imposed limitations, consider declaring your `@Bean` methods on non-`@Configuration` classes, e.g. on plain `@Component` classes instead. Cross-method calls between `@Bean` methods won't get intercepted then, so you'll have to exclusively rely on dependency injection at the constructor or method level there.

### 1.12.5. Composing Java-based configurations

#### Using the `@Import` annotation

Much as the `<import/>` element is used within Spring XML files to aid in modularizing configurations, the `@Import` annotation allows for loading `@Bean` definitions from another configuration class:

```
@Configuration
public class ConfigA {

    @Bean
    public A a() {
        return new A();
    }
}

@Configuration
@Import(ConfigA.class)
public class ConfigB {

    @Bean
    public B b() {
        return new B();
    }
}
```

Now, rather than needing to specify both `ConfigA.class` and `ConfigB.class` when instantiating the context, only `ConfigB` needs to be supplied explicitly:

```
public static void main(String[] args) {  
    ApplicationContext ctx = new AnnotationConfigApplicationContext(ConfigB.class);  
  
    // now both beans A and B will be available...  
    A a = ctx.getBean(A.class);  
    B b = ctx.getBean(B.class);  
}
```

This approach simplifies container instantiation, as only one class needs to be dealt with, rather than requiring the developer to remember a potentially large number of `@Configuration` classes during construction.



As of Spring Framework 4.2, `@Import` also supports references to regular component classes, analogous to the `AnnotationConfigApplicationContext.register` method. This is particularly useful if you'd like to avoid component scanning, using a few configuration classes as entry points for explicitly defining all your components.

#### Injecting dependencies on imported `@Bean` definitions

The example above works, but is simplistic. In most practical scenarios, beans will have dependencies on one another across configuration classes. When using XML, this is not an issue, per se, because there is no compiler involved, and one can simply declare `ref="someBean"` and trust that Spring will work it out during container initialization. Of course, when using `@Configuration` classes, the Java compiler places constraints on the configuration model, in that references to other beans must be valid Java syntax.

Fortunately, solving this problem is simple. As we already discussed, `@Bean` method can have an arbitrary number of parameters describing the bean dependencies. Let's consider a more real-world scenario with several `@Configuration` classes, each depending on beans declared in the others:

```

@Configuration
public class ServiceConfig {

    @Bean
    public TransferService transferService(AccountRepository accountRepository) {
        return new TransferServiceImpl(accountRepository);
    }
}

@Configuration
public class RepositoryConfig {

    @Bean
    public AccountRepository accountRepository(DataSource dataSource) {
        return new JdbcAccountRepository(dataSource);
    }
}

@Configuration
@Import({ServiceConfig.class, RepositoryConfig.class})
public class SystemTestConfig {

    @Bean
    public DataSource dataSource() {
        // return new DataSource
    }
}

public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(SystemTestConfig.class);
    // everything wires up across configuration classes...
    TransferService transferService = ctx.getBean(TransferService.class);
    transferService.transfer("100.00", "A123", "C456");
}

```

There is another way to achieve the same result. Remember that `@Configuration` classes are ultimately just another bean in the container: This means that they can take advantage of `@Autowired` and `@Value` injection etc just like any other bean!

Make sure that the dependencies you inject that way are of the simplest kind only. `@Configuration` classes are processed quite early during the initialization of the context and forcing a dependency to be injected this way may lead to unexpected early initialization. Whenever possible, resort to parameter-based injection as in the example above.



Also, be particularly careful with `BeanPostProcessor` and `BeanFactoryPostProcessor` definitions via `@Bean`. Those should usually be declared as `static @Bean` methods, not triggering the instantiation of their containing configuration class. Otherwise, `@Autowired` and `@Value` won't work on the configuration class itself since it is being created as a bean instance too early.

```

@Configuration
public class ServiceConfig {

    @Autowired
    private AccountRepository accountRepository;

    @Bean
    public TransferService transferService() {
        return new TransferServiceImpl(accountRepository);
    }
}

@Configuration
public class RepositoryConfig {

    private final DataSource dataSource;

    @Autowired
    public RepositoryConfig(DataSource dataSource) {
        this.dataSource = dataSource;
    }

    @Bean
    public AccountRepository accountRepository() {
        return new JdbcAccountRepository(dataSource);
    }
}

@Configuration
@Import({ServiceConfig.class, RepositoryConfig.class})
public class SystemTestConfig {

    @Bean
    public DataSource dataSource() {
        // return new DataSource
    }
}

public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(SystemTestConfig.class);
    // everything wires up across configuration classes...
    TransferService transferService = ctx.getBean(TransferService.class);
    transferService.transfer("100.00", "A123", "C456");
}

```



Constructor injection in `@Configuration` classes is only supported as of Spring Framework 4.3. Note also that there is no need to specify `@Autowired` if the target bean defines only one constructor; in the example above, `@Autowired` is not necessary on the `RepositoryConfig` constructor.

#### *Fully-qualifying imported beans for ease of navigation*

In the scenario above, using `@Autowired` works well and provides the desired modularity, but determining exactly where the autowired bean definitions are declared is still somewhat ambiguous. For example, as a developer looking at `ServiceConfig`, how do you know exactly where the `@Autowired AccountRepository` bean is declared? It's not explicit in the code, and this may be just fine. Remember that the [Spring Tool Suite](#) provides tooling that can render graphs showing how everything is wired up - that may be all you need. Also, your Java IDE can easily find all declarations and uses of the `AccountRepository` type, and will quickly show you the location of `@Bean` methods that return that type.

In cases where this ambiguity is not acceptable and you wish to have direct navigation from within your IDE from one `@Configuration` class to another, consider autowiring the configuration classes themselves:

```
@Configuration
public class ServiceConfig {

    @Autowired
    private RepositoryConfig repositoryConfig;

    @Bean
    public TransferService transferService() {
        // navigate 'through' the config class to the @Bean method!
        return new TransferServiceImpl(repositoryConfig.accountRepository());
    }
}
```

In the situation above, it is completely explicit where `AccountRepository` is defined. However, `ServiceConfig` is now tightly coupled to `RepositoryConfig`; that's the tradeoff. This tight coupling can be somewhat mitigated by using interface-based or abstract class-based `@Configuration` classes. Consider the following:

```

@Configuration
public class ServiceConfig {

    @Autowired
    private RepositoryConfig repositoryConfig;

    @Bean
    public TransferService transferService() {
        return new TransferServiceImpl(repositoryConfig.accountRepository());
    }
}

@Configuration
public interface RepositoryConfig {

    @Bean
    AccountRepository accountRepository();
}

@Configuration
public class DefaultRepositoryConfig implements RepositoryConfig {

    @Bean
    public AccountRepository accountRepository() {
        return new JdbcAccountRepository(...);
    }
}

@Configuration
@Import({ServiceConfig.class, DefaultRepositoryConfig.class}) // import the concrete config!
public class SystemTestConfig {

    @Bean
    public DataSource dataSource() {
        // return DataSource
    }
}

public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(SystemTestConfig.class);
    TransferService transferService = ctx.getBean(TransferService.class);
    transferService.transfer(100.00, "A123", "C456");
}

```

Now `ServiceConfig` is loosely coupled with respect to the concrete `DefaultRepositoryConfig`, and built-in IDE tooling is still useful: it will be easy for the developer to get a type hierarchy of

`RepositoryConfig` implementations. In this way, navigating `@Configuration` classes and their dependencies becomes no different than the usual process of navigating interface-based code.



If you would like to influence the startup creation order of certain beans, consider declaring some of them as `@Lazy` (for creation on first access instead of on startup) or as `@DependsOn` on certain other beans (making sure that specific other beans will be created before the current bean, beyond what the latter's direct dependencies imply).

## Conditionally include `@Configuration` classes or `@Bean` methods

It is often useful to conditionally enable or disable a complete `@Configuration` class, or even individual `@Bean` methods, based on some arbitrary system state. One common example of this is to use the `@Profile` annotation to activate beans only when a specific profile has been enabled in the Spring Environment (see [Bean definition profiles](#) for details).

The `@Profile` annotation is actually implemented using a much more flexible annotation called `@Conditional`. The `@Conditional` annotation indicates specific `org.springframework.context.annotation.Condition` implementations that should be consulted before a `@Bean` is registered.

Implementations of the `Condition` interface simply provide a `matches(...)` method that returns `true` or `false`. For example, here is the actual `Condition` implementation used for `@Profile`:

```
@Override  
public boolean matches(ConditionContext context, AnnotatedTypeMetadata metadata) {  
    if (context.getEnvironment() != null) {  
        // Read the @Profile annotation attributes  
        MultiValueMap<String, Object> attrs = metadata.getAllAnnotationAttributes(  
            Profile.class.getName());  
        if (attrs != null) {  
            for (Object value : attrs.get("value")) {  
                if (context.getEnvironment().acceptsProfiles(((String[]) value))) {  
                    return true;  
                }  
            }  
            return false;  
        }  
    }  
    return true;  
}
```

See the [@Conditional javadocs](#) for more detail.

## Combining Java and XML configuration

Spring's `@Configuration` class support does not aim to be a 100% complete replacement for Spring XML. Some facilities such as Spring XML namespaces remain an ideal way to configure the container. In cases where XML is convenient or necessary, you have a choice: either instantiate the

container in an "XML-centric" way using, for example, `ClassPathXmlApplicationContext`, or in a "Java-centric" fashion using `AnnotationConfigApplicationContext` and the `@ImportResource` annotation to import XML as needed.

### XML-centric use of `@Configuration` classes

It may be preferable to bootstrap the Spring container from XML and include `@Configuration` classes in an ad-hoc fashion. For example, in a large existing codebase that uses Spring XML, it will be easier to create `@Configuration` classes on an as-needed basis and include them from the existing XML files. Below you'll find the options for using `@Configuration` classes in this kind of "XML-centric" situation.

#### *Declaring `@Configuration` classes as plain Spring `<bean/>` elements*

Remember that `@Configuration` classes are ultimately just bean definitions in the container. In this example, we create a `@Configuration` class named `AppConfig` and include it within `system-test-config.xml` as a `<bean/>` definition. Because `<context:annotation-config/>` is switched on, the container will recognize the `@Configuration` annotation and process the `@Bean` methods declared in `AppConfig` properly.

```
@Configuration
public class AppConfig {

    @Autowired
    private DataSource dataSource;

    @Bean
    public AccountRepository accountRepository() {
        return new JdbcAccountRepository(dataSource);
    }

    @Bean
    public TransferService transferService() {
        return new TransferService(accountRepository());
    }
}
```

#### **system-test-config.xml:**

```

<beans>
    <!-- enable processing of annotations such as @Autowired and @Configuration -->
    <context:annotation-config/>
    <context:property-placeholder location="classpath:/com/acme/jdbc.properties"/>

    <bean class="com.acme.AppConfig"/>

    <bean class="org.springframework.jdbc.datasource.DriverManagerDataSource">
        <property name="url" value="${jdbc.url}"/>
        <property name="username" value="${jdbc.username}"/>
        <property name="password" value="${jdbc.password}"/>
    </bean>
</beans>

```

### jdbc.properties:

```

jdbc.url=jdbc:hsqldb:hsq://localhost/xdb
jdbc.username=sa
jdbc.password=

```

```

public static void main(String[] args) {
    ApplicationContext ctx = new ClassPathXmlApplicationContext(
    "classpath:/com/acme/system-test-config.xml");
    TransferService transferService = ctx.getBean(TransferService.class);
    // ...
}

```

**i** In `system-test-config.xml` above, the `AppConfig <bean/>` does not declare an `id` element. While it would be acceptable to do so, it is unnecessary given that no other bean will ever refer to it, and it is unlikely that it will be explicitly fetched from the container by name. Likewise with the `DataSource` bean - it is only ever autowired by type, so an explicit bean `id` is not strictly required.

Using `<context:component-scan/>` to pick up `@Configuration` classes

Because `@Configuration` is meta-annotated with `@Component`, `@Configuration`-annotated classes are automatically candidates for component scanning. Using the same scenario as above, we can redefine `system-test-config.xml` to take advantage of component-scanning. Note that in this case, we don't need to explicitly declare `<context:annotation-config/>`, because `<context:component-scan/>` enables the same functionality.

### system-test-config.xml:

```

<beans>
    <!-- picks up and registers AppConfig as a bean definition -->
    <context:component-scan base-package="com.acme"/>
    <context:property-placeholder location="classpath:/com/acme/jdbc.properties"/>

    <bean class="org.springframework.jdbc.datasource.DriverManagerDataSource">
        <property name="url" value="${jdbc.url}"/>
        <property name="username" value="${jdbc.username}"/>
        <property name="password" value="${jdbc.password}"/>
    </bean>
</beans>

```

### @Configuration class-centric use of XML with @ImportResource

In applications where `@Configuration` classes are the primary mechanism for configuring the container, it will still likely be necessary to use at least some XML. In these scenarios, simply use `@ImportResource` and define only as much XML as is needed. Doing so achieves a "Java-centric" approach to configuring the container and keeps XML to a bare minimum.

```

@Configuration
@ImportResource("classpath:/com/acme/properties-config.xml")
public class AppConfig {

    @Value("${jdbc.url}")
    private String url;

    @Value("${jdbc.username}")
    private String username;

    @Value("${jdbc.password}")
    private String password;

    @Bean
    public DataSource dataSource() {
        return new DriverManagerDataSource(url, username, password);
    }
}

```

```

properties-config.xml
<beans>
    <context:property-placeholder location="classpath:/com/acme/jdbc.properties"/>
</beans>

```

```
jdbc.properties  
jdbc.url=jdbc:hsqldb:hsq://localhost/xdb  
jdbc.username=sa  
jdbc.password=
```

```
public static void main(String[] args) {  
    ApplicationContext ctx = new AnnotationConfigApplicationContext(AppConfig.class);  
    TransferService transferService = ctx.getBean(TransferService.class);  
    // ...  
}
```

## 1.13. Environment abstraction

The **Environment** is an abstraction integrated in the container that models two key aspects of the application environment: *profiles* and *properties*.

A *profile* is a named, logical group of bean definitions to be registered with the container only if the given profile is active. Beans may be assigned to a profile whether defined in XML or via annotations. The role of the **Environment** object with relation to profiles is in determining which profiles (if any) are currently active, and which profiles (if any) should be active by default.

Properties play an important role in almost all applications, and may originate from a variety of sources: properties files, JVM system properties, system environment variables, JNDI, servlet context parameters, ad-hoc Properties objects, Maps, and so on. The role of the **Environment** object with relation to properties is to provide the user with a convenient service interface for configuring property sources and resolving properties from them.

### 1.13.1. Bean definition profiles

Bean definition profiles is a mechanism in the core container that allows for registration of different beans in different environments. The word *environment* can mean different things to different users and this feature can help with many use cases, including:

- working against an in-memory datasource in development vs looking up that same datasource from JNDI when in QA or production
- registering monitoring infrastructure only when deploying an application into a performance environment
- registering customized implementations of beans for customer A vs. customer B deployments

Let's consider the first use case in a practical application that requires a **DataSource**. In a test environment, the configuration may look like this:

```

@Bean
public DataSource dataSource() {
    return new EmbeddedDatabaseBuilder()
        .setType(EmbeddedDatabaseType.HSQL)
        .addScript("my-schema.sql")
        .addScript("my-test-data.sql")
        .build();
}

```

Let's now consider how this application will be deployed into a QA or production environment, assuming that the datasource for the application will be registered with the production application server's JNDI directory. Our `dataSource` bean now looks like this:

```

@Bean(destroyMethod="")
public DataSource dataSource() throws Exception {
    Context ctx = new InitialContext();
    return (DataSource) ctx.lookup("java:comp/env/jdbc/datasource");
}

```

The problem is how to switch between using these two variations based on the current environment. Over time, Spring users have devised a number of ways to get this done, usually relying on a combination of system environment variables and XML `<import/>` statements containing `#{placeholder}` tokens that resolve to the correct configuration file path depending on the value of an environment variable. Bean definition profiles is a core container feature that provides a solution to this problem.

If we generalize the example use case above of environment-specific bean definitions, we end up with the need to register certain bean definitions in certain contexts, while not in others. You could say that you want to register a certain profile of bean definitions in situation A, and a different profile in situation B. Let's first see how we can update our configuration to reflect this need.

## **@Profile**

The `@Profile` annotation allows you to indicate that a component is eligible for registration when one or more specified profiles are active. Using our example above, we can rewrite the `dataSource` configuration as follows:

```

@Configuration
<strong>@Profile("development")</strong>
public class StandaloneDataConfig {

    @Bean
    public DataSource dataSource() {
        return new EmbeddedDatabaseBuilder()
            .setType(EmbeddedDatabaseType.HSQL)
            .addScript("classpath:com/bank/config/sql/schema.sql")
            .addScript("classpath:com/bank/config/sql/test-data.sql")
            .build();
    }
}

```

```

@Configuration
<strong>@Profile("production")</strong>
public class JndiDataConfig {

    @Bean(destroyMethod="")
    public DataSource dataSource() throws Exception {
        Context ctx = new InitialContext();
        return (DataSource) ctx.lookup("java:comp/env/jdbc/datasource");
    }
}

```



As mentioned before, with `@Bean` methods, you will typically choose to use programmatic JNDI lookups: either using Spring's `JndiTemplate` / `JndiLocatorDelegate` helpers or the straight JNDI `InitialContext` usage shown above, but not the `JndiObjectFactoryBean` variant which would force you to declare the return type as the `FactoryBean` type.

`@Profile` can be used as a `meta-annotation` for the purpose of creating a custom *composed annotation*. The following example defines a custom `@Production` annotation that can be used as a drop-in replacement for `@Profile("production")`:

```

@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
<strong>@Profile("production")</strong>
public @interface Production {
}

```

If a `@Configuration` class is marked with `@Profile`, all of the `@Bean` methods and `@Import` annotations associated with that class will be bypassed unless one or more of the specified profiles are active. If a `@Component` or `@Configuration` class is marked with `@Profile({"p1", "p2"})`, that class will not be registered/processed unless profiles 'p1' and/or 'p2' have been activated. If a given profile is prefixed with the NOT operator (`!`), the annotated element will be registered if the profile is **not** active. For example, given `@Profile({"p1", "!p2"})`, registration will occur if profile 'p1' is active or if profile 'p2' is not active.



`@Profile` can also be declared at the method level to include only one particular bean of a configuration class, e.g. for alternative variants of a particular bean:

```
@Configuration
public class AppConfig {

    @Bean("dataSource")
    <strong>@Profile("development")</strong>
    public DataSource standaloneDataSource() {
        return new EmbeddedDatabaseBuilder()
            .setType(EmbeddedDatabaseType.HSQL)
            .addScript("classpath:com/bank/config/sql/schema.sql")
            .addScript("classpath:com/bank/config/sql/test-data.sql")
            .build();
    }

    @Bean("dataSource")
    <strong>@Profile("production")</strong>
    public DataSource jndiDataSource() throws Exception {
        Context ctx = new InitialContext();
        return (DataSource) ctx.lookup("java:comp/env/jdbc/datasource");
    }
}
```

With `@Profile` on `@Bean` methods, a special scenario may apply: In the case of overloaded `@Bean` methods of the same Java method name (analogous to constructor overloading), an `@Profile` condition needs to be consistently declared on all overloaded methods. If the conditions are inconsistent, only the condition on the first declaration among the overloaded methods will matter. `@Profile` can therefore not be used to select an overloaded method with a particular argument signature over another; resolution between all factory methods for the same bean follows Spring's constructor resolution algorithm at creation time.



If you would like to define alternative beans with different profile conditions, use distinct Java method names pointing to the same bean name via the `@Bean` name attribute, as indicated in the example above. If the argument signatures are all the same (e.g. all of the variants have no-arg factory methods), this is the only way to represent such an arrangement in a valid Java class in the first place (since there can only be one method of a particular name and argument signature).

## XML bean definition profiles

The XML counterpart is the `profile` attribute of the `<beans>` element. Our sample configuration above can be rewritten in two XML files as follows:

```
<beans profile="development"
    xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jdbc="http://www.springframework.org/schema/jdbc"
    xsi:schemaLocation="...>

    <jdbc:embedded-database id="dataSource">
        <jdbc:script location="classpath:com/bank/config/sql/schema.sql"/>
        <jdbc:script location="classpath:com/bank/config/sql/test-data.sql"/>
    </jdbc:embedded-database>
</beans>
```

```
<beans profile="production"
    xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jee="http://www.springframework.org/schema/jee"
    xsi:schemaLocation="...>

    <jee:jndi-lookup id="dataSource" jndi-name="java:comp/env/jdbc/datasource"/>
</beans>
```

It is also possible to avoid that split and nest `<beans/>` elements within the same file:

```

<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:jdbc="http://www.springframework.org/schema/jdbc"
       xmlns:jee="http://www.springframework.org/schema/jee"
       xsi:schemaLocation="...>

    <!-- other bean definitions -->

    <beans profile="development">
        <jdbc:embedded-database id="dataSource">
            <jdbc:script location="classpath:com/bank/config/sql/schema.sql"/>
            <jdbc:script location="classpath:com/bank/config/sql/test-data.sql"/>
        </jdbc:embedded-database>
    </beans>

    <beans profile="production">
        <jee:jndi-lookup id="dataSource" jndi-name="java:comp/env/jdbc/datasource"/>
    </beans>
</beans>

```

The `spring-bean.xsd` has been constrained to allow such elements only as the last ones in the file. This should help provide flexibility without incurring clutter in the XML files.

## Activating a profile

Now that we have updated our configuration, we still need to instruct Spring which profile is active. If we started our sample application right now, we would see a `NoSuchBeanDefinitionException` thrown, because the container could not find the Spring bean named `dataSource`.

Activating a profile can be done in several ways, but the most straightforward is to do it programmatically against the `Environment` API which is available via an `ApplicationContext`:

```

AnnotationConfigApplicationContext ctx = new AnnotationConfigApplicationContext();
ctx.getEnvironment(). setActiveProfiles("development");
ctx.register(SomeConfig.class, StandaloneDataConfig.class, JndiDataConfig.class);
ctx.refresh();

```

In addition, profiles may also be activated declaratively through the `spring.profiles.active` property which may be specified through system environment variables, JVM system properties, servlet context parameters in `web.xml`, or even as an entry in JNDI (see `PropertySource abstraction`). In integration tests, active profiles can be declared via the `@ActiveProfiles` annotation in the `spring-test` module (see `Context configuration with environment profiles`).

Note that profiles are not an "either-or" proposition; it is possible to activate multiple profiles at once. Programmatically, simply provide multiple profile names to the `setActiveProfiles()` method, which accepts `String...` varargs:

```
ctx.getEnvironment().setActiveProfiles("profile1", "profile2");
```

Declaratively, `spring.profiles.active` may accept a comma-separated list of profile names:

```
-Dspring.profiles.active="profile1,profile2"
```

## Default profile

The `default` profile represents the profile that is enabled by default. Consider the following:

```
@Configuration
<strong>@Profile("default")</strong>
public class DefaultDataConfig {

    @Bean
    public DataSource dataSource() {
        return new EmbeddedDatabaseBuilder()
            .setType(EmbeddedDatabaseType.HSQL)
            .addScript("classpath:com/bank/config/sql/schema.sql")
            .build();
    }
}
```

If no profile is active, the `dataSource` above will be created; this can be seen as a way to provide a `default` definition for one or more beans. If any profile is enabled, the `default` profile will not apply.

The name of the default profile can be changed using `setDefaultProfiles()` on the `Environment` or declaratively using the `spring.profiles.default` property.

### 1.13.2. PropertySource abstraction

Spring's `Environment` abstraction provides search operations over a configurable hierarchy of property sources. To explain fully, consider the following:

```
ApplicationContext ctx = new GenericApplicationContext();
Environment env = ctx.getEnvironment();
boolean containsFoo = env.containsProperty("foo");
System.out.println("Does my environment contain the 'foo' property? " + containsFoo);
```

In the snippet above, we see a high-level way of asking Spring whether the `foo` property is defined for the current environment. To answer this question, the `Environment` object performs a search over a set of `PropertySource` objects. A `PropertySource` is a simple abstraction over any source of key-value pairs, and Spring's `StandardEnvironment` is configured with two `PropertySource` objects—one representing the set of JVM system properties (*a la* `System.getProperties()`) and one representing the set of system environment variables (*a la* `System.getenv()`).



These default property sources are present for `StandardEnvironment`, for use in standalone applications. `StandardServletEnvironment` is populated with additional default property sources including servlet config and servlet context parameters. It can optionally enable a `JndiPropertySource`. See the javadocs for details.

Concretely, when using the `StandardEnvironment`, the call to `env.containsProperty("foo")` will return true if a `foo` system property or `foo` environment variable is present at runtime.

The search performed is hierarchical. By default, system properties have precedence over environment variables, so if the `foo` property happens to be set in both places during a call to `env.getProperty("foo")`, the system property value will 'win' and be returned preferentially over the environment variable. Note that property values will not get merged but rather completely overridden by a preceding entry.



For a common `StandardServletEnvironment`, the full hierarchy looks as follows, with the highest-precedence entries at the top:

- `ServletConfig` parameters (if applicable, e.g. in case of a `DispatcherServlet` context)
- `ServletContext` parameters (`web.xml` context-param entries)
- JNDI environment variables ("`java:comp/env/`" entries)
- JVM system properties ("`-D`" command-line arguments)
- JVM system environment (operating system environment variables)

Most importantly, the entire mechanism is configurable. Perhaps you have a custom source of properties that you'd like to integrate into this search. No problem—simply implement and instantiate your own `PropertySource` and add it to the set of `PropertySources` for the current `Environment`:

```
ConfigurableApplicationContext ctx = new GenericApplicationContext();
MutablePropertySources sources = ctx.getEnvironment().getPropertySources();
sources.addFirst(new MyPropertySource());
```

In the code above, `MyPropertySource` has been added with highest precedence in the search. If it contains a `foo` property, it will be detected and returned ahead of any `foo` property in any other `PropertySource`. The `MutablePropertySources` API exposes a number of methods that allow for precise manipulation of the set of property sources.

### 1.13.3. @PropertySource

The `@PropertySource` annotation provides a convenient and declarative mechanism for adding a `PropertySource` to Spring's `Environment`.

Given a file "app.properties" containing the key/value pair `testbean.name=myTestBean`, the following `@Configuration` class uses `@PropertySource` in such a way that a call to `testBean.getName()` will return

"myTestBean".

```
@Configuration
<strong>@PropertySource("classpath:/com/myco/app.properties")</strong>
public class AppConfig {

    @Autowired
    Environment env;

    @Bean
    public TestBean testBean() {
        TestBean testBean = new TestBean();
        testBean.setName(env.getProperty("testbean.name"));
        return testBean;
    }
}
```

Any \${…} placeholders present in a `@PropertySource` resource location will be resolved against the set of property sources already registered against the environment. For example:

```
@Configuration
@PropertySource("classpath:/com/${my.placeholder:default/path}/app.properties")
public class AppConfig {

    @Autowired
    Environment env;

    @Bean
    public TestBean testBean() {
        TestBean testBean = new TestBean();
        testBean.setName(env.getProperty("testbean.name"));
        return testBean;
    }
}
```

Assuming that "my.placeholder" is present in one of the property sources already registered, e.g. system properties or environment variables, the placeholder will be resolved to the corresponding value. If not, then "default/path" will be used as a default. If no default is specified and a property cannot be resolved, an `IllegalArgumentException` will be thrown.

#### 1.13.4. Placeholder resolution in statements

Historically, the value of placeholders in elements could be resolved only against JVM system properties or environment variables. No longer is this the case. Because the Environment abstraction is integrated throughout the container, it's easy to route resolution of placeholders through it. This means that you may configure the resolution process in any way you like: change the precedence of searching through system properties and environment variables, or remove them entirely; add your own property sources to the mix as appropriate.

Concretely, the following statement works regardless of where the `customer` property is defined, as long as it is available in the `Environment`:

```
<beans>
    <import resource="com/bank/service/${customer}-config.xml"/>
</beans>
```

## 1.14. Registering a LoadTimeWeaver

The `LoadTimeWeaver` is used by Spring to dynamically transform classes as they are loaded into the Java virtual machine (JVM).

To enable load-time weaving add the `@EnableLoadTimeWeaving` to one of your `@Configuration` classes:

```
@Configuration
@EnableLoadTimeWeaving
public class AppConfig { }
```

Alternatively for XML configuration use the `context:load-time-weaver` element:

```
<beans>
    <context:load-time-weaver/>
</beans>
```

Once configured for the `ApplicationContext`. Any bean within that `ApplicationContext` may implement `LoadTimeWeaverAware`, thereby receiving a reference to the load-time weaver instance. This is particularly useful in combination with `Spring's JPA support` where load-time weaving may be necessary for JPA class transformation. Consult the `LocalContainerEntityManagerFactoryBean` javadocs for more detail. For more on AspectJ load-time weaving, see `Load-time weaving with AspectJ in the Spring Framework`.

## 1.15. Additional capabilities of the ApplicationContext

As was discussed in the chapter introduction, the `org.springframework.beans.factory` package provides basic functionality for managing and manipulating beans, including in a programmatic way. The `org.springframework.context` package adds the `ApplicationContext` interface, which extends the `BeanFactory` interface, in addition to extending other interfaces to provide additional functionality in a more *application framework-oriented style*. Many people use the `ApplicationContext` in a completely declarative fashion, not even creating it programmatically, but instead relying on support classes such as `ContextLoader` to automatically instantiate an `ApplicationContext` as part of the normal startup process of a Java EE web application.

To enhance `BeanFactory` functionality in a more framework-oriented style the context package also provides the following functionality:

- Access to messages in i18n-style, through the `MessageSource` interface.
- Access to resources, such as URLs and files, through the `ResourceLoader` interface.
- Event publication to namely beans implementing the `ApplicationListener` interface, through the use of the `ApplicationEventPublisher` interface.
- Loading of multiple (hierarchical) contexts, allowing each to be focused on one particular layer, such as the web layer of an application, through the `HierarchicalBeanFactory` interface.

### 1.15.1. Internationalization using MessageSource

The `ApplicationContext` interface extends an interface called `MessageSource`, and therefore provides internationalization (i18n) functionality. Spring also provides the interface `HierarchicalMessageSource`, which can resolve messages hierarchically. Together these interfaces provide the foundation upon which Spring effects message resolution. The methods defined on these interfaces include:

- `String getMessage(String code, Object[] args, String default, Locale loc)`: The basic method used to retrieve a message from the `MessageSource`. When no message is found for the specified locale, the default message is used. Any arguments passed in become replacement values, using the `MessageFormat` functionality provided by the standard library.
- `String getMessage(String code, Object[] args, Locale loc)`: Essentially the same as the previous method, but with one difference: no default message can be specified; if the message cannot be found, a `NoSuchMessageException` is thrown.
- `String getMessage(MessageSourceResolvable resolvable, Locale locale)`: All properties used in the preceding methods are also wrapped in a class named `MessageSourceResolvable`, which you can use with this method.

When an `ApplicationContext` is loaded, it automatically searches for a `MessageSource` bean defined in the context. The bean must have the name `messageSource`. If such a bean is found, all calls to the preceding methods are delegated to the message source. If no message source is found, the `ApplicationContext` attempts to find a parent containing a bean with the same name. If it does, it uses that bean as the `MessageSource`. If the `ApplicationContext` cannot find any source for messages, an empty `DelegatingMessageSource` is instantiated in order to be able to accept calls to the methods defined above.

Spring provides two `MessageSource` implementations,  `ResourceBundleMessageSource` and `StaticMessageSource`. Both implement `HierarchicalMessageSource` in order to do nested messaging. The `StaticMessageSource` is rarely used but provides programmatic ways to add messages to the source. The  `ResourceBundleMessageSource` is shown in the following example:

```

<beans>
    <bean id="messageSource"
        class="org.springframework.context.support.ResourceBundleMessageSource">
        <property name="basenames">
            <list>
                <value>format</value>
                <value>exceptions</value>
                <value>windows</value>
            </list>
        </property>
    </bean>
</beans>

```

In the example it is assumed you have three resource bundles defined in your classpath called `format`, `exceptions` and `windows`. Any request to resolve a message will be handled in the JDK standard way of resolving messages through ResourceBundles. For the purposes of the example, assume the contents of two of the above resource bundle files are...

```
# in format.properties
message=Alligators rock!
```

```
# in exceptions.properties
argument.required=The {0} argument is required.
```

A program to execute the `MessageSource` functionality is shown in the next example. Remember that all `ApplicationContext` implementations are also `MessageSource` implementations and so can be cast to the `MessageSource` interface.

```

public static void main(String[] args) {
    MessageSource resources = new ClassPathXmlApplicationContext("beans.xml");
    String message = resources.getMessage("message", null, "Default", null);
    System.out.println(message);
}

```

The resulting output from the above program will be...

```
Alligators rock!
```

So to summarize, the `MessageSource` is defined in a file called `beans.xml`, which exists at the root of your classpath. The `messageSource` bean definition refers to a number of resource bundles through its `basenames` property. The three files that are passed in the list to the `basenames` property exist as files at the root of your classpath and are called `format.properties`, `exceptions.properties`, and `windows.properties` respectively.

The next example shows arguments passed to the message lookup; these arguments will be converted into Strings and inserted into placeholders in the lookup message.

```
<beans>

    <!-- this MessageSource is being used in a web application -->
    <bean id="messageSource" class=
"org.springframework.context.support.ResourceBundleMessageSource">
        <property name="basename" value="exceptions"/>
    </bean>

    <!-- lets inject the above MessageSource into this POJO -->
    <bean id="example" class="com.foo.Example">
        <property name="messages" ref="messageSource"/>
    </bean>

</beans>
```

```
public class Example {

    private MessageSource messages;

    public void setMessages(MessageSource messages) {
        this.messages = messages;
    }

    public void execute() {
        String message = this.messages.getMessage("argument.required",
            new Object [] {"userDao"}, "Required", null);
        System.out.println(message);
    }
}
```

The resulting output from the invocation of the `execute()` method will be...

The `userDao` argument is required.

With regard to internationalization (i18n), Spring's various `MessageSource` implementations follow the same locale resolution and fallback rules as the standard JDK `ResourceBundle`. In short, and continuing with the example `messageSource` defined previously, if you want to resolve messages against the British (`en-GB`) locale, you would create files called `format_en_GB.properties`, `exceptions_en_GB.properties`, and `windows_en_GB.properties` respectively.

Typically, locale resolution is managed by the surrounding environment of the application. In this example, the locale against which (British) messages will be resolved is specified manually.

```
# in exceptions_en_GB.properties  
argument.required=Ebagum lad, the {0} argument is required, I say, required.
```

```
public static void main(final String[] args) {  
    MessageSource resources = new ClassPathXmlApplicationContext("beans.xml");  
    String message = resources.getMessage("argument.required",  
        new Object [] {"userDao"}, "Required", Locale.UK);  
    System.out.println(message);  
}
```

The resulting output from the running of the above program will be...

Ebagum lad, the 'userDao' argument is required, I say, required.

You can also use the `MessageSourceAware` interface to acquire a reference to any `MessageSource` that has been defined. Any bean that is defined in an `ApplicationContext` that implements the `MessageSourceAware` interface is injected with the application context's `MessageSource` when the bean is created and configured.



As an alternative to `ResourceBundleMessageSource`, Spring provides a `ReloadableResourceBundleMessageSource` class. This variant supports the same bundle file format but is more flexible than the standard JDK based `ResourceBundleMessageSource` implementation. In particular, it allows for reading files from any Spring resource location (not just from the classpath) and supports hot reloading of bundle property files (while efficiently caching them in between). Check out the `ReloadableResourceBundleMessageSource` javadocs for details.

### 1.15.2. Standard and custom events

Event handling in the `ApplicationContext` is provided through the `ApplicationEvent` class and `ApplicationListener` interface. If a bean that implements the `ApplicationListener` interface is deployed into the context, every time an `ApplicationEvent` gets published to the `ApplicationContext`, that bean is notified. Essentially, this is the standard *Observer* design pattern.



As of Spring 4.2, the event infrastructure has been significantly improved and offer an `annotation-based model` as well as the ability to publish any arbitrary event, that is an object that does not necessarily extend from `ApplicationEvent`. When such an object is published we wrap it in an event for you.

Spring provides the following standard events:

Table 7. Built-in Events

Event	Explanation
<code>ContextRefreshedEvent</code>	<p>Published when the <code>ApplicationContext</code> is initialized or refreshed, for example, using the <code>refresh()</code> method on the <code>ConfigurableApplicationContext</code> interface.</p> <p>"Initialized" here means that all beans are loaded, post-processor beans are detected and activated, singletons are pre-instantiated, and the <code>ApplicationContext</code> object is ready for use. As long as the context has not been closed, a refresh can be triggered multiple times, provided that the chosen <code>ApplicationContext</code> actually supports such "hot" refreshes. For example, <code>XmlWebApplicationContext</code> supports hot refreshes, but <code>GenericApplicationContext</code> does not.</p>
<code>ContextStartedEvent</code>	<p>Published when the <code>ApplicationContext</code> is started, using the <code>start()</code> method on the <code>ConfigurableApplicationContext</code> interface.</p> <p>"Started" here means that all <code>Lifecycle</code> beans receive an explicit start signal. Typically this signal is used to restart beans after an explicit stop, but it may also be used to start components that have not been configured for autostart, for example, components that have not already started on initialization.</p>
<code>ContextStoppedEvent</code>	<p>Published when the <code>ApplicationContext</code> is stopped, using the <code>stop()</code> method on the <code>ConfigurableApplicationContext</code> interface.</p> <p>"Stopped" here means that all <code>Lifecycle</code> beans receive an explicit stop signal. A stopped context may be restarted through a <code>start()</code> call.</p>
<code>ContextClosedEvent</code>	<p>Published when the <code>ApplicationContext</code> is closed, using the <code>close()</code> method on the <code>ConfigurableApplicationContext</code> interface.</p> <p>"Closed" here means that all singleton beans are destroyed. A closed context reaches its end of life; it cannot be refreshed or restarted.</p>
<code>RequestHandledEvent</code>	<p>A web-specific event telling all beans that an HTTP request has been serviced. This event is published <i>after</i> the request is complete. This event is only applicable to web applications using Spring's <code>DispatcherServlet</code>.</p>

You can also create and publish your own custom events. This example demonstrates a simple class that extends Spring's `ApplicationEvent` base class:

```

public class BlackListEvent extends ApplicationEvent {

    private final String address;
    private final String test;

    public BlackListEvent(Object source, String address, String test) {
        super(source);
        this.address = address;
        this.test = test;
    }

    // accessor and other methods...
}

```

To publish a custom `ApplicationEvent`, call the `publishEvent()` method on an `ApplicationEventPublisher`. Typically this is done by creating a class that implements `ApplicationEventPublisherAware` and registering it as a Spring bean. The following example demonstrates such a class:

```

public class EmailService implements ApplicationEventPublisherAware {

    private List<String> blackList;
    private ApplicationEventPublisher publisher;

    public void setBlackList(List<String> blackList) {
        this.blackList = blackList;
    }

    public void setApplicationEventPublisher(ApplicationEventPublisher publisher) {
        this.publisher = publisher;
    }

    public void sendEmail(String address, String text) {
        if (blackList.contains(address)) {
            BlackListEvent event = new BlackListEvent(this, address, text);
            publisher.publishEvent(event);
            return;
        }
        // send email...
    }
}

```

At configuration time, the Spring container will detect that `EmailService` implements `ApplicationEventPublisherAware` and will automatically call `setApplicationEventPublisher()`. In reality, the parameter passed in will be the Spring container itself; you're simply interacting with the application context via its `ApplicationEventPublisher` interface.

To receive the custom `ApplicationEvent`, create a class that implements `ApplicationListener` and

register it as a Spring bean. The following example demonstrates such a class:

```
public class BlackListNotifier implements ApplicationListener<BlackListEvent> {

    private String notificationAddress;

    public void setNotificationAddress(String notificationAddress) {
        this.notificationAddress = notificationAddress;
    }

    public void onApplicationEvent(BlackListEvent event) {
        // notify appropriate parties via notificationAddress...
    }
}
```

Notice that `ApplicationListener` is generically parameterized with the type of your custom event, `BlackListEvent`. This means that the `onApplicationEvent()` method can remain type-safe, avoiding any need for downcasting. You may register as many event listeners as you wish, but note that by default event listeners receive events synchronously. This means the `publishEvent()` method blocks until all listeners have finished processing the event. One advantage of this synchronous and single-threaded approach is that when a listener receives an event, it operates inside the transaction context of the publisher if a transaction context is available. If another strategy for event publication becomes necessary, refer to the javadoc for Spring's `ApplicationEventMulticaster` interface.

The following example shows the bean definitions used to register and configure each of the classes above:

```
<bean id="emailService" class="example.EmailService">
    <property name="blackList">
        <list>
            <value>known.spammer@example.org</value>
            <value>known.hacker@example.org</value>
            <value>john.doe@example.org</value>
        </list>
    </property>
</bean>

<bean id="blackListNotifier" class="example.BlackListNotifier">
    <property name="notificationAddress" value="blacklist@example.org"/>
</bean>
```

Putting it all together, when the `sendEmail()` method of the `emailService` bean is called, if there are any emails that should be blacklisted, a custom event of type `BlackListEvent` is published. The `blackListNotifier` bean is registered as an `ApplicationListener` and thus receives the `BlackListEvent`, at which point it can notify appropriate parties.



Spring's eventing mechanism is designed for simple communication between Spring beans within the same application context. However, for more sophisticated enterprise integration needs, the separately-maintained [Spring Integration](#) project provides complete support for building lightweight, [pattern-oriented](#), event-driven architectures that build upon the well-known Spring programming model.

## Annotation-based event listeners

As of Spring 4.2, an event listener can be registered on any public method of a managed bean via the `EventListener` annotation. The `BlackListNotifier` can be rewritten as follows:

```
public class BlackListNotifier {  
  
    private String notificationAddress;  
  
    public void setNotificationAddress(String notificationAddress) {  
        this.notificationAddress = notificationAddress;  
    }  
  
    @EventListener  
    public void processBlackListEvent(BlackListEvent event) {  
        // notify appropriate parties via notificationAddress...  
    }  
}
```

As you can see above, the method signature once again declares the event type it listens to, but this time with a flexible name and without implementing a specific listener interface. The event type can also be narrowed through generics as long as the actual event type resolves your generic parameter in its implementation hierarchy.

If your method should listen to several events or if you want to define it with no parameter at all, the event type(s) can also be specified on the annotation itself:

```
@EventListener({ContextStartedEvent.class, ContextRefreshedEvent.class})  
public void handleContextStart() {  
    ...  
}
```

It is also possible to add additional runtime filtering via the `condition` attribute of the annotation that defines a [SpEL expression](#) that should match to actually invoke the method for a particular event.

For instance, our notifier can be rewritten to be only invoked if the `test` attribute of the event is equal to `foo`:

```

@EventListener(condition = "#blEvent.test == 'foo'")
public void processBlackListEvent(BlackListEvent blEvent) {
    // notify appropriate parties via notificationAddress...
}

```

Each **SpEL** expression evaluates again a dedicated context. The next table lists the items made available to the context so one can use them for conditional event processing:

*Table 8. Event SpEL available metadata*

Name	Location	Description	Example
Event	root object	The actual <b>ApplicationEvent</b>	#root.event
Arguments array	root object	The arguments (as array) used for invoking the target	#root.args[0]
<i>Argument name</i>	evaluation context	Name of any of the method arguments. If for some reason the names are not available (e.g. no debug information), the argument names are also available under the #a<#arg> where #arg stands for the argument index (starting from 0).	#blEvent or #a0 (one can also use #p0 or #p<#arg> notation as an alias).

Note that **#root.event** allows you to access to the underlying event, even if your method signature actually refers to an arbitrary object that was published.

If you need to publish an event as the result of processing another, just change the method signature to return the event that should be published, something like:

```

@EventListener
public ListUpdateEvent handleBlackListEvent(BlackListEvent event) {
    // notify appropriate parties via notificationAddress and
    // then publish a ListUpdateEvent...
}

```



This feature is not supported for **asynchronous listeners**.

This new method will publish a new **ListUpdateEvent** for every **BlackListEvent** handled by the method above. If you need to publish several events, just return a **Collection** of events instead.

## Asynchronous Listeners

If you want a particular listener to process events asynchronously, simply reuse the [regular @Async support](#):

```
@EventListener  
@Async  
public void processBlackListEvent(BlackListEvent event) {  
    // BlackListEvent is processed in a separate thread  
}
```

Be aware of the following limitations when using asynchronous events:

1. If the event listener throws an [Exception](#) it will not be propagated to the caller, check [AsyncUncaughtExceptionHandler](#) for more details.
2. Such event listener cannot send replies. If you need to send another event as the result of the processing, inject [ApplicationEventPublisher](#) to send the event manually.

## Ordering listeners

If you need the listener to be invoked before another one, just add the [@Order](#) annotation to the method declaration:

```
@EventListener  
@Order(42)  
public void processBlackListEvent(BlackListEvent event) {  
    // notify appropriate parties via notificationAddress...  
}
```

## Generic events

You may also use generics to further define the structure of your event. Consider an [EntityCreatedEvent<T>](#) where [T](#) is the type of the actual entity that got created. You can create the following listener definition to only receive [EntityCreatedEvent](#) for a [Person](#):

```
@EventListener  
public void onPersonCreated(EntityCreatedEvent<Person> event) {  
    ...  
}
```

Due to type erasure, this will only work if the event that is fired resolves the generic parameter(s) on which the event listener filters on (that is something like [class PersonCreatedEvent extends EntityCreatedEvent<Person> { ... }](#)).

In certain circumstances, this may become quite tedious if all events follow the same structure (as it should be the case for the event above). In such a case, you can implement [ResolvableTypeProvider](#) to *guide* the framework beyond what the runtime environment provides:

```

public class EntityCreatedEvent<T>
    extends ApplicationEvent implements ResolvableTypeProvider {

    public EntityCreatedEvent(T entity) {
        super(entity);
    }

    @Override
    public ResolvableType getResolvableType() {
        return ResolvableType.forClassWithGenerics(getClass(),
            ResolvableType.forInstancegetSource());
    }
}

```



This works not only for `ApplicationEvent` but any arbitrary object that you'd send as an event.

### 1.15.3. Convenient access to low-level resources

For optimal usage and understanding of application contexts, users should generally familiarize themselves with Spring's `Resource` abstraction, as described in the chapter [Resources](#).

An application context is a `ResourceLoader`, which can be used to load `Resources`. A `Resource` is essentially a more feature rich version of the JDK class `java.net.URL`, in fact, the implementations of the `Resource` wrap an instance of `java.net.URL` where appropriate. A `Resource` can obtain low-level resources from almost any location in a transparent fashion, including from the classpath, a filesystem location, anywhere describable with a standard URL, and some other variations. If the resource location string is a simple path without any special prefixes, where those resources come from is specific and appropriate to the actual application context type.

You can configure a bean deployed into the application context to implement the special callback interface, `ResourceLoaderAware`, to be automatically called back at initialization time with the application context itself passed in as the `ResourceLoader`. You can also expose properties of type `Resource`, to be used to access static resources; they will be injected into it like any other properties. You can specify those `Resource` properties as simple String paths, and rely on a special JavaBean `PropertyEditor` that is automatically registered by the context, to convert those text strings to actual `Resource` objects when the bean is deployed.

The location path or paths supplied to an `ApplicationContext` constructor are actually resource strings, and in simple form are treated appropriately to the specific context implementation. `ClassPathXmlApplicationContext` treats a simple location path as a classpath location. You can also use location paths (resource strings) with special prefixes to force loading of definitions from the classpath or a URL, regardless of the actual context type.

### 1.15.4. Convenient ApplicationContext instantiation for web applications

You can create `ApplicationContext` instances declaratively by using, for example, a `ContextLoader`. Of course you can also create `ApplicationContext` instances programmatically by using one of the

`ApplicationContext` implementations.

You can register an `ApplicationContext` using the `ContextLoaderListener` as follows:

```
<context-param>
    <param-name>contextConfigLocation</param-name>
    <param-value>/WEB-INF/daoContext.xml /WEB-INF/applicationContext.xml</param-value>
</context-param>

<listener>
    <listener-class>org.springframework.web.context.ContextLoaderListener</listener-
class>
</listener>
```

The listener inspects the `contextConfigLocation` parameter. If the parameter does not exist, the listener uses `/WEB-INF/applicationContext.xml` as a default. When the parameter *does* exist, the listener separates the String by using predefined delimiters (comma, semicolon and whitespace) and uses the values as locations where application contexts will be searched. Ant-style path patterns are supported as well. Examples are `/WEB-INF/*Context.xml` for all files with names ending with "Context.xml", residing in the "WEB-INF" directory, and `/WEB-INF/**/*Context.xml`, for all such files in any subdirectory of "WEB-INF".

### 1.15.5. Deploying a Spring ApplicationContext as a Java EE RAR file

It is possible to deploy a Spring ApplicationContext as a RAR file, encapsulating the context and all of its required bean classes and library JARs in a Java EE RAR deployment unit. This is the equivalent of bootstrapping a standalone ApplicationContext, just hosted in Java EE environment, being able to access the Java EE servers facilities. RAR deployment is more natural alternative to scenario of deploying a headless WAR file, in effect, a WAR file without any HTTP entry points that is used only for bootstrapping a Spring ApplicationContext in a Java EE environment.

RAR deployment is ideal for application contexts that do not need HTTP entry points but rather consist only of message endpoints and scheduled jobs. Beans in such a context can use application server resources such as the JTA transaction manager and JNDI-bound JDBC DataSources and JMS ConnectionFactory instances, and may also register with the platform's JMX server - all through Spring's standard transaction management and JNDI and JMX support facilities. Application components can also interact with the application server's JCA WorkManager through Spring's `TaskExecutor` abstraction.

Check out the javadoc of the `SpringContextResourceAdapter` class for the configuration details involved in RAR deployment.

*For a simple deployment of a Spring ApplicationContext as a Java EE RAR file:* package all application classes into a RAR file, which is a standard JAR file with a different file extension. Add all required library JARs into the root of the RAR archive. Add a "META-INF/ra.xml" deployment descriptor (as shown in `SpringContextResourceAdapters` javadoc) and the corresponding Spring XML bean definition file(s) (typically "META-INF/applicationContext.xml"), and drop the resulting RAR file into your application server's deployment directory.



Such RAR deployment units are usually self-contained; they do not expose components to the outside world, not even to other modules of the same application. Interaction with a RAR-based ApplicationContext usually occurs through JMS destinations that it shares with other modules. A RAR-based ApplicationContext may also, for example, schedule some jobs, reacting to new files in the file system (or the like). If it needs to allow synchronous access from the outside, it could for example export RMI endpoints, which of course may be used by other application modules on the same machine.

## 1.16. The BeanFactory

The [BeanFactory](#) provides the underlying basis for Spring's IoC functionality but it is only used directly in integration with other third-party frameworks and is now largely historical in nature for most users of Spring. The [BeanFactory](#) and related interfaces, such as [BeanFactoryAware](#), [InitializingBean](#), [DisposableBean](#), are still present in Spring for the purposes of backward compatibility with the large number of third-party frameworks that integrate with Spring. Often third-party components that can not use more modern equivalents such as [@PostConstruct](#) or [@PreDestroy](#) in order to avoid a dependency on JSR-250.

This section provides additional background into the differences between the [BeanFactory](#) and [ApplicationContext](#) and how one might access the IoC container directly through a classic singleton lookup.

### 1.16.1. BeanFactory or ApplicationContext?

Use an [ApplicationContext](#) unless you have a good reason for not doing so.

Because the [ApplicationContext](#) includes all functionality of the [BeanFactory](#), it is generally recommended over the [BeanFactory](#), except for a few situations such as in embedded applications running on resource-constrained devices where memory consumption might be critical and a few extra kilobytes might make a difference. However, for most typical enterprise applications and systems, the [ApplicationContext](#) is what you will want to use. Spring makes *heavy* use of the [BeanPostProcessor extension point](#) (to effect proxying and so on). If you use only a plain [BeanFactory](#), a fair amount of support such as transactions and AOP will not take effect, at least not without some extra steps on your part. This situation could be confusing because nothing is actually wrong with the configuration.

The following table lists features provided by the [BeanFactory](#) and [ApplicationContext](#) interfaces and implementations.

Table 9. Feature Matrix

Feature	BeanFactory	ApplicationContext
Bean instantiation/wiring	Yes	Yes
Automatic <a href="#">BeanPostProcessor</a> registration	No	Yes

Feature	BeanFactory	ApplicationContext
Automatic <code>BeanFactoryPostProcessor</code> registration	No	Yes
Convenient <code>MessageSource</code> access (for i18n)	No	Yes
<code>ApplicationEvent</code> publication	No	Yes

To explicitly register a bean post-processor with a `BeanFactory` implementation, you need to write code like this:

```
DefaultListableBeanFactory factory = new DefaultListableBeanFactory();
// populate the factory with bean definitions

// now register any needed BeanPostProcessor instances
MyBeanPostProcessor postProcessor = new MyBeanPostProcessor();
factory.addBeanPostProcessor(postProcessor);

// now start using the factory
```

To explicitly register a `BeanFactoryPostProcessor` when using a `BeanFactory` implementation, you must write code like this:

```
DefaultListableBeanFactory factory = new DefaultListableBeanFactory();
XmlBeanDefinitionReader reader = new XmlBeanDefinitionReader(factory);
reader.loadBeanDefinitions(new FileSystemResource("beans.xml"));

// bring in some property values from a Properties file
PropertyPlaceholderConfigurer cfg = new PropertyPlaceholderConfigurer();
cfg.setLocation(new FileSystemResource("jdbc.properties"));

// now actually do the replacement
cfg.postProcessBeanFactory(factory);
```

In both cases, the explicit registration step is inconvenient, which is one reason why the various `ApplicationContext` implementations are preferred above plain `BeanFactory` implementations in the vast majority of Spring-backed applications, especially when using `BeanFactoryPostProcessors` and `BeanPostProcessors`. These mechanisms implement important functionality such as property placeholder replacement and AOP.

# Chapter 2. Resources

## 2.1. Introduction

Java's standard `java.net.URL` class and standard handlers for various URL prefixes unfortunately are not quite adequate enough for all access to low-level resources. For example, there is no standardized `URL` implementation that may be used to access a resource that needs to be obtained from the classpath, or relative to a `ServletContext`. While it is possible to register new handlers for specialized `URL` prefixes (similar to existing handlers for prefixes such as `http:`), this is generally quite complicated, and the `URL` interface still lacks some desirable functionality, such as a method to check for the existence of the resource being pointed to.

## 2.2. The Resource interface

Spring's `Resource` interface is meant to be a more capable interface for abstracting access to low-level resources.

```
public interface Resource extends InputStreamSource {  
  
    boolean exists();  
  
    boolean isOpen();  
  
    URL getURL() throws IOException;  
  
    File getFile() throws IOException;  
  
    Resource createRelative(String relativePath) throws IOException;  
  
    String getFilename();  
  
    String getDescription();  
}
```

```
public interface InputStreamSource {  
  
    InputStream getInputStream() throws IOException;  
}
```

Some of the most important methods from the `Resource` interface are:

- `getInputStream()`: locates and opens the resource, returning an `InputStream` for reading from the resource. It is expected that each invocation returns a fresh `InputStream`. It is the responsibility of the caller to close the stream.

- `exists()`: returns a `boolean` indicating whether this resource actually exists in physical form.
- `isOpen()`: returns a `boolean` indicating whether this resource represents a handle with an open stream. If `true`, the `InputStream` cannot be read multiple times, and must be read once only and then closed to avoid resource leaks. Will be `false` for all usual resource implementations, with the exception of `InputStreamResource`.
- `getDescription()`: returns a description for this resource, to be used for error output when working with the resource. This is often the fully qualified file name or the actual URL of the resource.

Other methods allow you to obtain an actual `URL` or `File` object representing the resource (if the underlying implementation is compatible, and supports that functionality).

The `Resource` abstraction is used extensively in Spring itself, as an argument type in many method signatures when a resource is needed. Other methods in some Spring APIs (such as the constructors to various `ApplicationContext` implementations), take a `String` which in unadorned or simple form is used to create a `Resource` appropriate to that context implementation, or via special prefixes on the `String` path, allow the caller to specify that a specific `Resource` implementation must be created and used.

While the `Resource` interface is used a lot with Spring and by Spring, it's actually very useful to use as a general utility class by itself in your own code, for access to resources, even when your code doesn't know or care about any other parts of Spring. While this couples your code to Spring, it really only couples it to this small set of utility classes, which are serving as a more capable replacement for `URL`, and can be considered equivalent to any other library you would use for this purpose.

It is important to note that the `Resource` abstraction does not replace functionality: it wraps it where possible. For example, a `UrlResource` wraps a URL, and uses the wrapped `URL` to do its work.

## 2.3. Built-in Resource implementations

There are a number of `Resource` implementations that come supplied straight out of the box in Spring:

### 2.3.1. UrlResource

The `UrlResource` wraps a `java.net.URL`, and may be used to access any object that is normally accessible via a URL, such as files, an HTTP target, an FTP target, etc. All URLs have a standardized `String` representation, such that appropriate standardized prefixes are used to indicate one URL type from another. This includes `file:` for accessing filesystem paths, `http:` for accessing resources via the HTTP protocol, `ftp:` for accessing resources via FTP, etc.

A `UrlResource` is created by Java code explicitly using the `UrlResource` constructor, but will often be created implicitly when you call an API method which takes a `String` argument which is meant to represent a path. For the latter case, a JavaBeans `PropertyEditor` will ultimately decide which type of `Resource` to create. If the path string contains a few well-known (to it, that is) prefixes such as `classpath:`, it will create an appropriate specialized `Resource` for that prefix. However, if it doesn't recognize the prefix, it will assume the this is just a standard URL string, and will create a

`UrlResource`.

### 2.3.2. ClassPathResource

This class represents a resource which should be obtained from the classpath. This uses either the thread context class loader, a given class loader, or a given class for loading resources.

This `Resource` implementation supports resolution as `java.io.File` if the class path resource resides in the file system, but not for classpath resources which reside in a jar and have not been expanded (by the servlet engine, or whatever the environment is) to the filesystem. To address this the various `Resource` implementations always support resolution as a `java.net.URL`.

A `ClassPathResource` is created by Java code explicitly using the `ClassPathResource` constructor, but will often be created implicitly when you call an API method which takes a `String` argument which is meant to represent a path. For the latter case, a JavaBeans `PropertyEditor` will recognize the special prefix `classpath:` on the string path, and create a `ClassPathResource` in that case.

### 2.3.3. FileSystemResource

This is a `Resource` implementation for `java.io.File` handles. It obviously supports resolution as a `File`, and as a `URL`.

### 2.3.4. ServletContextResource

This is a `Resource` implementation for `ServletContext` resources, interpreting relative paths within the relevant web application's root directory.

This always supports stream access and URL access, but only allows `java.io.File` access when the web application archive is expanded and the resource is physically on the filesystem. Whether or not it's expanded and on the filesystem like this, or accessed directly from the JAR or somewhere else like a DB (it's conceivable) is actually dependent on the Servlet container.

### 2.3.5. InputStreamResource

A `Resource` implementation for a given `InputStream`. This should only be used if no specific `Resource` implementation is applicable. In particular, prefer `ByteArrayResource` or any of the file-based `Resource` implementations where possible.

In contrast to other `Resource` implementations, this is a descriptor for an *already* opened resource - therefore returning `true` from `isOpen()`. Do not use it if you need to keep the resource descriptor somewhere, or if you need to read a stream multiple times.

### 2.3.6. ByteArrayResource

This is a `Resource` implementation for a given byte array. It creates a `ByteArrayInputStream` for the given byte array.

It's useful for loading content from any given byte array, without having to resort to a single-use `InputStreamResource`.

## 2.4. The ResourceLoader

The `ResourceLoader` interface is meant to be implemented by objects that can return (i.e. load) `Resource` instances.

```
public interface ResourceLoader {  
  
    Resource getResource(String location);  
  
}
```

All application contexts implement the `ResourceLoader` interface, and therefore all application contexts may be used to obtain `Resource` instances.

When you call `getResource()` on a specific application context, and the location path specified doesn't have a specific prefix, you will get back a `Resource` type that is appropriate to that particular application context. For example, assume the following snippet of code was executed against a `ClassPathXmlApplicationContext` instance:

```
Resource template = ctx.getResource("some/resource/path/myTemplate.txt");
```

What would be returned would be a `ClassPathResource`; if the same method was executed against a `FileSystemXmlApplicationContext` instance, you'd get back a `FileSystemResource`. For a `WebApplicationContext`, you'd get back a `ServletContextResource`, and so on.

As such, you can load resources in a fashion appropriate to the particular application context.

On the other hand, you may also force `ClassPathResource` to be used, regardless of the application context type, by specifying the special `classpath:` prefix:

```
Resource template = ctx.getResource("classpath:some/resource/path/myTemplate.txt");
```

Similarly, one can force a `UrlResource` to be used by specifying any of the standard `java.net.URL` prefixes:

```
Resource template = ctx.getResource("file:///some/resource/path/myTemplate.txt");
```

```
Resource template = ctx.getResource("http://myhost.com/resource/path/myTemplate.txt");
```

The following table summarizes the strategy for converting `Strings` to `Resources`:

*Table 10. Resource strings*

Prefix	Example	Explanation
classpath:	classpath:com/myapp/config.xml	Loaded from the classpath.
file:	file:///data/config.xml	Loaded as a <a href="#">URL</a> , from the filesystem. [3: But see also <a href="#">FileSystemResource caveats</a> .]
http:	http://myserver/logo.png	Loaded as a <a href="#">URL</a> .
(none)	/data/config.xml	Depends on the underlying <a href="#">ApplicationContext</a> .

## 2.5. The ResourceLoaderAware interface

The [ResourceLoaderAware](#) interface is a special marker interface, identifying objects that expect to be provided with a [ResourceLoader](#) reference.

```
public interface ResourceLoaderAware {
    void setResourceLoader(ResourceLoader resourceLoader);
}
```

When a class implements [ResourceLoaderAware](#) and is deployed into an application context (as a Spring-managed bean), it is recognized as [ResourceLoaderAware](#) by the application context. The application context will then invoke the `setResourceLoader(ResourceLoader)`, supplying itself as the argument (remember, all application contexts in Spring implement the [ResourceLoader](#) interface).

Of course, since an [ApplicationContext](#) is a [ResourceLoader](#), the bean could also implement the [ApplicationContextAware](#) interface and use the supplied application context directly to load resources, but in general, it's better to use the specialized [ResourceLoader](#) interface if that's all that's needed. The code would just be coupled to the resource loading interface, which can be considered a utility interface, and not the whole Spring [ApplicationContext](#) interface.

As of Spring 2.5, you can rely upon autowiring of the [ResourceLoader](#) as an alternative to implementing the [ResourceLoaderAware](#) interface. The "traditional" `constructor` and `byType` autowiring modes (as described in [Autowiring collaborators](#)) are now capable of providing a dependency of type [ResourceLoader](#) for either a constructor argument or setter method parameter respectively. For more flexibility (including the ability to autowire fields and multiple parameter methods), consider using the new annotation-based autowiring features. In that case, the [ResourceLoader](#) will be autowired into a field, constructor argument, or method parameter that is expecting the [ResourceLoader](#) type as long as the field, constructor, or method in question carries the `@Autowired` annotation. For more information, see [@Autowired](#).

## 2.6. Resources as dependencies

If the bean itself is going to determine and supply the resource path through some sort of dynamic process, it probably makes sense for the bean to use the [ResourceLoader](#) interface to load resources. Consider as an example the loading of a template of some sort, where the specific resource that is needed depends on the role of the user. If the resources are static, it makes sense to eliminate the

use of the `ResourceLoader` interface completely, and just have the bean expose the `Resource` properties it needs, and expect that they will be injected into it.

What makes it trivial to then inject these properties, is that all application contexts register and use a special JavaBeans `PropertyEditor` which can convert `String` paths to `Resource` objects. So if `myBean` has a template property of type `Resource`, it can be configured with a simple string for that resource, as follows:

```
<bean id="myBean" class="..."><property name="template" value="some/resource/path/myTemplate.txt"/></bean>
```

Note that the resource path has no prefix, so because the application context itself is going to be used as the `ResourceLoader`, the resource itself will be loaded via a `ClassPathResource`, `FileSystemResource`, or `ServletContextResource` (as appropriate) depending on the exact type of the context.

If there is a need to force a specific `Resource` type to be used, then a prefix may be used. The following two examples show how to force a `ClassPathResource` and a `UrlResource` (the latter being used to access a filesystem file).

```
<property name="template" value="classpath:some/resource/path/myTemplate.txt">
```

```
<property name="template" value="file:///some/resource/path/myTemplate.txt"/>
```

## 2.7. Application contexts and Resource paths

### 2.7.1. Constructing application contexts

An application context constructor (for a specific application context type) generally takes a string or array of strings as the location path(s) of the resource(s) such as XML files that make up the definition of the context.

When such a location path doesn't have a prefix, the specific `Resource` type built from that path and used to load the bean definitions, depends on and is appropriate to the specific application context. For example, if you create a `ClassPathXmlApplicationContext` as follows:

```
ApplicationContext ctx = new ClassPathXmlApplicationContext("conf/appContext.xml");
```

The bean definitions will be loaded from the classpath, as a `ClassPathResource` will be used. But if you create a `FileSystemXmlApplicationContext` as follows:

```
ApplicationContext ctx =  
    new FileSystemXmlApplicationContext("conf/appContext.xml");
```

The bean definition will be loaded from a filesystem location, in this case relative to the current working directory.

Note that the use of the special classpath prefix or a standard URL prefix on the location path will override the default type of `Resource` created to load the definition. So this `FileSystemXmlApplicationContext`...

```
ApplicationContext ctx =  
    new FileSystemXmlApplicationContext("classpath:conf/appContext.xml");
```

- i. will actually load its bean definitions from the classpath. However, it is still a `FileSystemXmlApplicationContext`. If it is subsequently used as a `ResourceLoader`, any unprefixed paths will still be treated as filesystem paths.

### Constructing ClassPathXmlApplicationContext instances - shortcuts

The `ClassPathXmlApplicationContext` exposes a number of constructors to enable convenient instantiation. The basic idea is that one supplies merely a string array containing just the filenames of the XML files themselves (without the leading path information), and one *also* supplies a `Class`; the `ClassPathXmlApplicationContext` will derive the path information from the supplied class.

An example will hopefully make this clear. Consider a directory layout that looks like this:

```
com/  
  foo/  
    services.xml  
    daos.xml  
    MessengerService.class
```

A `ClassPathXmlApplicationContext` instance composed of the beans defined in the '`services.xml`' and '`daos.xml`' could be instantiated like so...

```
ApplicationContext ctx = new ClassPathXmlApplicationContext(  
    new String[] {"services.xml", "daos.xml"}, MessengerService.class);
```

Please do consult the `ClassPathXmlApplicationContext` javadocs for details on the various constructors.

#### 2.7.2. Wildcards in application context constructor resource paths

The resource paths in application context constructor values may be a simple path (as shown above) which has a one-to-one mapping to a target Resource, or alternately may contain the special

"classpath\*:" prefix and/or internal Ant-style regular expressions (matched using Spring's `PathMatcher` utility). Both of the latter are effectively wildcards

One use for this mechanism is when doing component-style application assembly. All components can 'publish' context definition fragments to a well-known location path, and when the final application context is created using the same path prefixed via `classpath*:`, all component fragments will be picked up automatically.

Note that this wildcarding is specific to use of resource paths in application context constructors (or when using the `PathMatcher` utility class hierarchy directly), and is resolved at construction time. It has nothing to do with the `Resource` type itself. It's not possible to use the `classpath*:` prefix to construct an actual `Resource`, as a resource points to just one resource at a time.

## Ant-style Patterns

When the path location contains an Ant-style pattern, for example:

```
/WEB-INF/*-context.xml  
com/mycompany/**/applicationContext.xml  
file:C:/some/path/*-context.xml  
classpath:com/mycompany/**/applicationContext.xml
```

The resolver follows a more complex but defined procedure to try to resolve the wildcard. It produces a Resource for the path up to the last non-wildcard segment and obtains a URL from it. If this URL is not a `jar:` URL or container-specific variant (e.g. `zip:` in WebLogic, `wsjar` in WebSphere, etc.), then a `java.io.File` is obtained from it and used to resolve the wildcard by traversing the filesystem. In the case of a jar URL, the resolver either gets a `java.net.JarURLConnection` from it or manually parses the jar URL and then traverses the contents of the jar file to resolve the wildcards.

### Implications on portability

If the specified path is already a file URL (either explicitly, or implicitly because the base `ResourceLoader` is a filesystem one, then wildcarding is guaranteed to work in a completely portable fashion.

If the specified path is a classpath location, then the resolver must obtain the last non-wildcard path segment URL via a `ClassLoader.getResource()` call. Since this is just a node of the path (not the file at the end) it is actually undefined (in the `ClassLoader` javadocs) exactly what sort of a URL is returned in this case. In practice, it is always a `java.io.File` representing the directory, where the classpath resource resolves to a filesystem location, or a jar URL of some sort, where the classpath resource resolves to a jar location. Still, there is a portability concern on this operation.

If a jar URL is obtained for the last non-wildcard segment, the resolver must be able to get a `java.net.JarURLConnection` from it, or manually parse the jar URL, to be able to walk the contents of the jar, and resolve the wildcard. This will work in most environments, but will fail in others, and it is strongly recommended that the wildcard resolution of resources coming from jars be thoroughly tested in your specific environment before you rely on it.

## The classpath\*: prefix

When constructing an XML-based application context, a location string may use the special `classpath*`: prefix:

```
ApplicationContext ctx =  
    new ClassPathXmlApplicationContext("classpath*:conf/appContext.xml");
```

This special prefix specifies that all classpath resources that match the given name must be obtained (internally, this essentially happens via a `ClassLoader.getResources(...)` call), and then merged to form the final application context definition.



The wildcard classpath relies on the `getResources()` method of the underlying classloader. As most application servers nowadays supply their own classloader implementation, the behavior might differ especially when dealing with jar files. A simple test to check if `classpath*` works is to use the classloader to load a file from within a jar on the classpath: `getClass().getClassLoader().getResources("<someFileInsideTheJar>")`. Try this test with files that have the same name but are placed inside two different locations. In case an inappropriate result is returned, check the application server documentation for settings that might affect the classloader behavior.

The `classpath*`: prefix can also be combined with a `PathMatcher` pattern in the rest of the location path, for example `classpath*:META-INF/*-beans.xml`. In this case, the resolution strategy is fairly simple: a `ClassLoader.getResources()` call is used on the last non-wildcard path segment to get all the matching resources in the class loader hierarchy, and then off each resource the same `PathMatcher` resolution strategy described above is used for the wildcard subpath.

## Other notes relating to wildcards

Please note that `classpath*`: when combined with Ant-style patterns will only work reliably with at least one root directory before the pattern starts, unless the actual target files reside in the file system. This means that a pattern like `classpath*:*.*.xml` might not retrieve files from the root of jar files but rather only from the root of expanded directories.

Spring's ability to retrieve classpath entries originates from the JDK's `ClassLoader.getResources()` method which only returns file system locations for a passed-in empty string (indicating potential roots to search). Spring evaluates `URLClassLoader` runtime configuration and the "java.class.path" manifest in jar files as well but this is not guaranteed to lead to portable behavior.

The scanning of classpath packages requires the presence of corresponding directory entries in the classpath. When you build JARs with Ant, make sure that you do *not* activate the files-only switch of the JAR task. Also, classpath directories may not get exposed based on security policies in some environments, e.g. standalone apps on JDK 1.7.0\_45 and higher (which requires 'Trusted-Library' setup in your manifests; see <http://stackoverflow.com/questions/19394570/java-jre-7u45-breaks-classloader-getresources>).



On JDK 9's module path (Jigsaw), Spring's classpath scanning generally works as expected. Putting resources into a dedicated directory is highly recommendable here as well, avoiding the aforementioned portability problems with searching the jar file root level.

Ant-style patterns with `classpath`: resources are not guaranteed to find matching resources if the root package to search is available in multiple class path locations. This is because a resource such as

```
com/mycompany/package1/service-context.xml
```

may be in only one location, but when a path such as

```
classpath:com/mycompany/**/service-context.xml
```

is used to try to resolve it, the resolver will work off the (first) URL returned by `getResource("com/mycompany")`. If this base package node exists in multiple classloader locations, the actual end resource may not be underneath. Therefore, preferably, use "``classpath*:``" with the same Ant-style pattern in such a case, which will search all class path locations that contain the root package.

### 2.7.3. FileSystemResource caveats

A `FileSystemResource` that is not attached to a `FileSystemApplicationContext` (that is, a `FileSystemApplicationContext` is not the actual `ResourceLoader`) will treat absolute vs. relative paths as you would expect. Relative paths are relative to the current working directory, while absolute paths are relative to the root of the filesystem.

For backwards compatibility (historical) reasons however, this changes when the `FileSystemApplicationContext` is the `ResourceLoader`. The `FileSystemApplicationContext` simply forces all attached `FileSystemResource` instances to treat all location paths as relative, whether they start with a leading slash or not. In practice, this means the following are equivalent:

```
ApplicationContext ctx =  
    new FileSystemXmlApplicationContext("conf/context.xml");
```

```
ApplicationContext ctx =  
    new FileSystemXmlApplicationContext("/conf/context.xml");
```

As are the following: (Even though it would make sense for them to be different, as one case is relative and the other absolute.)

```
FileSystemXmlApplicationContext ctx = ...;  
ctx.getResource("some/resource/path/myTemplate.txt");
```

```
FileSystemXmlApplicationContext ctx = ...;  
ctx.getResource("/some/resource/path/myTemplate.txt");
```

In practice, if true absolute filesystem paths are needed, it is better to forgo the use of absolute paths with `FileSystemResource` / `FileSystemXmlApplicationContext`, and just force the use of a `UrlResource`, by using the `file:` URL prefix.

```
// actual context type doesn't matter, the Resource will always be UrlResource  
ctx.getResource("file:///some/resource/path/myTemplate.txt");
```

```
// force this FileSystemXmlApplicationContext to load its definition via a UrlResource  
ApplicationContext ctx =  
    new FileSystemXmlApplicationContext("file:///conf/context.xml");
```

# Chapter 3. Validation, Data Binding, and Type Conversion

## 3.1. Introduction

### JSR-303/JSR-349 Bean Validation

Spring Framework 4.0 supports Bean Validation 1.0 (JSR-303) and Bean Validation 1.1 (JSR-349) in terms of setup support, also adapting it to Spring's `Validator` interface.

An application can choose to enable Bean Validation once globally, as described in [Spring Validation](#), and use it exclusively for all validation needs.

An application can also register additional Spring `Validator` instances per `DataBinder` instance, as described in [Configuring a DataBinder](#). This may be useful for plugging in validation logic without the use of annotations.

There are pros and cons for considering validation as business logic, and Spring offers a design for validation (and data binding) that does not exclude either one of them. Specifically validation should not be tied to the web tier, should be easy to localize and it should be possible to plug in any validator available. Considering the above, Spring has come up with a `Validator` interface that is both basic and eminently usable in every layer of an application.

Data binding is useful for allowing user input to be dynamically bound to the domain model of an application (or whatever objects you use to process user input). Spring provides the so-called `DataBinder` to do exactly that. The `Validator` and the `DataBinder` make up the `validation` package, which is primarily used in but not limited to the MVC framework.

The `BeanWrapper` is a fundamental concept in the Spring Framework and is used in a lot of places. However, you probably will not have the need to use the `BeanWrapper` directly. Because this is reference documentation however, we felt that some explanation might be in order. We will explain the `BeanWrapper` in this chapter since, if you were going to use it at all, you would most likely do so when trying to bind data to objects.

Spring's `DataBinder` and the lower-level `BeanWrapper` both use `PropertyEditors` to parse and format property values. The `PropertyEditor` concept is part of the JavaBeans specification, and is also explained in this chapter. Spring 3 introduces a "core.convert" package that provides a general type conversion facility, as well as a higher-level "format" package for formatting UI field values. These new packages may be used as simpler alternatives to `PropertyEditors`, and will also be discussed in this chapter.

## 3.2. Validation using Spring's Validator interface

Spring features a `Validator` interface that you can use to validate objects. The `Validator` interface works using an `Errors` object so that while validating, validators can report validation failures to

the `Errors` object.

Let's consider a small data object:

```
public class Person {  
  
    private String name;  
    private int age;  
  
    // the usual getters and setters...  
}
```

We're going to provide validation behavior for the `Person` class by implementing the following two methods of the `org.springframework.validation.Validator` interface:

- `supports(Class)` - Can this `Validator` validate instances of the supplied `Class`?
- `validate(Object, org.springframework.validation.Errors)` - validates the given object and in case of validation errors, registers those with the given `Errors` object

Implementing a `Validator` is fairly straightforward, especially when you know of the `ValidationUtils` helper class that the Spring Framework also provides.

```
public class PersonValidator implements Validator {  
  
    /**  
     * This Validator validates *just* Person instances  
     */  
    public boolean supports(Class clazz) {  
        return Person.class.equals(clazz);  
    }  
  
    public void validate(Object obj, Errors e) {  
        ValidationUtils.rejectIfEmpty(e, "name", "name.empty");  
        Person p = (Person) obj;  
        if (p.getAge() < 0) {  
            e.rejectValue("age", "negativevalue");  
        } else if (p.getAge() > 110) {  
            e.rejectValue("age", "too.darn.old");  
        }  
    }  
}
```

As you can see, the `static rejectIfEmpty(..)` method on the `ValidationUtils` class is used to reject the '`name`' property if it is `null` or the empty string. Have a look at the `ValidationUtils` javadocs to see what functionality it provides besides the example shown previously.

While it is certainly possible to implement a single `Validator` class to validate each of the nested objects in a rich object, it may be better to encapsulate the validation logic for each nested class of

object in its own `Validator` implementation. A simple example of a 'rich' object would be a `Customer` that is composed of two `String` properties (a first and second name) and a complex `Address` object. `Address` objects may be used independently of `Customer` objects, and so a distinct `AddressValidator` has been implemented. If you want your `CustomerValidator` to reuse the logic contained within the `AddressValidator` class without resorting to copy-and-paste, you can dependency-inject or instantiate an `AddressValidator` within your `CustomerValidator`, and use it like so:

```
public class CustomerValidator implements Validator {  
  
    private final Validator addressValidator;  
  
    public CustomerValidator(Validator addressValidator) {  
        if (addressValidator == null) {  
            throw new IllegalArgumentException("The supplied [Validator] is " +  
                "required and must not be null.");  
        }  
        if (!addressValidator.supports(Address.class)) {  
            throw new IllegalArgumentException("The supplied [Validator] must " +  
                "support the validation of [Address] instances.");  
        }  
        this.addressValidator = addressValidator;  
    }  
  
    /**  
     * This Validator validates Customer instances, and any subclasses of Customer too  
     */  
    public boolean supports(Class clazz) {  
        return Customer.class.isAssignableFrom(clazz);  
    }  
  
    public void validate(Object target, Errors errors) {  
        ValidationUtils.rejectIfEmptyOrWhitespace(errors, "firstName", "  
field.required");  
        ValidationUtils.rejectIfEmptyOrWhitespace(errors, "surname", "field.required"  
);  
        Customer customer = (Customer) target;  
        try {  
            errors.pushNestedPath("address");  
            ValidationUtils.invokeValidator(this.addressValidator, customer.  
getAddress(), errors);  
        } finally {  
            errors.popNestedPath();  
        }  
    }  
}
```

Validation errors are reported to the `Errors` object passed to the validator. In case of Spring Web MVC you can use `<spring:bind/>` tag to inspect the error messages, but of course you can also inspect the errors object yourself. More information about the methods it offers can be found in the

javadocs.

## 3.3. Resolving codes to error messages

We've talked about databinding and validation. Outputting messages corresponding to validation errors is the last thing we need to discuss. In the example we've shown above, we rejected the `name` and the `age` field. If we're going to output the error messages by using a `MessageSource`, we will do so using the error code we've given when rejecting the field ('name' and 'age' in this case). When you call (either directly, or indirectly, using for example the `ValidationUtils` class) `rejectValue` or one of the other `reject` methods from the `Errors` interface, the underlying implementation will not only register the code you've passed in, but also a number of additional error codes. What error codes it registers is determined by the `MessageCodesResolver` that is used. By default, the `DefaultMessageCodesResolver` is used, which for example not only registers a message with the code you gave, but also messages that include the field name you passed to the reject method. So in case you reject a field using `rejectValue("age", "too.darn.old")`, apart from the `too.darn.old` code, Spring will also register `too.darn.old.age` and `too.darn.old.age.int` (so the first will include the field name and the second will include the type of the field); this is done as a convenience to aid developers in targeting error messages and suchlike.

More information on the `MessageCodesResolver` and the default strategy can be found online in the javadocs of `MessageCodesResolver` and `DefaultMessageCodesResolver`, respectively.

## 3.4. Bean manipulation and the BeanWrapper

The `org.springframework.beans` package adheres to the JavaBeans standard provided by Oracle. A JavaBean is simply a class with a default no-argument constructor, which follows a naming convention where (by way of an example) a property named `bingoMadness` would have a setter method `setBingoMadness(..)` and a getter method `getBingoMadness()`. For more information about JavaBeans and the specification, please refer to Oracle's website ([javabeans](#)).

One quite important class in the beans package is the `BeanWrapper` interface and its corresponding implementation (`BeanWrapperImpl`). As quoted from the javadocs, the `BeanWrapper` offers functionality to set and get property values (individually or in bulk), get property descriptors, and to query properties to determine if they are readable or writable. Also, the `BeanWrapper` offers support for nested properties, enabling the setting of properties on sub-properties to an unlimited depth. Then, the `BeanWrapper` supports the ability to add standard JavaBeans `PropertyChangeListeners` and `VetoableChangeListeners`, without the need for supporting code in the target class. Last but not least, the `BeanWrapper` provides support for the setting of indexed properties. The `BeanWrapper` usually isn't used by application code directly, but by the `DataBinder` and the `BeanFactory`.

The way the `BeanWrapper` works is partly indicated by its name: *it wraps a bean* to perform actions on that bean, like setting and retrieving properties.

### 3.4.1. Setting and getting basic and nested properties

Setting and getting properties is done using the `setPropertyValue(s)` and `getPropertyValue(s)` methods that both come with a couple of overloaded variants. They're all described in more detail

in the javadocs Spring comes with. What's important to know is that there are a couple of conventions for indicating properties of an object. A couple of examples:

Table 11. Examples of properties

Expression	Explanation
name	Indicates the property <code>name</code> corresponding to the methods <code>getName()</code> or <code>isName()</code> and <code>setName(..)</code>
account.name	Indicates the nested property <code>name</code> of the property <code>account</code> corresponding e.g. to the methods <code>getAccount().setName()</code> or <code>getAccount().getName()</code>
account[2]	Indicates the <i>third</i> element of the indexed property <code>account</code> . Indexed properties can be of type <code>array</code> , <code>list</code> or other <i>naturally ordered</i> collection
account[COMPANYNAME]	Indicates the value of the map entry indexed by the key <code>COMPANYNAME</code> of the Map property <code>account</code>

Below you'll find some examples of working with the `BeanWrapper` to get and set properties.

(This next section is not vitally important to you if you're not planning to work with the `BeanWrapper` directly. If you're just using the `DataBinder` and the `BeanFactory` and their out-of-the-box implementation, you should skip ahead to the section about `PropertyEditors`.)

Consider the following two classes:

```
public class Company {  
  
    private String name;  
    private Employee managingDirector;  
  
    public String getName() {  
        return this.name;  
    }  
  
    public void setName(String name) {  
        this.name = name;  
    }  
  
    public Employee getManagingDirector() {  
        return this.managingDirector;  
    }  
  
    public void setManagingDirector(Employee managingDirector) {  
        this.managingDirector = managingDirector;  
    }  
}
```

```

public class Employee {

    private String name;

    private float salary;

    public String getName() {
        return this.name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public float getSalary() {
        return salary;
    }

    public void setSalary(float salary) {
        this.salary = salary;
    }
}

```

The following code snippets show some examples of how to retrieve and manipulate some of the properties of instantiated [Companies](#) and [Employees](#):

```

BeanWrapper company = new BeanWrapperImpl(new Company());
// setting the company name..
company.setPropertyValue("name", "Some Company Inc.");
// ... can also be done like this:
PropertyValue value = new PropertyValue("name", "Some Company Inc.");
company.setPropertyValue(value);

// ok, let's create the director and tie it to the company:
BeanWrapper jim = new BeanWrapperImpl(new Employee());
jim.setPropertyValue("name", "Jim Stravinsky");
company.setPropertyValue("managingDirector", jim.getWrappedInstance());

// retrieving the salary of the managingDirector through the company
Float salary = (Float) company.getPropertyValue("managingDirector.salary");

```

### 3.4.2. Built-in PropertyEditor implementations

Spring uses the concept of [PropertyEditors](#) to effect the conversion between an [Object](#) and a [String](#). If you think about it, it sometimes might be handy to be able to represent properties in a different way than the object itself. For example, a [Date](#) can be represented in a human readable way (as the [String '2007-14-09'](#)), while we're still able to convert the human readable form back to the original date (or even better: convert any date entered in a human readable form, back to [Date](#) objects). This

behavior can be achieved by *registering custom editors*, of type `java.beans.PropertyEditor`. Registering custom editors on a `BeanWrapper` or alternately in a specific IoC container as mentioned in the previous chapter, gives it the knowledge of how to convert properties to the desired type. Read more about `PropertyEditors` in the javadocs of the `java.beans` package provided by Oracle.

A couple of examples where property editing is used in Spring:

- *setting properties on beans* is done using `PropertyEditors`. When mentioning `java.lang.String` as the value of a property of some bean you're declaring in XML file, Spring will (if the setter of the corresponding property has a `Class`-parameter) use the `ClassEditor` to try to resolve the parameter to a `Class` object.
- *parsing HTTP request parameters* in Spring's MVC framework is done using all kinds of `PropertyEditors` that you can manually bind in all subclasses of the `CommandController`.

Spring has a number of built-in `PropertyEditors` to make life easy. Each of those is listed below and they are all located in the `org.springframework.beans.propertyeditors` package. Most, but not all (as indicated below), are registered by default by `BeanWrapperImpl`. Where the property editor is configurable in some fashion, you can of course still register your own variant to override the default one:

*Table 12. Built-in PropertyEditors*

Class	Explanation
<code>ByteArrayPropertyEditor</code>	Editor for byte arrays. Strings will simply be converted to their corresponding byte representations. Registered by default by <code>BeanWrapperImpl</code> .
<code>ClassEditor</code>	Parses Strings representing classes to actual classes and the other way around. When a class is not found, an <code>IllegalArgumentException</code> is thrown. Registered by default by <code>BeanWrapperImpl</code> .
<code>CustomBooleanEditor</code>	Customizable property editor for <code>Boolean</code> properties. Registered by default by <code>BeanWrapperImpl</code> , but, can be overridden by registering custom instance of it as custom editor.
<code>CustomCollectionEditor</code>	Property editor for Collections, converting any source <code>Collection</code> to a given target <code>Collection</code> type.
<code>CustomDateEditor</code>	Customizable property editor for <code>java.util.Date</code> , supporting a custom <code>DateFormat</code> . NOT registered by default. Must be user registered as needed with appropriate format.
<code>CustomNumberEditor</code>	Customizable property editor for any Number subclass like <code>Integer</code> , <code>Long</code> , <code>Float</code> , <code>Double</code> . Registered by default by <code>BeanWrapperImpl</code> , but can be overridden by registering custom instance of it as a custom editor.

Class	Explanation
<code>FileEditor</code>	Capable of resolving Strings to <code>java.io.File</code> objects. Registered by default by <code>BeanWrapperImpl</code> .
<code>InputStreamEditor</code>	One-way property editor, capable of taking a text string and producing (via an intermediate <code>ResourceEditor</code> and <code>Resource</code> ) an <code>InputStream</code> , so <code>InputStream</code> properties may be directly set as Strings. Note that the default usage will not close the <code>InputStream</code> for you! Registered by default by <code>BeanWrapperImpl</code> .
<code>LocaleEditor</code>	Capable of resolving Strings to <code>Locale</code> objects and vice versa (the String format is <code>[country][variant]</code> , which is the same thing the <code>toString()</code> method of <code>Locale</code> provides). Registered by default by <code>BeanWrapperImpl</code> .
<code>PatternEditor</code>	Capable of resolving Strings to <code>java.util.regex.Pattern</code> objects and vice versa.
<code>PropertiesEditor</code>	Capable of converting Strings (formatted using the format as defined in the javadocs of the <code>java.util.Properties</code> class) to <code>Properties</code> objects. Registered by default by <code>BeanWrapperImpl</code> .
<code>StringTrimmerEditor</code>	Property editor that trims Strings. Optionally allows transforming an empty string into a <code>null</code> value. NOT registered by default; must be user registered as needed.
<code>URLEditor</code>	Capable of resolving a String representation of a URL to an actual <code>URL</code> object. Registered by default by <code>BeanWrapperImpl</code> .

Spring uses the `java.beans.PropertyEditorManager` to set the search path for property editors that might be needed. The search path also includes `sun.bean.editors`, which includes `PropertyEditor` implementations for types such as `Font`, `Color`, and most of the primitive types. Note also that the standard JavaBeans infrastructure will automatically discover `PropertyEditor` classes (without you having to register them explicitly) if they are in the same package as the class they handle, and have the same name as that class, with '`Editor`' appended; for example, one could have the following class and package structure, which would be sufficient for the `FooEditor` class to be recognized and used as the `PropertyEditor` for `Foo`-typed properties.

```

com
  chank
    pop
      Foo
        FooEditor // the PropertyEditor for the Foo class
  
```

Note that you can also use the standard `BeanInfo` JavaBeans mechanism here as well (described [in not-amazing-detail here](#)). Find below an example of using the `BeanInfo` mechanism for explicitly

registering one or more `PropertyEditor` instances with the properties of an associated class.

```
com
  chank
    pop
      Foo
        FooBeanInfo // the BeanInfo for the Foo class
```

Here is the Java source code for the referenced `FooBeanInfo` class. This would associate a `CustomNumberEditor` with the `age` property of the `Foo` class.

```
public class FooBeanInfo extends SimpleBeanInfo {

    public PropertyDescriptor[] getPropertyDescriptors() {
        try {
            final PropertyEditor numberPE = new CustomNumberEditor(Integer.class,
true);
            PropertyDescriptor ageDescriptor = new PropertyDescriptor("age", Foo.
class) {
                public PropertyEditor createPropertyEditor(Object bean) {
                    return numberPE;
                };
            };
            return new PropertyDescriptor[] { ageDescriptor };
        }
        catch (IntrospectionException ex) {
            throw new Error(ex.toString());
        }
    }
}
```

## Registering additional custom `PropertyEditors`

When setting bean properties as a string value, a Spring IoC container ultimately uses standard JavaBeans `PropertyEditors` to convert these Strings to the complex type of the property. Spring pre-registers a number of custom `PropertyEditors` (for example, to convert a classname expressed as a string into a real `Class` object). Additionally, Java's standard JavaBeans `PropertyEditor` lookup mechanism allows a `PropertyEditor` for a class simply to be named appropriately and placed in the same package as the class it provides support for, to be found automatically.

If there is a need to register other custom `PropertyEditors`, there are several mechanisms available. The most manual approach, which is not normally convenient or recommended, is to simply use the `registerCustomEditor()` method of the `ConfigurableBeanFactory` interface, assuming you have a `BeanFactory` reference. Another, slightly more convenient, mechanism is to use a special bean factory post-processor called `CustomEditorConfigurer`. Although bean factory post-processors can be used with `BeanFactory` implementations, the `CustomEditorConfigurer` has a nested property setup, so it is strongly recommended that it is used with the `ApplicationContext`, where it may be deployed in similar fashion to any other bean, and automatically detected and applied.

Note that all bean factories and application contexts automatically use a number of built-in property editors, through their use of something called a `BeanWrapper` to handle property conversions. The standard property editors that the `BeanWrapper` registers are listed in [the previous section](#). Additionally, `ApplicationContexts` also override or add an additional number of editors to handle resource lookups in a manner appropriate to the specific application context type.

Standard JavaBeans `PropertyEditor` instances are used to convert property values expressed as strings to the actual complex type of the property. `CustomEditorConfigurer`, a bean factory post-processor, may be used to conveniently add support for additional `PropertyEditor` instances to an `ApplicationContext`.

Consider a user class `ExoticType`, and another class `DependsOnExoticType` which needs `ExoticType` set as a property:

```
package example;

public class ExoticType {

    private String name;

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

public class DependsOnExoticType {

    private ExoticType type;

    public void setType(ExoticType type) {
        this.type = type;
    }
}
```

When things are properly set up, we want to be able to assign the type property as a string, which a `PropertyEditor` will behind the scenes convert into an actual `ExoticType` instance:

```
<bean id="sample" class="example.DependsOnExoticType">
    <property name="type" value="aNameForExoticType"/>
</bean>
```

The `PropertyEditor` implementation could look similar to this:

```
// converts string representation to ExoticType object
package example;

public class ExoticTypeEditor extends PropertyEditorSupport {

    public void setAsText(String text) {
        setValue(new ExoticType(text.toUpperCase()));
    }
}
```

Finally, we use `CustomEditorConfigurer` to register the new `PropertyEditor` with the `ApplicationContext`, which will then be able to use it as needed:

```
<bean class="org.springframework.beans.factory.config.CustomEditorConfigurer">
    <property name="customEditors">
        <map>
            <entry key="example.ExoticType" value="example.ExoticTypeEditor"/>
        </map>
    </property>
</bean>
```

## Using PropertyEditorRegistrars

Another mechanism for registering property editors with the Spring container is to create and use a `PropertyEditorRegistrar`. This interface is particularly useful when you need to use the same set of property editors in several different situations: write a corresponding registrar and reuse that in each case. `PropertyEditorRegistrars` work in conjunction with an interface called `PropertyEditorRegistry`, an interface that is implemented by the Spring `BeanWrapper` (and `DataBinder`). `PropertyEditorRegistrars` are particularly convenient when used in conjunction with the `CustomEditorConfigurer` (introduced [here](#)), which exposes a property called `setPropertyEditorRegistrars(..)`: `PropertyEditorRegistrars` added to a `CustomEditorConfigurer` in this fashion can easily be shared with `DataBinder` and Spring MVC `Controllers`. Furthermore, it avoids the need for synchronization on custom editors: a `PropertyEditorRegistrar` is expected to create fresh `PropertyEditor` instances for each bean creation attempt.

Using a `PropertyEditorRegistrar` is perhaps best illustrated with an example. First off, you need to create your own `PropertyEditorRegistrar` implementation:

```

package com.foo.editors.spring;

public final class CustomPropertyEditorRegistrar implements PropertyEditorRegistrar {

    public void registerCustomEditors(PropertyEditorRegistry registry) {

        // it is expected that new PropertyEditor instances are created
        registry.registerCustomEditor(ExoticType.class, new ExoticTypeEditor());

        // you could register as many custom property editors as are required here...
    }
}

```

See also the `org.springframework.beans.support.ResourceEditorRegistrar` for an example `PropertyEditorRegistrar` implementation. Notice how in its implementation of the `registerCustomEditors(..)` method it creates new instances of each property editor.

Next we configure a `CustomEditorConfigurer` and inject an instance of our `CustomPropertyEditorRegistrar` into it:

```

<bean class="org.springframework.beans.factory.config.CustomEditorConfigurer">
    <property name="propertyEditorRegistrars">
        <list>
            <ref bean="customPropertyEditorRegistrar"/>
        </list>
    </property>
</bean>

<bean id="customPropertyEditorRegistrar"
      class="com.foo.editors.spring.CustomPropertyEditorRegistrar"/>

```

Finally, and in a bit of a departure from the focus of this chapter, for those of you using [Spring's MVC web framework](#), using `PropertyEditorRegistrars` in conjunction with data-binding `Controllers` (such as `SimpleFormController`) can be very convenient. Find below an example of using a `PropertyEditorRegistrar` in the implementation of an `initBinder(..)` method:

```

public final class RegisterUserController extends SimpleFormController {

    private final PropertyEditorRegistrar customPropertyEditorRegistrar;

    public RegisterUserController(PropertyEditorRegistrar propertyEditorRegistrar) {
        this.customPropertyEditorRegistrar = propertyEditorRegistrar;
    }

    protected void initBinder(HttpServletRequest request,
        ServletRequestDataBinder binder) throws Exception {
        <strong>this.customPropertyEditorRegistrar.registerCustomEditors(binder);</strong>
    }

    // other methods to do with registering a User
}

```

This style of `PropertyEditor` registration can lead to concise code (the implementation of `initBinder(..)` is just one line long!), and allows common `PropertyEditor` registration code to be encapsulated in a class and then shared amongst as many `Controllers` as needed.

## 3.5. Spring Type Conversion

Spring 3 introduces a `core.convert` package that provides a general type conversion system. The system defines an SPI to implement type conversion logic, as well as an API to execute type conversions at runtime. Within a Spring container, this system can be used as an alternative to `PropertyEditors` to convert externalized bean property value strings to required property types. The public API may also be used anywhere in your application where type conversion is needed.

### 3.5.1. Converter SPI

The SPI to implement type conversion logic is simple and strongly typed:

```

package org.springframework.core.convert.converter;

public interface Converter<S, T> {

    T convert(S source);
}

```

To create your own converter, simply implement the interface above. Parameterize `S` as the type you are converting from, and `T` as the type you are converting to. Such a converter can also be applied transparently if a collection or array of `S` needs to be converted to an array or collection of `T`, provided that a delegating array/collection converter has been registered as well (which `DefaultConversionService` does by default).

For each call to `convert(S)`, the source argument is guaranteed to be NOT null. Your Converter may throw any unchecked exception if conversion fails; specifically, an `IllegalArgumentException` should be thrown to report an invalid source value. Take care to ensure that your `Converter` implementation is thread-safe.

Several converter implementations are provided in the `core.convert.support` package as a convenience. These include converters from Strings to Numbers and other common types. Consider `StringToInteger` as an example for a typical `Converter` implementation:

```
package org.springframework.core.convert.support;

final class StringToInteger implements Converter<String, Integer> {

    public Integer convert(String source) {
        return Integer.valueOf(source);
    }

}
```

### 3.5.2.ConverterFactory

When you need to centralize the conversion logic for an entire class hierarchy, for example, when converting from String to `java.lang.Enum` objects, implement `ConverterFactory`:

```
package org.springframework.core.convert.converter;

public interfaceConverterFactory<S, R> {

    <T extends R> Converter<S, T> getConverter(Class<T> targetType);

}
```

Parameterize S to be the type you are converting from and R to be the base type defining the *range* of classes you can convert to. Then implement `getConverter(Class<T>)`, where T is a subclass of R.

Consider the `StringToEnum`ConverterFactory as an example:

```

package org.springframework.core.convert.support;

final class StringToEnumConverterFactory implements ConverterFactory<String, Enum> {

    public <T extends Enum> Converter<String, T> getConverter(Class<T> targetType) {
        return new StringToEnumConverter(targetType);
    }

    private final class StringToEnumConverter<T extends Enum> implements Converter
    <String, T> {

        private Class<T> enumType;

        public StringToEnumConverter(Class<T> enumType) {
            this.enumType = enumType;
        }

        public T convert(String source) {
            return (T) Enum.valueOf(this.enumType, source.trim());
        }
    }
}

```

### 3.5.3. GenericConverter

When you require a sophisticated Converter implementation, consider the GenericConverter interface. With a more flexible but less strongly typed signature, a GenericConverter supports converting between multiple source and target types. In addition, a GenericConverter makes available source and target field context you can use when implementing your conversion logic. Such context allows a type conversion to be driven by a field annotation, or generic information declared on a field signature.

```

package org.springframework.core.convert.converter;

public interface GenericConverter {

    public Set<ConvertiblePair> getConvertibleTypes();

    Object convert(Object source, TypeDescriptor sourceType, TypeDescriptor
targetType);

}

```

To implement a GenericConverter, have getConvertibleTypes() return the supported source → target type pairs. Then implement convert(Object, TypeDescriptor, TypeDescriptor) to implement your conversion logic. The source TypeDescriptor provides access to the source field holding the value being converted. The target TypeDescriptor provides access to the target field where the converted

value will be set.

A good example of a `GenericConverter` is a converter that converts between a Java Array and a Collection. Such an `ArrayToCollectionConverter` introspects the field that declares the target Collection type to resolve the Collection's element type. This allows each element in the source array to be converted to the Collection element type before the Collection is set on the target field.



Because `GenericConverter` is a more complex SPI interface, only use it when you need it. Favor `Converter` or `ConverterFactory` for basic type conversion needs.

## ConditionalGenericConverter

Sometimes you only want a `Converter` to execute if a specific condition holds true. For example, you might only want to execute a `Converter` if a specific annotation is present on the target field. Or you might only want to execute a `Converter` if a specific method, such as a `static valueOf` method, is defined on the target class. `ConditionalGenericConverter` is the union of the `GenericConverter` and `ConditionalConverter` interfaces that allows you to define such custom matching criteria:

```
public interface ConditionalConverter {  
  
    boolean matches(TypeDescriptor sourceType, TypeDescriptor targetType);  
  
}  
  
public interface ConditionalGenericConverter  
    extends GenericConverter, ConditionalConverter {  
  
}
```

A good example of a `ConditionalGenericConverter` is an `EntityConverter` that converts between an persistent entity identifier and an entity reference. Such a `EntityConverter` might only match if the target entity type declares a static finder method e.g. `findAccount(Long)`. You would perform such a finder method check in the implementation of `matches(TypeDescriptor, TypeDescriptor)`.

### 3.5.4. ConversionService API

The `ConversionService` defines a unified API for executing type conversion logic at runtime. Converters are often executed behind this facade interface:

```

package org.springframework.core.convert;

public interface ConversionService {

    boolean canConvert(Class<?> sourceType, Class<?> targetType);

    <T> T convert(Object source, Class<T> targetType);

    boolean canConvert(TypeDescriptor sourceType, TypeDescriptor targetType);

    Object convert(Object source, TypeDescriptor sourceType, TypeDescriptor
targetType);

}

```

Most `ConversionService` implementations also implement `ConverterRegistry`, which provides an SPI for registering converters. Internally, a `ConversionService` implementation delegates to its registered converters to carry out type conversion logic.

A robust `ConversionService` implementation is provided in the `core.convert.support` package. `GenericConversionService` is the general-purpose implementation suitable for use in most environments. `ConversionServiceFactory` provides a convenient factory for creating common `ConversionService` configurations.

### 3.5.5. Configuring a `ConversionService`

A `ConversionService` is a stateless object designed to be instantiated at application startup, then shared between multiple threads. In a Spring application, you typically configure a `ConversionService` instance per Spring container (or `ApplicationContext`). That `ConversionService` will be picked up by Spring and then used whenever a type conversion needs to be performed by the framework. You may also inject this `ConversionService` into any of your beans and invoke it directly.



If no `ConversionService` is registered with Spring, the original `PropertyEditor`-based system is used.

To register a default `ConversionService` with Spring, add the following bean definition with id `conversionService`:

```

<bean id="conversionService"
      class="org.springframework.context.support.ConversionServiceFactoryBean"/>

```

A default `ConversionService` can convert between strings, numbers, enums, collections, maps, and other common types. To supplement or override the default converters with your own custom converter(s), set the `converters` property. Property values may implement either of the `Converter`, `ConverterFactory`, or `GenericConverter` interfaces.

```

<bean id="conversionService"
      class="org.springframework.context.support.ConversionServiceFactoryBean">
    <property name="converters">
      <set>
        <bean class="example.MyCustomConverter"/>
      </set>
    </property>
</bean>

```

It is also common to use a `ConversionService` within a Spring MVC application. See [Conversion and Formatting](#) in the Spring MVC chapter.

In certain situations you may wish to apply formatting during conversion. See [FormatterRegistry SPI](#) for details on using `FormattingConversionServiceFactoryBean`.

### 3.5.6. Using a `ConversionService` programmatically

To work with a `ConversionService` instance programmatically, simply inject a reference to it like you would for any other bean:

```

@Service
public class MyService {

    @Autowired
    public MyService(ConversionService conversionService) {
        this.conversionService = conversionService;
    }

    public void doIt() {
        this.conversionService.convert(...)
    }
}

```

For most use cases, the `convert` method specifying the `targetType` can be used but it will not work with more complex types such as a collection of a parameterized element. If you want to convert a `List` of `Integer` to a `List` of `String` programmatically, for instance, you need to provide a formal definition of the source and target types.

Fortunately, `TypeDescriptor` provides various options to make that straightforward:

```

DefaultConversionService cs = new DefaultConversionService();

List<Integer> input = ....
cs.convert(
    input,
    TypeDescriptor.forObject(input), // List<Integer> type descriptor
    TypeDescriptor.collection(List.class, TypeDescriptor.valueOf(String.class)));

```

Note that `DefaultConversionService` registers converters automatically which are appropriate for most environments. This includes collection converters, scalar converters, and also basic `Object` to `String` converters. The same converters can be registered with any `ConverterRegistry` using the static `addDefaultConverters` method on the `DefaultConversionService` class.

Converters for value types will be reused for arrays and collections, so there is no need to create a specific converter to convert from a `Collection` of `S` to a `Collection` of `T`, assuming that standard collection handling is appropriate.

## 3.6. Spring Field Formatting

As discussed in the previous section, `core.convert` is a general-purpose type conversion system. It provides a unified `ConversionService` API as well as a strongly-typed Converter SPI for implementing conversion logic from one type to another. A Spring Container uses this system to bind bean property values. In addition, both the Spring Expression Language (SpEL) and DataBinder use this system to bind field values. For example, when SpEL needs to coerce a `Short` to a `Long` to complete an `expression.setValue(Object bean, Object value)` attempt, the `core.convert` system performs the coercion.

Now consider the type conversion requirements of a typical client environment such as a web or desktop application. In such environments, you typically convert *from String* to support the client postback process, as well as back *to String* to support the view rendering process. In addition, you often need to localize String values. The more general `core.convert` Converter SPI does not address such *formatting* requirements directly. To directly address them, Spring 3 introduces a convenient Formatter SPI that provides a simple and robust alternative to PropertyEditors for client environments.

In general, use the Converter SPI when you need to implement general-purpose type conversion logic; for example, for converting between a `java.util.Date` and `java.lang.Long`. Use the Formatter SPI when you're working in a client environment, such as a web application, and need to parse and print localized field values. The `ConversionService` provides a unified type conversion API for both SPIs.

### 3.6.1. Formatter SPI

The Formatter SPI to implement field formatting logic is simple and strongly typed:

```
package org.springframework.format;

public interface Formatter<T> extends Printer<T>, Parser<T> {
```

Where Formatter extends from the Printer and Parser building-block interfaces:

```
public interface Printer<T> {
    String print(T fieldValue, Locale locale);
}
```

```
import java.text.ParseException;

public interface Parser<T> {
    T parse(String clientValue, Locale locale) throws ParseException;
}
```

To create your own Formatter, simply implement the Formatter interface above. Parameterize T to be the type of object you wish to format, for example, `java.util.Date`. Implement the `print()` operation to print an instance of T for display in the client locale. Implement the `parse()` operation to parse an instance of T from the formatted representation returned from the client locale. Your Formatter should throw a `ParseException` or `IllegalArgumentException` if a parse attempt fails. Take care to ensure your Formatter implementation is thread-safe.

Several Formatter implementations are provided in `format` subpackages as a convenience. The `number` package provides a `NumberFormatter`, `CurrencyFormatter`, and `PercentFormatter` to format `java.lang.Number` objects using a `java.text.NumberFormat`. The `datetime` package provides a `DateFormatter` to format `java.util.Date` objects with a `java.text.DateFormat`. The `datetime.joda` package provides comprehensive datetime formatting support based on the [Joda Time library](#).

Consider `DateFormatter` as an example `Formatter` implementation:

```

package org.springframework.format.datetime;

public final class DateFormatter implements Formatter<Date> {

    private String pattern;

    public DateFormatter(String pattern) {
        this.pattern = pattern;
    }

    public String print(Date date, Locale locale) {
        if (date == null) {
            return "";
        }
        return getDateFormat(locale).format(date);
    }

    public Date parse(String formatted, Locale locale) throws ParseException {
        if (formatted.length() == 0) {
            return null;
        }
        return getDateFormat(locale).parse(formatted);
    }

    protected DateFormat getDateFormat(Locale locale) {
        DateFormat dateFormat = new SimpleDateFormat(this.pattern, locale);
        dateFormat.setLenient(false);
        return dateFormat;
    }
}

```

The Spring team welcomes community-driven `Formatter` contributions; see [jira.spring.io](https://jira.spring.io) to contribute.

### 3.6.2. Annotation-driven Formatting

As you will see, field formatting can be configured by field type or annotation. To bind an Annotation to a formatter, implement `AnnotationFormatterFactory`:

```
package org.springframework.format;

public interface AnnotationFormatterFactory<A extends Annotation> {

    Set<Class<?>> getFieldTypes();

    Printer<?> getPrinter(A annotation, Class<?> fieldType);

    Parser<?> getParser(A annotation, Class<?> fieldType);

}
```

Parameterize A to be the field annotationType you wish to associate formatting logic with, for example `org.springframework.format.annotation.DateTimeFormat`. Have `getFieldTypes()` return the types of fields the annotation may be used on. Have `getPrinter()` return a Printer to print the value of an annotated field. Have `getParser()` return a Parser to parse a clientValue for an annotated field.

The example AnnotationFormatterFactory implementation below binds the `@NumberFormat` Annotation to a formatter. This annotation allows either a number style or pattern to be specified:

```

public final class NumberFormatAnnotationFormatterFactory
    implements AnnotationFormatterFactory<NumberFormat> {

    public Set<Class<?>> getFieldTypes() {
        return new HashSet<Class<?>>(asList(new Class<?>[] {
            Short.class, Integer.class, Long.class, Float.class,
            Double.class, BigDecimal.class, BigInteger.class }));
    }

    public Printer<Number> getPrinter(NumberFormat annotation, Class<?> fieldType) {
        return configureFormatterFrom(annotation, fieldType);
    }

    public Parser<Number> getParser(NumberFormat annotation, Class<?> fieldType) {
        return configureFormatterFrom(annotation, fieldType);
    }

    private Formatter<Number> configureFormatterFrom(NumberFormat annotation,
        Class<?> fieldType) {
        if (!annotation.pattern().isEmpty()) {
            return new NumberFormatter(annotation.pattern());
        } else {
            Style style = annotation.style();
            if (style == Style.PERCENT) {
                return new PercentFormatter();
            } else if (style == Style.CURRENCY) {
                return new CurrencyFormatter();
            } else {
                return new NumberFormatter();
            }
        }
    }
}

```

To trigger formatting, simply annotate fields with @NumberFormat:

```

public class MyModel {

    @NumberFormat(style=Style.CURRENCY)
    private BigDecimal decimal;

}

```

## Format Annotation API

A portable format annotation API exists in the `org.springframework.format.annotation` package. Use `@NumberFormat` to format `java.lang.Number` fields. Use `@DateTimeFormat` to format `java.util.Date`, `java.util.Calendar`, `java.util.Long`, or Joda Time fields.

The example below uses @DateTimeFormat to format a java.util.Date as a ISO Date (yyyy-MM-dd):

```
public class MyModel {  
  
    @DateTimeFormat(iso=ISO.DATE)  
    private Date date;  
  
}
```

### 3.6.3. FormatterRegistry SPI

The FormatterRegistry is an SPI for registering formatters and converters. `FormattingConversionService` is an implementation of FormatterRegistry suitable for most environments. This implementation may be configured programmatically or declaratively as a Spring bean using `FormattingConversionServiceFactoryBean`. Because this implementation also implements `ConversionService`, it can be directly configured for use with Spring's DataBinder and the Spring Expression Language (SpEL).

Review the FormatterRegistry SPI below:

```
package org.springframework.format;  
  
public interface FormatterRegistry extends ConverterRegistry {  
  
    void addFormatterForFieldType(Class<?> fieldType, Printer<?> printer, Parser<?>  
        parser);  
  
    void addFormatterForFieldType(Class<?> fieldType, Formatter<?> formatter);  
  
    void addFormatterForFieldType(Formatter<?> formatter);  
  
    void addFormatterForAnnotation(AnnotationFormatterFactory<?, ?> factory);  
  
}
```

As shown above, Formatters can be registered by fieldType or annotation.

The FormatterRegistry SPI allows you to configure Formatting rules centrally, instead of duplicating such configuration across your Controllers. For example, you might want to enforce that all Date fields are formatted a certain way, or fields with a specific annotation are formatted in a certain way. With a shared FormatterRegistry, you define these rules once and they are applied whenever formatting is needed.

### 3.6.4. FormatterRegistrar SPI

The FormatterRegistrar is an SPI for registering formatters and converters through the FormatterRegistry:

```
package org.springframework.format;

public interface FormatterRegistrar {

    void registerFormatters(FormatterRegistry registry);

}
```

A `FormatterRegistrar` is useful when registering multiple related converters and formatters for a given formatting category, such as Date formatting. It can also be useful where declarative registration is insufficient. For example when a formatter needs to be indexed under a specific field type different from its own `<T>` or when registering a Printer/Parser pair. The next section provides more information on converter and formatter registration.

### 3.6.5. Configuring Formatting in Spring MVC

See [Conversion and Formatting](#) in the Spring MVC chapter.

## 3.7. Configuring a global date & time format

By default, date and time fields that are not annotated with `@DateTimeFormat` are converted from strings using the `DateFormat.SHORT` style. If you prefer, you can change this by defining your own global format.

You will need to ensure that Spring does not register default formatters, and instead you should register all formatters manually. Use the `org.springframework.format.datetime.joda.JodaTimeFormatterRegistrar` or `org.springframework.format.datetime.DateFormatterRegistrar` class depending on whether you use the Joda Time library.

For example, the following Java configuration will register a global ' `yyyyMMdd`' format. This example does not depend on the Joda Time library:

```

@Configuration
public class AppConfig {

    @Bean
    public FormattingConversionService conversionService() {

        // Use the DefaultFormattingConversionService but do not register defaults
        DefaultFormattingConversionService conversionService = new
DefaultFormattingConversionService(false);

        // Ensure @NumberFormat is still supported
        conversionService.addFormatterForFieldAnnotation(new
NumberFormatAnnotationFormatterFactory());

        // Register date conversion with a specific global format
        DateFormatterRegistrar registrar = new DateFormatterRegistrar();
        registrar.setFormatter(new DateFormatter("yyyy-MM-dd"));
        registrar.registerFormatters(conversionService);

        return conversionService;
    }
}

```

If you prefer XML based configuration you can use a [FormattingConversionServiceFactoryBean](#). Here is the same example, this time using Joda Time:

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd>

    <bean id="conversionService" class=
"org.springframework.format.support.FormattingConversionServiceFactoryBean">
        <property name="registerDefaultFormatters" value="false" />
        <property name="formatters">
            <set>
                <bean class=
"org.springframework.format.number.NumberFormatAnnotationFormatterFactory" />
                </set>
            </property>
            <property name="formatterRegistrars">
                <set>
                    <bean class=
"org.springframework.format.datetime.joda.JodaTimeFormatterRegistrar">
                        <property name="dateFormatter">
                            <bean class=
"org.springframework.format.datetime.joda.DateTimeFormatterFactoryBean">
                                <property name="pattern" value="yyyy-MMdd"/>
                            </bean>
                        </property>
                    </bean>
                </set>
            </property>
        </bean>
    </beans>

```



Joda Time provides separate distinct types to represent `date`, `time` and `date-time` values. The `dateFormatter`, `timeFormatter` and `dateTimeFormatter` properties of the `JodaTimeFormatterRegistrar` should be used to configure the different formats for each type. The `DateTimeFormatterFactoryBean` provides a convenient way to create formatters.

If you are using Spring MVC remember to explicitly configure the conversion service that is used. For Java based `@Configuration` this means extending the `WebMvcConfigurationSupport` class and overriding the `mvcConversionService()` method. For XML you should use the '`conversion-service`' attribute of the `mvc:annotation-driven` element. See [Conversion and Formatting](#) for details.

## 3.8. Spring Validation

Spring 3 introduces several enhancements to its validation support. First, the JSR-303 Bean Validation API is now fully supported. Second, when used programmatically, Spring's DataBinder can now validate objects as well as bind to them. Third, Spring MVC now has support for

declaratively validating `@Controller` inputs.

### 3.8.1. Overview of the JSR-303 Bean Validation API

JSR-303 standardizes validation constraint declaration and metadata for the Java platform. Using this API, you annotate domain model properties with declarative validation constraints and the runtime enforces them. There are a number of built-in constraints you can take advantage of. You may also define your own custom constraints.

To illustrate, consider a simple `PersonForm` model with two properties:

```
public class PersonForm {  
    private String name;  
    private int age;  
}
```

JSR-303 allows you to define declarative validation constraints against such properties:

```
public class PersonForm {  
  
    @NotNull  
    @Size(max=64)  
    private String name;  
  
    @Min(0)  
    private int age;  
}
```

When an instance of this class is validated by a JSR-303 Validator, these constraints will be enforced.

For general information on JSR-303/JSR-349, see the [Bean Validation website](#). For information on the specific capabilities of the default reference implementation, see the [Hibernate Validator](#) documentation. To learn how to setup a Bean Validation provider as a Spring bean, keep reading.

### 3.8.2. Configuring a Bean Validation Provider

Spring provides full support for the Bean Validation API. This includes convenient support for bootstrapping a JSR-303/JSR-349 Bean Validation provider as a Spring bean. This allows for a `javax.validation.ValidatorFactory` or `javax.validation.Validator` to be injected wherever validation is needed in your application.

Use the `LocalValidatorFactoryBean` to configure a default Validator as a Spring bean:

```
<bean id="validator"  
      class="org.springframework.validation.beanvalidation.LocalValidatorFactoryBean"/>
```

The basic configuration above will trigger Bean Validation to initialize using its default bootstrap mechanism. A JSR-303/JSR-349 provider, such as Hibernate Validator, is expected to be present in the classpath and will be detected automatically.

## Injecting a Validator

`LocalValidatorFactoryBean` implements both `javax.validation.ValidatorFactory` and `javax.validation.Validator`, as well as Spring's `org.springframework.validation.Validator`. You may inject a reference to either of these interfaces into beans that need to invoke validation logic.

Inject a reference to `javax.validation.Validator` if you prefer to work with the Bean Validation API directly:

```
import javax.validation.Validator;

@Service
public class MyService {

    @Autowired
    private Validator validator;
```

Inject a reference to `org.springframework.validation.Validator` if your bean requires the Spring Validation API:

```
import org.springframework.validation.Validator;

@Service
public class MyService {

    @Autowired
    private Validator validator;

}
```

## Configuring Custom Constraints

Each Bean Validation constraint consists of two parts. First, a `@Constraint` annotation that declares the constraint and its configurable properties. Second, an implementation of the `javax.validation.ConstraintValidator` interface that implements the constraint's behavior. To associate a declaration with an implementation, each `@Constraint` annotation references a corresponding `ValidationConstraint` implementation class. At runtime, a `ConstraintValidatorFactory` instantiates the referenced implementation when the constraint annotation is encountered in your domain model.

By default, the `LocalValidatorFactoryBean` configures a `SpringConstraintValidatorFactory` that uses Spring to create `ConstraintValidator` instances. This allows your custom `ConstraintValidators` to benefit from dependency injection like any other Spring bean.

Shown below is an example of a custom `@Constraint` declaration, followed by an associated `ConstraintValidator` implementation that uses Spring for dependency injection:

```
@Target({ElementType.METHOD, ElementType.FIELD})
@Retention(RetentionPolicy.RUNTIME)
@Constraint(validatedBy=MyConstraintValidator.class)
public @interface MyConstraint {
}
```

```
import javax.validation.ConstraintValidator;

public class MyConstraintValidator implements ConstraintValidator {

    @Autowired;
    private Foo aDependency;

    ...
}
```

As you can see, a `ConstraintValidator` implementation may have its dependencies `@Autowired` like any other Spring bean.

### Spring-driven Method Validation

The method validation feature supported by Bean Validation 1.1, and as a custom extension also by Hibernate Validator 4.3, can be integrated into a Spring context through a `MethodValidationPostProcessor` bean definition:

```
<bean class=
"org.springframework.validation.beanvalidation.MethodValidationPostProcessor"/>
```

In order to be eligible for Spring-driven method validation, all target classes need to be annotated with Spring's `@Validated` annotation, optionally declaring the validation groups to use. Check out the `MethodValidationPostProcessor` javadocs for setup details with Hibernate Validator and Bean Validation 1.1 providers.

### Additional Configuration Options

The default `LocalValidatorFactoryBean` configuration should prove sufficient for most cases. There are a number of configuration options for various Bean Validation constructs, from message interpolation to traversal resolution. See the `LocalValidatorFactoryBean` javadocs for more information on these options.

### 3.8.3. Configuring a DataBinder

Since Spring 3, a `DataBinder` instance can be configured with a `Validator`. Once configured, the `Validator` may be invoked by calling `binder.validate()`. Any validation Errors are automatically

added to the binder's `BindingResult`.

When working with the `DataBinder` programmatically, this can be used to invoke validation logic after binding to a target object:

```
Foo target = new Foo();
DataBinder binder = new DataBinder(target);
binder.setValidator(new FooValidator());

// bind to the target object
binder.bind(propertyValues);

// validate the target object
binder.validate();

// get BindingResult that includes any validation errors
BindingResult results = binder.getBindingResult();
```

A `DataBinder` can also be configured with multiple `Validator` instances via `dataBinder.addValidators` and `dataBinder.replaceValidators`. This is useful when combining globally configured Bean Validation with a Spring `Validator` configured locally on a `DataBinder` instance. See [\[validation-mvc-configuring\]](#).

### 3.8.4. Spring MVC 3 Validation

See [Validation](#) in the Spring MVC chapter.

# Chapter 4. Spring Expression Language (SpEL)

## 4.1. Introduction

The Spring Expression Language (SpEL for short) is a powerful expression language that supports querying and manipulating an object graph at runtime. The language syntax is similar to Unified EL but offers additional features, most notably method invocation and basic string templating functionality.

While there are several other Java expression languages available, OGNL, MVEL, and JBoss EL, to name a few, the Spring Expression Language was created to provide the Spring community with a single well supported expression language that can be used across all the products in the Spring portfolio. Its language features are driven by the requirements of the projects in the Spring portfolio, including tooling requirements for code completion support within the eclipse based Spring Tool Suite. That said, SpEL is based on a technology agnostic API allowing other expression language implementations to be integrated should the need arise.

While SpEL serves as the foundation for expression evaluation within the Spring portfolio, it is not directly tied to Spring and can be used independently. In order to be self contained, many of the examples in this chapter use SpEL as if it were an independent expression language. This requires creating a few bootstrapping infrastructure classes such as the parser. Most Spring users will not need to deal with this infrastructure and will instead only author expression strings for evaluation. An example of this typical use is the integration of SpEL into creating XML or annotated based bean definitions as shown in the section [Expression support for defining bean definitions](#).

This chapter covers the features of the expression language, its API, and its language syntax. In several places an Inventor and Inventor's Society class are used as the target objects for expression evaluation. These class declarations and the data used to populate them are listed at the end of the chapter.

## 4.2. Feature overview

The expression language supports the following functionality

- Literal expressions
- Boolean and relational operators
- Regular expressions
- Class expressions
- Accessing properties, arrays, lists, maps
- Method invocation
- Relational operators
- Assignment

- Calling constructors
- Bean references
- Array construction
- Inline lists
- Inline maps
- Ternary operator
- Variables
- User defined functions
- Collection projection
- Collection selection
- Templated expressions

## 4.3. Expression evaluation using Spring's Expression interface

This section introduces the simple use of SpEL interfaces and its expression language. The complete language reference can be found in the section [Language Reference](#).

The following code introduces the SpEL API to evaluate the literal string expression 'Hello World'.

```
ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("<strong>'Hello World'</strong>");
String message = (String) exp.getValue();
```

The value of the message variable is simply 'Hello World'.

The SpEL classes and interfaces you are most likely to use are located in the packages `org.springframework.expression` and its sub packages and `spel.support`.

The interface `ExpressionParser` is responsible for parsing an expression string. In this example the expression string is a string literal denoted by the surrounding single quotes. The interface `Expression` is responsible for evaluating the previously defined expression string. There are two exceptions that can be thrown, `ParseException` and `EvaluationException` when calling `parser.parseExpression` and `exp.getValue` respectively.

SpEL supports a wide range of features, such as calling methods, accessing properties, and calling constructors.

As an example of method invocation, we call the `concat` method on the string literal.

```
ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("<strong>'Hello World'.concat('!')</strong>");
String message = (String) exp.getValue();
```

The value of message is now 'Hello World!'.

As an example of calling a JavaBean property, the String property `Bytes` can be called as shown below.

```
ExpressionParser parser = new SpelExpressionParser();

// invokes 'getBytes()'
Expression exp = parser.parseExpression("<strong>'Hello World'.bytes</strong>");
byte[] bytes = (byte[]) exp.getValue();
```

SpEL also supports nested properties using standard *dot* notation, i.e. `prop1.prop2.prop3` and the setting of property values

Public fields may also be accessed.

```
ExpressionParser parser = new SpelExpressionParser();

// invokes 'getBytes().length'
Expression exp = parser.parseExpression("<strong>'Hello World'.bytes.length</strong>");
int length = (Integer) exp.getValue();
```

The `String`'s constructor can be called instead of using a string literal.

```
ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("<strong>new String('hello
world').toUpperCase()</strong>");
String message = exp.getValue(String.class);
```

Note the use of the generic method `public <T> T getValue(Class<T> desiredResultType)`. Using this method removes the need to cast the value of the expression to the desired result type. An `EvaluationException` will be thrown if the value cannot be cast to the type `T` or converted using the registered type converter.

The more common usage of SpEL is to provide an expression string that is evaluated against a specific object instance (called the root object). There are two options here and which to choose depends on whether the object against which the expression is being evaluated will be changing with each call to evaluate the expression. In the following example we retrieve the `name` property from an instance of the `Inventor` class.

```

// Create and set a calendar
GregorianCalendar c = new GregorianCalendar();
c.set(1856, 7, 9);

// The constructor arguments are name, birthday, and nationality.
Inventor tesla = new Inventor("Nikola Tesla", c.getTime(), "Serbian");

ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("<strong>name</strong>");

EvaluationContext context = new StandardEvaluationContext(tesla);
String name = (String) exp.getValue(context);

```

In the last line, the value of the string variable `name` will be set to "Nikola Tesla". The class `StandardEvaluationContext` is where you can specify which object the "name" property will be evaluated against. This is the mechanism to use if the root object is unlikely to change, it can simply be set once in the evaluation context. If the root object is likely to change repeatedly, it can be supplied on each call to `getValue`, as this next example shows:

```

// Create and set a calendar
GregorianCalendar c = new GregorianCalendar();
c.set(1856, 7, 9);

// The constructor arguments are name, birthday, and nationality.
Inventor tesla = new Inventor("Nikola Tesla", c.getTime(), "Serbian");

ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("<strong>name</strong>");

String name = (String) exp.getValue(tesla);

```

In this case the inventor `tesla` has been supplied directly to `getValue` and the expression evaluation infrastructure creates and manages a default evaluation context internally - it did not require one to be supplied.

The `StandardEvaluationContext` is relatively expensive to construct and during repeated usage it builds up cached state that enables subsequent expression evaluations to be performed more quickly. For this reason it is better to cache and reuse them where possible, rather than construct a new one for each expression evaluation.

In some cases it can be desirable to use a configured evaluation context and yet still supply a different root object on each call to `getValue`. `getValue` allows both to be specified on the same call. In these situations the root object passed on the call is considered to override any (which maybe null) specified on the evaluation context.



In standalone usage of SpEL there is a need to create the parser, parse expressions and perhaps provide evaluation contexts and a root context object. However, more common usage is to provide only the SpEL expression string as part of a configuration file, for example for Spring bean or Spring Web Flow definitions. In this case, the parser, evaluation context, root object and any predefined variables are all set up implicitly, requiring the user to specify nothing other than the expressions.

As a final introductory example, the use of a boolean operator is shown using the Inventor object in the previous example.

```
Expression exp = parser.parseExpression("name == 'Nikola Tesla'");
boolean result = exp.getValue(context, Boolean.class); // evaluates to true
```

### 4.3.1. The EvaluationContext interface

The interface `EvaluationContext` is used when evaluating an expression to resolve properties, methods, fields, and to help perform type conversion. The out-of-the-box implementation, `StandardEvaluationContext`, uses reflection to manipulate the object, caching `java.lang.reflect.Method`, `java.lang.reflect.Field`, and `java.lang.reflect.Constructor` instances for increased performance.

The `StandardEvaluationContext` is where you may specify the root object to evaluate against via the method `setRootObject()` or passing the root object into the constructor. You can also specify variables and functions that will be used in the expression using the methods `setVariable()` and `registerFunction()`. The use of variables and functions are described in the language reference sections [Variables](#) and [Functions](#). The `StandardEvaluationContext` is also where you can register custom `ConstructorResolvers`, `MethodResolvers`, and `PropertyAccessors` to extend how SpEL evaluates expressions. Please refer to the javadoc of these classes for more details.

#### Type conversion

By default SpEL uses the conversion service available in Spring core (`org.springframework.core.convert.ConversionService`). This conversion service comes with many converters built in for common conversions but is also fully extensible so custom conversions between types can be added. Additionally it has the key capability that it is generics aware. This means that when working with generic types in expressions, SpEL will attempt conversions to maintain type correctness for any objects it encounters.

What does this mean in practice? Suppose assignment, using `setValue()`, is being used to set a `List` property. The type of the property is actually `List<Boolean>`. SpEL will recognize that the elements of the list need to be converted to `Boolean` before being placed in it. A simple example:

```

class Simple {
    public List<Boolean> booleanList = new ArrayList<Boolean>();
}

Simple simple = new Simple();

simple.booleanList.add(true);

StandardEvaluationContext simpleContext = new StandardEvaluationContext(simple);

// false is passed in here as a string. SpEL and the conversion service will
// correctly recognize that it needs to be a Boolean and convert it
parser.parseExpression("booleanList[0]").setValue(simpleContext, "false");

// b will be false
Boolean b = simple.booleanList.get(0);

```

### 4.3.2. Parser configuration

It is possible to configure the SpEL expression parser using a parser configuration object ([org.springframework.expression.spel.SpelParserConfiguration](#)). The configuration object controls the behavior of some of the expression components. For example, if indexing into an array or collection and the element at the specified index is `null` it is possible to automatically create the element. This is useful when using expressions made up of a chain of property references. If indexing into an array or list and specifying an index that is beyond the end of the current size of the array or list it is possible to automatically grow the array or list to accommodate that index.

```

class Demo {
    public List<String> list;
}

// Turn on:
// - auto null reference initialization
// - auto collection growing
SpelParserConfiguration config = new SpelParserConfiguration(true,true);

ExpressionParser parser = new SpelExpressionParser(config);

Expression expression = parser.parseExpression("list[3]");

Demo demo = new Demo();

Object o = expression.getValue(demo);

// demo.list will now be a real collection of 4 entries
// Each entry is a new empty String

```

It is also possible to configure the behaviour of the SpEL expression compiler.

### 4.3.3. SpEL compilation

Spring Framework 4.1 includes a basic expression compiler. Expressions are usually interpreted which provides a lot of dynamic flexibility during evaluation but does not provide the optimum performance. For occasional expression usage this is fine, but when used by other components like Spring Integration, performance can be very important and there is no real need for the dynamism.

The new SpEL compiler is intended to address this need. The compiler will generate a real Java class on the fly during evaluation that embodies the expression behavior and use that to achieve much faster expression evaluation. Due to the lack of typing around expressions the compiler uses information gathered during the interpreted evaluations of an expression when performing compilation. For example, it does not know the type of a property reference purely from the expression but during the first interpreted evaluation it will find out what it is. Of course, basing the compilation on this information could cause trouble later if the types of the various expression elements change over time. For this reason compilation is best suited to expressions whose type information is not going to change on repeated evaluations.

For a basic expression like this:

```
someArray[0].someProperty.someOtherProperty < 0.1
```

which involves array access, some property dereferencing and numeric operations, the performance gain can be very noticeable. In an example micro benchmark run of 50000 iterations, it was taking 75ms to evaluate using only the interpreter and just 3ms using the compiled version of the expression.

#### Compiler configuration

The compiler is not turned on by default, but there are two ways to turn it on. It can be turned on using the parser configuration process discussed earlier or via a system property when SpEL usage is embedded inside another component. This section discusses both of these options.

It is important to understand that there are a few modes the compiler can operate in, captured in an enum ([org.springframework.expression.spel.SpelCompilerMode](#)). The modes are as follows:

- **OFF** - The compiler is switched off; this is the default.
- **IMMEDIATE** - In immediate mode the expressions are compiled as soon as possible. This is typically after the first interpreted evaluation. If the compiled expression fails (typically due to a type changing, as described above) then the caller of the expression evaluation will receive an exception.
- **MIXED** - In mixed mode the expressions silently switch between interpreted and compiled mode over time. After some number of interpreted runs they will switch to compiled form and if something goes wrong with the compiled form (like a type changing, as described above) then the expression will automatically switch back to interpreted form again. Sometime later it may generate another compiled form and switch to it. Basically the exception that the user gets in **IMMEDIATE** mode is instead handled internally.

**IMMEDIATE** mode exists because **MIXED** mode could cause issues for expressions that have side effects. If a compiled expression blows up after partially succeeding it may have already done something

that has affected the state of the system. If this has happened the caller may not want it to silently re-run in interpreted mode since part of the expression may be running twice.

After selecting a mode, use the `SpelParserConfiguration` to configure the parser:

```
SpelParserConfiguration config = new SpelParserConfiguration(SpelCompilerMode
    .IMMEDIATE,
    this.getClass().getClassLoader());

SpelExpressionParser parser = new SpelExpressionParser(config);

Expression expr = parser.parseExpression("payload");

MyMessage message = new MyMessage();

Object payload = expr.getValue(message);
```

When specifying the compiler mode it is also possible to specify a classloader (passing null is allowed). Compiled expressions will be defined in a child classloader created under any that is supplied. It is important to ensure if a classloader is specified it can see all the types involved in the expression evaluation process. If none is specified then a default classloader will be used (typically the context classloader for the thread that is running during expression evaluation).

The second way to configure the compiler is for use when SpEL is embedded inside some other component and it may not be possible to configure via a configuration object. In these cases it is possible to use a system property. The property `spring.expression.compiler.mode` can be set to one of the `SpelCompilerMode` enum values (`off`, `immediate`, or `mixed`).

### Compiler limitations

With Spring Framework 4.1 the basic compilation framework is in place. However, the framework does not yet support compiling every kind of expression. The initial focus has been on the common expressions that are likely to be used in performance critical contexts. These kinds of expression cannot be compiled at the moment:

- expressions involving assignment
- expressions relying on the conversion service
- expressions using custom resolvers or accessors
- expressions using selection or projection

More and more types of expression will be compilable in the future.

## 4.4. Expression support for defining bean definitions

SpEL expressions can be used with XML or annotation-based configuration metadata for defining `BeanDefinitions`. In both cases the syntax to define the expression is of the form `#{ <expression string> }`.

#### 4.4.1. XML based configuration

A property or constructor-arg value can be set using expressions as shown below.

```
<bean id="numberGuess" class="org.springframework.samples.NumberGuess">
    <property name="randomNumber" value="#{ T(java.lang.Math).random() * 100.0 }"/>

    <!-- other properties -->
</bean>
```

The variable `systemProperties` is predefined, so you can use it in your expressions as shown below. Note that you do not have to prefix the predefined variable with the `#` symbol in this context.

```
<bean id="taxCalculator" class="org.springframework.samples.TaxCalculator">
    <property name="defaultLocale" value="#{ systemProperties['user.region'] }"/>

    <!-- other properties -->
</bean>
```

You can also refer to other bean properties by name, for example.

```
<bean id="numberGuess" class="org.springframework.samples.NumberGuess">
    <property name="randomNumber" value="#{ T(java.lang.Math).random() * 100.0 }"/>

    <!-- other properties -->
</bean>

<bean id="shapeGuess" class="org.springframework.samples.ShapeGuess">
    <property name="initialShapeSeed" value="#{ numberGuess.randomNumber }"/>

    <!-- other properties -->
</bean>
```

#### 4.4.2. Annotation-based configuration

The `@Value` annotation can be placed on fields, methods and method/constructor parameters to specify a default value.

Here is an example to set the default value of a field variable.

```
public static class FieldValueTestBean

    @Value("#{ systemProperties['user.region'] }")
    private String defaultLocale;

    public void setDefaultLocale(String defaultLocale) {
        this.defaultLocale = defaultLocale;
    }

    public String getDefaultLocale() {
        return this.defaultLocale;
    }

}
```

The equivalent but on a property setter method is shown below.

```
public static class PropertyValueTestBean

    private String defaultLocale;

    @Value("#{ systemProperties['user.region'] }")
    public void setDefaultLocale(String defaultLocale) {
        this.defaultLocale = defaultLocale;
    }

    public String getDefaultLocale() {
        return this.defaultLocale;
    }

}
```

Autowired methods and constructors can also use the `@Value` annotation.

```

public class SimpleMovieLister {

    private MovieFinder movieFinder;
    private String defaultLocale;

    @Autowired
    public void configure(MovieFinder movieFinder,
        @Value("#{ systemProperties['user.region'] }") String defaultLocale) {
        this.movieFinder = movieFinder;
        this.defaultLocale = defaultLocale;
    }

    // ...
}

```

```

public class MovieRecommender {

    private String defaultLocale;

    private CustomerPreferenceDao customerPreferenceDao;

    @Autowired
    public MovieRecommender(CustomerPreferenceDao customerPreferenceDao,
        @Value("#{systemProperties['user.country']}") String defaultLocale) {
        this.customerPreferenceDao = customerPreferenceDao;
        this.defaultLocale = defaultLocale;
    }

    // ...
}

```

## 4.5. Language Reference

### 4.5.1. Literal expressions

The types of literal expressions supported are strings, numeric values (int, real, hex), boolean and null. Strings are delimited by single quotes. To put a single quote itself in a string, use two single quote characters.

The following listing shows simple usage of literals. Typically they would not be used in isolation like this but rather as part of a more complex expression, for example using a literal on one side of a logical comparison operator.

```

ExpressionParser parser = new SpelExpressionParser();

// evals to "Hello World"
String helloWorld = (String) parser.parseExpression("'Hello World'").getValue();

double avogadrosNumber = (Double) parser.parseExpression("6.0221415E+23").getValue();

// evals to 2147483647
int maxValue = (Integer) parser.parseExpression("0x7FFFFFFF").getValue();

boolean trueValue = (Boolean) parser.parseExpression("true").getValue();

Object nullValue = parser.parseExpression("null").getValue();

```

Numbers support the use of the negative sign, exponential notation, and decimal points. By default real numbers are parsed using Double.parseDouble().

#### 4.5.2. Properties, Arrays, Lists, Maps, Indexers

Navigating with property references is easy: just use a period to indicate a nested property value. The instances of the `Inventor` class, `pupin`, and `tesla`, were populated with data listed in the section [Classes used in the examples](#). To navigate "down" and get Tesla's year of birth and Pupin's city of birth the following expressions are used.

```

// evals to 1856
int year = (Integer) parser.parseExpression("Birthdate.Year + 1900").getValue(context);

String city = (String) parser.parseExpression("placeOfBirth.City").getValue(context);

```

Case insensitivity is allowed for the first letter of property names. The contents of arrays and lists are obtained using square bracket notation.

```

ExpressionParser parser = new SpelExpressionParser();

// Inventions Array
StandardEvaluationContext teslaContext = new StandardEvaluationContext(tesla);

// evaluates to "Induction motor"
String invention = parser.parseExpression("inventions[3]").getValue(
    teslaContext, String.class);

// Members List
StandardEvaluationContext societyContext = new StandardEvaluationContext(ieee);

// evaluates to "Nikola Tesla"
String name = parser.parseExpression("Members[0].Name").getValue(
    societyContext, String.class);

// List and Array navigation
// evaluates to "Wireless communication"
String invention = parser.parseExpression("Members[0].Inventions[6]").getValue(
    societyContext, String.class);

```

The contents of maps are obtained by specifying the literal key value within the brackets. In this case, because keys for the Officers map are strings, we can specify string literals.

```

// Officer's Dictionary

Inventor pupin = parser.parseExpression("Officers['president']").getValue(
    societyContext, Inventor.class);

// evaluates to "Idvor"
String city = parser.parseExpression("Officers['president'].PlaceOfBirth.City")
.getValue(
    societyContext, String.class);

// setting values
parser.parseExpression("Officers['advisors'][0].PlaceOfBirth.Country").setValue(
    societyContext, "Croatia");

```

### 4.5.3. Inline lists

Lists can be expressed directly in an expression using {} notation.

```

// evaluates to a Java list containing the four numbers
List numbers = (List) parser.parseExpression("{1,2,3,4}").getValue(context);

List listOfLists = (List) parser.parseExpression("{{'a','b'},{'x','y'}}").getValue(
    context);

```

`{}` by itself means an empty list. For performance reasons, if the list is itself entirely composed of fixed literals then a constant list is created to represent the expression, rather than building a new list on each evaluation.

#### 4.5.4. Inline Maps

Maps can also be expressed directly in an expression using `{key:value}` notation.

```
// evaluates to a Java map containing the two entries
Map inventorInfo = (Map) parser.parseExpression("{name:'Nikola',dob:'10-July-1856'}")
.getValue(context);

Map mapOfMaps = (Map) parser.parseExpression(
  "{name:{first:'Nikola',last:'Tesla'},dob:{day:10,month:'July',year:1856}}").getValue(c
ontext);
```

`{:}` by itself means an empty map. For performance reasons, if the map is itself composed of fixed literals or other nested constant structures (lists or maps) then a constant map is created to represent the expression, rather than building a new map on each evaluation. Quoting of the map keys is optional, the examples above are not using quoted keys.

#### 4.5.5. Array construction

Arrays can be built using the familiar Java syntax, optionally supplying an initializer to have the array populated at construction time.

```
int[] numbers1 = (int[]) parser.parseExpression("new int[4]").getValue(context);

// Array with initializer
int[] numbers2 = (int[]) parser.parseExpression("new int[]{1,2,3}").getValue(context);

// Multi dimensional array
int[][] numbers3 = (int[][][]) parser.parseExpression("new int[4][5]").getValue(context
);
```

It is not currently allowed to supply an initializer when constructing a multi-dimensional array.

#### 4.5.6. Methods

Methods are invoked using typical Java programming syntax. You may also invoke methods on literals. Varargs are also supported.

```
// string literal, evaluates to "bc"
String bc = parser.parseExpression("'abc'.substring(1, 3)").getValue(String.class);

// evaluates to true
boolean isMember = parser.parseExpression("isMember('Mihajlo Pupin')").getValue(
    societyContext, Boolean.class);
```

## 4.5.7. Operators

### Relational operators

The relational operators; equal, not equal, less than, less than or equal, greater than, and greater than or equal are supported using standard operator notation.

```
// evaluates to true
boolean trueValue = parser.parseExpression("2 == 2").getValue(Boolean.class);

// evaluates to false
boolean falseValue = parser.parseExpression("2 < -5.0").getValue(Boolean.class);

// evaluates to true
boolean trueValue = parser.parseExpression("'black' < 'block'").getValue(Boolean.class);
```



Greater/less-than comparisons against `null` follow a simple rule: `null` is treated as nothing here (i.e. NOT as zero). As a consequence, any other value is always greater than `null` (`X > null` is always `true`) and no other value is ever less than nothing (`X < null` is always `false`).

If you prefer numeric comparisons instead, please avoid number-based `null` comparisons in favor of comparisons against zero (e.g. `X > 0` or `X < 0`).

In addition to standard relational operators SpEL supports the `instanceof` and regular expression based `matches` operator.

```
// evaluates to false
boolean falseValue = parser.parseExpression(
    "'xyz' instanceof T(Integer)").getValue(Boolean.class);

// evaluates to true
boolean trueValue = parser.parseExpression(
    "'5.00' matches '^-\?\d+(\.\d{2})?$', '$').getValue(Boolean.class);

// evaluates to false
boolean falseValue = parser.parseExpression(
    "'5.0067' matches '^-\?\d+(\.\d{2})?$', '$').getValue(Boolean.class);
```



Be careful with primitive types as they are immediately boxed up to the wrapper type, so `1 instanceof T(int)` evaluates to `false` while `1 instanceof T(Integer)` evaluates to `true`, as expected.

Each symbolic operator can also be specified as a purely alphabetic equivalent. This avoids problems where the symbols used have special meaning for the document type in which the expression is embedded (eg. an XML document). The textual equivalents are shown here: `lt (<)`, `gt (>)`, `le (≤)`, `ge (≥)`, `eq (==)`, `ne (!=)`, `div (/)`, `mod (%)`, `not (!)`. These are case insensitive.

## Logical operators

The logical operators that are supported are and, or, and not. Their use is demonstrated below.

```
// -- AND --
// evaluates to false
boolean falseValue = parser.parseExpression("true and false").getValue(Boolean.class);

// evaluates to true
String expression = "isMember('Nikola Tesla') and isMember('Mihajlo Pupin')";
boolean trueValue = parser.parseExpression(expression).getValue(societyContext,
Boolean.class);

// -- OR --
// evaluates to true
boolean trueValue = parser.parseExpression("true or false").getValue(Boolean.class);

// evaluates to true
String expression = "isMember('Nikola Tesla') or isMember('Albert Einstein')";
boolean trueValue = parser.parseExpression(expression).getValue(societyContext,
Boolean.class);

// -- NOT --
// evaluates to false
boolean falseValue = parser.parseExpression("!true").getValue(Boolean.class);

// -- AND and NOT --
String expression = "isMember('Nikola Tesla') and !isMember('Mihajlo Pupin')";
boolean falseValue = parser.parseExpression(expression).getValue(societyContext,
Boolean.class);
```

## Mathematical operators

The addition operator can be used on both numbers and strings. Subtraction, multiplication and division can be used only on numbers. Other mathematical operators supported are modulus (%) and exponential power (^). Standard operator precedence is enforced. These operators are demonstrated below.

```

// Addition
int two = parser.parseExpression("1 + 1").getValue(Integer.class); // 2

String testString = parser.parseExpression(
    "'test' + ' ' + 'string'").getValue(String.class); // 'test string'

// Subtraction
int four = parser.parseExpression("1 - -3").getValue(Integer.class); // 4

double d = parser.parseExpression("1000.00 - 1e4").getValue(Double.class); // -9000

// Multiplication
int six = parser.parseExpression("-2 * -3").getValue(Integer.class); // 6

double twentyFour = parser.parseExpression("2.0 * 3e0 * 4").getValue(Double.class); // 24.0

// Division
int minusTwo = parser.parseExpression("6 / -3").getValue(Integer.class); // -2

double one = parser.parseExpression("8.0 / 4e0 / 2").getValue(Double.class); // 1.0

// Modulus
int three = parser.parseExpression("7 % 4").getValue(Integer.class); // 3

int one = parser.parseExpression("8 / 5 % 2").getValue(Integer.class); // 1

// Operator precedence
int minusTwentyOne = parser.parseExpression("1+2-3*8").getValue(Integer.class); // -21

```

## 4.5.8. Assignment

Setting of a property is done by using the assignment operator. This would typically be done within a call to `setValue` but can also be done inside a call to `getValue`.

```

Inventor inventor = new Inventor();
StandardEvaluationContext inventorContext = new StandardEvaluationContext(inventor);

parser.parseExpression("Name").setValue(inventorContext, "Alexander Seovic2");

// alternatively

String aleks = parser.parseExpression(
    "Name = 'Alexandar Seovic'").getValue(inventorContext, String.class);

```

## 4.5.9. Types

The special `T` operator can be used to specify an instance of `java.lang.Class` (the *type*). Static methods

are invoked using this operator as well. The `StandardEvaluationContext` uses a `TypeLocator` to find types and the `StandardTypeLocator` (which can be replaced) is built with an understanding of the `java.lang` package. This means `T()` references to types within `java.lang` do not need to be fully qualified, but all other type references must be.

```
Class dateClass = parser.parseExpression("T(java.util.Date)").getValue(Class.class);

Class stringClass = parser.parseExpression("T(String)").getValue(Class.class);

boolean trueValue = parser.parseExpression(
    "T(java.math.RoundingMode).CEILING < T(java.math.RoundingMode).FLOOR")
    .getValue(Boolean.class);
```

#### 4.5.10. Constructors

Constructors can be invoked using the `new` operator. The fully qualified class name should be used for all but the primitive type and `String` (where `int`, `float`, etc, can be used).

```
Inventor einstein = p.parseExpression(
    "new org.springframework.samples.spel.inventor.Inventor('Albert Einstein', 'German')")
    .getValue(Inventor.class);

//create new inventor instance within add method of List
p.parseExpression(
    "Members.add(new org.springframework.samples.spel.inventor.Inventor(
        'Albert Einstein', 'German'))").getValue(societyContext);
```

#### 4.5.11. Variables

Variables can be referenced in the expression using the syntax `#variableName`. Variables are set using the method `setVariable` on the `StandardEvaluationContext`.

```
Inventor tesla = new Inventor("Nikola Tesla", "Serbian");
StandardEvaluationContext context = new StandardEvaluationContext(tesla);
context.setVariable("newName", "Mike Tesla");

parser.parseExpression("Name = #newName").getValue(context);

System.out.println(tesla.getName()) // "Mike Tesla"
```

#### The `#this` and `#root` variables

The variable `#this` is always defined and refers to the current evaluation object (against which unqualified references are resolved). The variable `#root` is always defined and refers to the root context object. Although `#this` may vary as components of an expression are evaluated, `#root` always refers to the root.

```

// create an array of integers
List<Integer> primes = new ArrayList<Integer>();
primes.addAll(Arrays.asList(2,3,5,7,11,13,17));

// create parser and set variable 'primes' as the array of integers
ExpressionParser parser = new SpelExpressionParser();
StandardEvaluationContext context = new StandardEvaluationContext();
context.setVariable("primes",primes);

// all prime numbers > 10 from the list (using selection ?{...})
// evaluates to [11, 13, 17]
List<Integer> primesGreaterThanTen = (List<Integer>) parser.parseExpression(
    "#primes.[#this>10]").getValue(context);

```

#### 4.5.12. Functions

You can extend SpEL by registering user defined functions that can be called within the expression string. The function is registered with the `StandardEvaluationContext` using the method.

```
public void registerFunction(String name, Method m)
```

A reference to a Java Method provides the implementation of the function. For example, a utility method to reverse a string is shown below.

```

public abstract class StringUtils {

    public static String reverseString(String input) {
        StringBuilder backwards = new StringBuilder();
        for (int i = 0; i < input.length(); i++)
            backwards.append(input.charAt(input.length() - 1 - i));
    }
    return backwards.toString();
}

```

This method is then registered with the evaluation context and can be used within an expression string.

```

ExpressionParser parser = new SpelExpressionParser();
StandardEvaluationContext context = new StandardEvaluationContext();

context.registerFunction("reverseString",
    StringUtils.class.getDeclaredMethod("reverseString", new Class[] { String.class })
);

String helloWorldReversed = parser.parseExpression(
    "#reverseString('hello')").getValue(context, String.class);

```

### 4.5.13. Bean references

If the evaluation context has been configured with a bean resolver it is possible to lookup beans from an expression using the (@) symbol.

```

ExpressionParser parser = new SpelExpressionParser();
StandardEvaluationContext context = new StandardEvaluationContext();
context.setBeanResolver(new MyBeanResolver());

// This will end up calling resolve(context,"foo") on MyBeanResolver during evaluation
Object bean = parser.parseExpression("@foo").getValue(context);

```

To access a factory bean itself, the bean name should instead be prefixed with a (&) symbol.

```

ExpressionParser parser = new SpelExpressionParser();
StandardEvaluationContext context = new StandardEvaluationContext();
context.setBeanResolver(new MyBeanResolver());

// This will end up calling resolve(context,"&foo") on MyBeanResolver during evaluation
Object bean = parser.parseExpression("&foo").getValue(context);

```

### 4.5.14. Ternary Operator (If-Then-Else)

You can use the ternary operator for performing if-then-else conditional logic inside the expression. A minimal example is:

```

String falseString = parser.parseExpression(
    "false ? 'trueExp' : 'falseExp'").getValue(String.class);

```

In this case, the boolean false results in returning the string value 'falseExp'. A more realistic example is shown below.

```

parser.parseExpression("Name").setValue(societyContext, "IEEE");
societyContext.setVariable("queryName", "Nikola Tesla");

expression = "isMember(#queryName)? #queryName + ' is a member of the ' " +
    "+ Name + ' Society' : #queryName + ' is not a member of the ' + Name + ' "
Society'";

String queryResultString = parser.parseExpression(expression)
    .getValue(societyContext, String.class);
// queryResultString = "Nikola Tesla is a member of the IEEE Society"

```

Also see the next section on the Elvis operator for an even shorter syntax for the ternary operator.

#### 4.5.15. The Elvis Operator

The Elvis operator is a shortening of the ternary operator syntax and is used in the [Groovy](#) language. With the ternary operator syntax you usually have to repeat a variable twice, for example:

```

String name = "Elvis Presley";
String displayName = name != null ? name : "Unknown";

```

Instead you can use the Elvis operator, named for the resemblance to Elvis' hair style.

```

ExpressionParser parser = new SpelExpressionParser();

String name = parser.parseExpression("name?:'Unknown'").getValue(String.class);

System.out.println(name); // 'Unknown'

```

Here is a more complex example.

```

ExpressionParser parser = new SpelExpressionParser();

Inventor tesla = new Inventor("Nikola Tesla", "Serbian");
StandardEvaluationContext context = new StandardEvaluationContext(tesla);

String name = parser.parseExpression("Name?:'Elvis Presley'").getValue(context,
String.class);

System.out.println(name); // Nikola Tesla

tesla.setName(null);

name = parser.parseExpression("Name?:'Elvis Presley'").getValue(context, String.class);

System.out.println(name); // Elvis Presley

```

#### 4.5.16. Safe Navigation operator

The Safe Navigation operator is used to avoid a `NullPointerException` and comes from the [Groovy](#) language. Typically when you have a reference to an object you might need to verify that it is not null before accessing methods or properties of the object. To avoid this, the safe navigation operator will simply return null instead of throwing an exception.

```

ExpressionParser parser = new SpelExpressionParser();

Inventor tesla = new Inventor("Nikola Tesla", "Serbian");
tesla.setPlaceOfBirth(new PlaceOfBirth("Smiljan"));

StandardEvaluationContext context = new StandardEvaluationContext(tesla);

String city = parser.parseExpression("PlaceOfBirth?.City").getValue(context, String
.class);
System.out.println(city); // Smiljan

tesla.setPlaceOfBirth(null);

city = parser.parseExpression("PlaceOfBirth?.City").getValue(context, String.class);

System.out.println(city); // null - does not throw NullPointerException!!!

```

The Elvis operator can be used to apply default values in expressions, e.g. in an `@Value` expression:



```
@Value("#{systemProperties['pop3.port'] ?: 25}")
```

This will inject a system property `pop3.port` if it is defined or 25 if not.

#### 4.5.17. Collection Selection

Selection is a powerful expression language feature that allows you to transform some source collection into another by selecting from its entries.

Selection uses the syntax `.?[selectionExpression]`. This will filter the collection and return a new collection containing a subset of the original elements. For example, selection would allow us to easily get a list of Serbian inventors:

```
List<Inventor> list = (List<Inventor>) parser.parseExpression("Members.?[Nationality == 'Serbian']").getValue(societyContext);
```

Selection is possible upon both lists and maps. In the former case the selection criteria is evaluated against each individual list element whilst against a map the selection criteria is evaluated against each map entry (objects of the Java type `Map.Entry`). Map entries have their key and value accessible as properties for use in the selection.

This expression will return a new map consisting of those elements of the original map where the entry value is less than 27.

```
Map newMap = parser.parseExpression("map.?[value<27]").getValue();
```

In addition to returning all the selected elements, it is possible to retrieve just the first or the last value. To obtain the first entry matching the selection the syntax is `^[…]` whilst to obtain the last matching selection the syntax is `$[…]`.

#### 4.5.18. Collection Projection

Projection allows a collection to drive the evaluation of a sub-expression and the result is a new collection. The syntax for projection is `![projectionExpression]`. Most easily understood by example, suppose we have a list of inventors but want the list of cities where they were born. Effectively we want to evaluate 'placeOfBirth.city' for every entry in the inventor list. Using projection:

```
// returns ['Smiljan', 'Idvor']
List placesOfBirth = (List)parser.parseExpression("Members.![placeOfBirth.city]");
```

A map can also be used to drive projection and in this case the projection expression is evaluated against each entry in the map (represented as a Java `Map.Entry`). The result of a projection across a

map is a list consisting of the evaluation of the projection expression against each map entry.

#### 4.5.19. Expression templating

Expression templates allow a mixing of literal text with one or more evaluation blocks. Each evaluation block is delimited with prefix and suffix characters that you can define, a common choice is to use `#{ }` as the delimiters. For example,

```
String randomPhrase = parser.parseExpression(  
    "random number is #{T(java.lang.Math).random()}",  
    new TemplateParserContext()).getValue(String.class);  
  
// evaluates to "random number is 0.7038186818312008"
```

The string is evaluated by concatenating the literal text 'random number is ' with the result of evaluating the expression inside the `#{ }` delimiter, in this case the result of calling that `random()` method. The second argument to the method `parseExpression()` is of the type `ParserContext`. The `ParserContext` interface is used to influence how the expression is parsed in order to support the expression templating functionality. The definition of `TemplateParserContext` is shown below.

```
public class TemplateParserContext implements ParserContext {  
  
    public String getExpressionPrefix() {  
        return "#{";  
    }  
  
    public String getExpressionSuffix() {  
        return "}";  
    }  
  
    public boolean isTemplate() {  
        return true;  
    }  
}
```

#### 4.6. Classes used in the examples

Inventor.java

```
package org.springframework.samples.spel.inventor;  
  
import java.util.Date;  
import java.util.GregorianCalendar;  
  
public class Inventor {  
  
    private String name;
```

```
private String nationality;
private String[] inventions;
private Date birthdate;
private PlaceOfBirth placeOfBirth;

public Inventor(String name, String nationality) {
    GregorianCalendar c= new GregorianCalendar();
    this.name = name;
    this.nationality = nationality;
    this.birthdate = c.getTime();
}

public Inventor(String name, Date birthdate, String nationality) {
    this.name = name;
    this.nationality = nationality;
    this.birthdate = birthdate;
}

public Inventor() {
}

public String getName() {
    return name;
}

public void setName(String name) {
    this.name = name;
}

public String getNationality() {
    return nationality;
}

public void setNationality(String nationality) {
    this.nationality = nationality;
}

public Date getBirthdate() {
    return birthdate;
}

public void setBirthdate(Date birthdate) {
    this.birthdate = birthdate;
}

public PlaceOfBirth getPlaceOfBirth() {
    return placeOfBirth;
}

public void setPlaceOfBirth(PlaceOfBirth placeOfBirth) {
    this.placeOfBirth = placeOfBirth;
```

```
}

public void setInventions(String[] inventions) {
    this.inventions = inventions;
}

public String[] getInventions() {
    return inventions;
}

}
```

PlaceOfBirth.java

```
package org.springframework.samples.spel.inventor;

public class PlaceOfBirth {

    private String city;
    private String country;

    public PlaceOfBirth(String city) {
        this.city=city;
    }

    public PlaceOfBirth(String city, String country) {
        this(city);
        this.country = country;
    }

    public String getCity() {
        return city;
    }

    public void setCity(String s) {
        this.city = s;
    }

    public String getCountry() {
        return country;
    }

    public void setCountry(String country) {
        this.country = country;
    }

}
```

Society.java

```
package org.springframework.samples.spel.inventor;

import java.util.*;

public class Society {

    private String name;

    public static String Advisors = "advisors";
    public static String President = "president";

    private List<Inventor> members = new ArrayList<Inventor>();
    private Map officers = new HashMap();

    public List getMembers() {
        return members;
    }

    public Map getOfficers() {
        return officers;
    }

    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public boolean isMember(String name) {
        for (Inventor inventor : members) {
            if (inventor.getName().equals(name)) {
                return true;
            }
        }
        return false;
    }

}
```

# Chapter 5. Aspect Oriented Programming with Spring

## 5.1. Introduction

*Aspect-Oriented Programming* (AOP) complements Object-Oriented Programming (OOP) by providing another way of thinking about program structure. The key unit of modularity in OOP is the class, whereas in AOP the unit of modularity is the *aspect*. Aspects enable the modularization of concerns such as transaction management that cut across multiple types and objects. (Such concerns are often termed *crosscutting* concerns in AOP literature.)

One of the key components of Spring is the *AOP framework*. While the Spring IoC container does not depend on AOP, meaning you do not need to use AOP if you don't want to, AOP complements Spring IoC to provide a very capable middleware solution.

### Spring 2.0+ AOP

Spring 2.0 introduced a simpler and more powerful way of writing custom aspects using either a [schema-based approach](#) or the [@AspectJ annotation style](#). Both of these styles offer fully typed advice and use of the AspectJ pointcut language, while still using Spring AOP for weaving.

The Spring 2.0+ schema- and @AspectJ-based AOP support is discussed in this chapter. The lower-level AOP support, as commonly exposed in Spring 1.2 applications, is discussed in [the following chapter](#).

AOP is used in the Spring Framework to...

- ... provide declarative enterprise services, especially as a replacement for EJB declarative services. The most important such service is [declarative transaction management](#).
- ... allow users to implement custom aspects, complementing their use of OOP with AOP.



If you are interested only in generic declarative services or other pre-packaged declarative middleware services such as pooling, you do not need to work directly with Spring AOP, and can skip most of this chapter.

### 5.1.1. AOP concepts

Let us begin by defining some central AOP concepts and terminology. These terms are not Spring-specific... unfortunately, AOP terminology is not particularly intuitive; however, it would be even more confusing if Spring used its own terminology.

- *Aspect*: a modularization of a concern that cuts across multiple classes. Transaction management is a good example of a crosscutting concern in enterprise Java applications. In Spring AOP, aspects are implemented using regular classes (the [schema-based approach](#)) or

regular classes annotated with the `@Aspect` annotation (the `@AspectJ style`).

- *Join point*: a point during the execution of a program, such as the execution of a method or the handling of an exception. In Spring AOP, a join point *always* represents a method execution.
- *Advice*: action taken by an aspect at a particular join point. Different types of advice include "around," "before" and "after" advice. (Advice types are discussed below.) Many AOP frameworks, including Spring, model an advice as an *interceptor*, maintaining a chain of interceptors *around* the join point.
- *Pointcut*: a predicate that matches join points. Advice is associated with a pointcut expression and runs at any join point matched by the pointcut (for example, the execution of a method with a certain name). The concept of join points as matched by pointcut expressions is central to AOP, and Spring uses the AspectJ pointcut expression language by default.
- *Introduction*: declaring additional methods or fields on behalf of a type. Spring AOP allows you to introduce new interfaces (and a corresponding implementation) to any advised object. For example, you could use an introduction to make a bean implement an `IsModified` interface, to simplify caching. (An introduction is known as an inter-type declaration in the AspectJ community.)
- *Target object*: object being advised by one or more aspects. Also referred to as the *advised* object. Since Spring AOP is implemented using runtime proxies, this object will always be a *proxied* object.
- *AOP proxy*: an object created by the AOP framework in order to implement the aspect contracts (advise method executions and so on). In the Spring Framework, an AOP proxy will be a JDK dynamic proxy or a CGLIB proxy.
- *Weaving*: linking aspects with other application types or objects to create an advised object. This can be done at compile time (using the AspectJ compiler, for example), load time, or at runtime. Spring AOP, like other pure Java AOP frameworks, performs weaving at runtime.

Types of advice:

- *Before advice*: Advice that executes before a join point, but which does not have the ability to prevent execution flow proceeding to the join point (unless it throws an exception).
- *After returning advice*: Advice to be executed after a join point completes normally: for example, if a method returns without throwing an exception.
- *After throwing advice*: Advice to be executed if a method exits by throwing an exception.
- *After (finally) advice*: Advice to be executed regardless of the means by which a join point exits (normal or exceptional return).
- *Around advice*: Advice that surrounds a join point such as a method invocation. This is the most powerful kind of advice. Around advice can perform custom behavior before and after the method invocation. It is also responsible for choosing whether to proceed to the join point or to shortcut the advised method execution by returning its own return value or throwing an exception.

Around advice is the most general kind of advice. Since Spring AOP, like AspectJ, provides a full range of advice types, we recommend that you use the least powerful advice type that can implement the required behavior. For example, if you need only to update a cache with the return

value of a method, you are better off implementing an after returning advice than an around advice, although an around advice can accomplish the same thing. Using the most specific advice type provides a simpler programming model with less potential for errors. For example, you do not need to invoke the `proceed()` method on the `JoinPoint` used for around advice, and hence cannot fail to invoke it.

In Spring 2.0, all advice parameters are statically typed, so that you work with advice parameters of the appropriate type (the type of the return value from a method execution for example) rather than `Object` arrays.

The concept of join points, matched by pointcuts, is the key to AOP which distinguishes it from older technologies offering only interception. Pointcuts enable advice to be targeted independently of the Object-Oriented hierarchy. For example, an around advice providing declarative transaction management can be applied to a set of methods spanning multiple objects (such as all business operations in the service layer).

### 5.1.2. Spring AOP capabilities and goals

Spring AOP is implemented in pure Java. There is no need for a special compilation process. Spring AOP does not need to control the class loader hierarchy, and is thus suitable for use in a Servlet container or application server.

Spring AOP currently supports only method execution join points (advising the execution of methods on Spring beans). Field interception is not implemented, although support for field interception could be added without breaking the core Spring AOP APIs. If you need to advise field access and update join points, consider a language such as AspectJ.

Spring AOP's approach to AOP differs from that of most other AOP frameworks. The aim is not to provide the most complete AOP implementation (although Spring AOP is quite capable); it is rather to provide a close integration between AOP implementation and Spring IoC to help solve common problems in enterprise applications.

Thus, for example, the Spring Framework's AOP functionality is normally used in conjunction with the Spring IoC container. Aspects are configured using normal bean definition syntax (although this allows powerful "autoproxying" capabilities): this is a crucial difference from other AOP implementations. There are some things you cannot do easily or efficiently with Spring AOP, such as advise very fine-grained objects (such as domain objects typically): AspectJ is the best choice in such cases. However, our experience is that Spring AOP provides an excellent solution to most problems in enterprise Java applications that are amenable to AOP.

Spring AOP will never strive to compete with AspectJ to provide a comprehensive AOP solution. We believe that both proxy-based frameworks like Spring AOP and full-blown frameworks such as AspectJ are valuable, and that they are complementary, rather than in competition. Spring seamlessly integrates Spring AOP and IoC with AspectJ, to enable all uses of AOP to be catered for within a consistent Spring-based application architecture. This integration does not affect the Spring AOP API or the AOP Alliance API: Spring AOP remains backward-compatible. See [the following chapter](#) for a discussion of the Spring AOP APIs.

One of the central tenets of the Spring Framework is that of *non-invasiveness*; this is the idea that you should not be forced to introduce framework-specific classes and interfaces into your business/domain model. However, in some places the Spring Framework does give you the option to introduce Spring Framework-specific dependencies into your codebase: the rationale in giving you such options is because in certain scenarios it might be just plain easier to read or code some specific piece of functionality in such a way. The Spring Framework (almost) always offers you the choice though: you have the freedom to make an informed decision as to which option best suits your particular use case or scenario.



One such choice that is relevant to this chapter is that of which AOP framework (and which AOP style) to choose. You have the choice of AspectJ and/or Spring AOP, and you also have the choice of either the @AspectJ annotation-style approach or the Spring XML configuration-style approach. The fact that this chapter chooses to introduce the @AspectJ-style approach first should not be taken as an indication that the Spring team favors the @AspectJ annotation-style approach over the Spring XML configuration-style.

See [Choosing which AOP declaration style to use](#) for a more complete discussion of the whys and wherefores of each style.

### 5.1.3. AOP Proxies

Spring AOP defaults to using standard JDK *dynamic proxies* for AOP proxies. This enables any interface (or set of interfaces) to be proxied.

Spring AOP can also use CGLIB proxies. This is necessary to proxy classes rather than interfaces. CGLIB is used by default if a business object does not implement an interface. As it is good practice to program to interfaces rather than classes; business classes normally will implement one or more business interfaces. It is possible to [force the use of CGLIB](#), in those (hopefully rare) cases where you need to advise a method that is not declared on an interface, or where you need to pass a proxied object to a method as a concrete type.

It is important to grasp the fact that Spring AOP is *proxy-based*. See [Understanding AOP proxies](#) for a thorough examination of exactly what this implementation detail actually means.

## 5.2. @AspectJ support

@AspectJ refers to a style of declaring aspects as regular Java classes annotated with annotations. The @AspectJ style was introduced by the [AspectJ project](#) as part of the AspectJ 5 release. Spring interprets the same annotations as AspectJ 5, using a library supplied by AspectJ for pointcut parsing and matching. The AOP runtime is still pure Spring AOP though, and there is no dependency on the AspectJ compiler or weaver.



Using the AspectJ compiler and weaver enables use of the full AspectJ language, and is discussed in [Using AspectJ with Spring applications](#).

## 5.2.1. Enabling @AspectJ Support

To use @AspectJ aspects in a Spring configuration you need to enable Spring support for configuring Spring AOP based on @AspectJ aspects, and *autoproxying* beans based on whether or not they are advised by those aspects. By autoproxying we mean that if Spring determines that a bean is advised by one or more aspects, it will automatically generate a proxy for that bean to intercept method invocations and ensure that advice is executed as needed.

The @AspectJ support can be enabled with XML or Java style configuration. In either case you will also need to ensure that AspectJ's `aspectjweaver.jar` library is on the classpath of your application (version 1.6.8 or later). This library is available in the '`lib`' directory of an AspectJ distribution or via the Maven Central repository.

### Enabling @AspectJ Support with Java configuration

To enable @AspectJ support with Java `@Configuration` add the `@EnableAspectJAutoProxy` annotation:

```
@Configuration  
@EnableAspectJAutoProxy  
public class AppConfig {  
}
```

### Enabling @AspectJ Support with XML configuration

To enable @AspectJ support with XML based configuration use the `aop:aspectj-autoproxy` element:

```
<aop:aspectj-autoproxy/>
```

This assumes that you are using schema support as described in [XML Schema-based configuration](#). See [the AOP schema](#) for how to import the tags in the `aop` namespace.

## 5.2.2. Declaring an aspect

With the @AspectJ support enabled, any bean defined in your application context with a class that is an @AspectJ aspect (has the `@Aspect` annotation) will be automatically detected by Spring and used to configure Spring AOP. The following example shows the minimal definition required for a not-very-useful aspect:

A regular bean definition in the application context, pointing to a bean class that has the `@Aspect` annotation:

```
<bean id="myAspect" class="org.xyz.NotVeryUsefulAspect">  
    <!-- configure properties of aspect here as normal -->  
</bean>
```

And the `NotVeryUsefulAspect` class definition, annotated with `org.aspectj.lang.annotation.Aspect`

annotation;

```
package org.xyz;
import org.aspectj.lang.annotation.Aspect;

@Aspect
public class NotVeryUsefulAspect {

}
```

Aspects (classes annotated with `@Aspect`) may have methods and fields just like any other class. They may also contain pointcut, advice, and introduction (inter-type) declarations.

#### *Autodetecting aspects through component scanning*

You may register aspect classes as regular beans in your Spring XML configuration, or autodetect them through classpath scanning - just like any other Spring-managed bean. However, note that the `@Aspect` annotation is *not* sufficient for autodetection in the classpath: For that purpose, you need to add a separate `@Component` annotation (or alternatively a custom stereotype annotation that qualifies, as per the rules of Spring's component scanner).

#### *Advising aspects with other aspects?*

In Spring AOP, it is *not* possible to have aspects themselves be the target of advice from other aspects. The `@Aspect` annotation on a class marks it as an aspect, and hence excludes it from auto-proxying.

### 5.2.3. Declaring a pointcut

Recall that pointcuts determine join points of interest, and thus enable us to control when advice executes. *Spring AOP only supports method execution join points for Spring beans*, so you can think of a pointcut as matching the execution of methods on Spring beans. A pointcut declaration has two parts: a signature comprising a name and any parameters, and a pointcut expression that determines *exactly* which method executions we are interested in. In the `@AspectJ` annotation-style of AOP, a pointcut signature is provided by a regular method definition, and the pointcut expression is indicated using the `@Pointcut` annotation (the method serving as the pointcut signature *must* have a `void` return type).

An example will help make this distinction between a pointcut signature and a pointcut expression clear. The following example defines a pointcut named '`anyOldTransfer`' that will match the execution of any method named '`transfer`':

```
@Pointcut("execution(* transfer(..))")// the pointcut expression
private void anyOldTransfer() {}// the pointcut signature
```

The pointcut expression that forms the value of the `@Pointcut` annotation is a regular AspectJ 5 pointcut expression. For a full discussion of AspectJ's pointcut language, see the [AspectJ](#)

[Programming Guide](#) (and for extensions, the [AspectJ 5 Developers Notebook](#)) or one of the books on AspectJ such as "Eclipse AspectJ" by Colyer et. al. or "AspectJ in Action" by Ramnivas Laddad.

## Supported Pointcut Designators

Spring AOP supports the following AspectJ pointcut designators (PCD) for use in pointcut expressions:

### Other pointcut types

The full AspectJ pointcut language supports additional pointcut designators that are not supported in Spring. These are: `call`, `get`, `set`, `preinitialization`, `staticinitialization`, `initialization`, `handler`, `adviceexecution`, `withincode`, `cflow`, `cflowbelow`, `if`, `@this`, and `@withincode`. Use of these pointcut designators in pointcut expressions interpreted by Spring AOP will result in an `IllegalArgumentException` being thrown.

The set of pointcut designators supported by Spring AOP may be extended in future releases to support more of the AspectJ pointcut designators.

- `execution` - for matching method execution join points, this is the primary pointcut designator you will use when working with Spring AOP
- `within` - limits matching to join points within certain types (simply the execution of a method declared within a matching type when using Spring AOP)
- `this` - limits matching to join points (the execution of methods when using Spring AOP) where the bean reference (Spring AOP proxy) is an instance of the given type
- `target` - limits matching to join points (the execution of methods when using Spring AOP) where the target object (application object being proxied) is an instance of the given type
- `args` - limits matching to join points (the execution of methods when using Spring AOP) where the arguments are instances of the given types
- `@target` - limits matching to join points (the execution of methods when using Spring AOP) where the class of the executing object has an annotation of the given type
- `@args` - limits matching to join points (the execution of methods when using Spring AOP) where the runtime type of the actual arguments passed have annotations of the given type(s)
- `@within` - limits matching to join points within types that have the given annotation (the execution of methods declared in types with the given annotation when using Spring AOP)
- `@annotation` - limits matching to join points where the subject of the join point (method being executed in Spring AOP) has the given annotation

Because Spring AOP limits matching to only method execution join points, the discussion of the pointcut designators above gives a narrower definition than you will find in the AspectJ programming guide. In addition, AspectJ itself has type-based semantics and at an execution join point both `this` and `target` refer to the same object - the object executing the method. Spring AOP is a proxy-based system and differentiates between the proxy object itself (bound to `this`) and the target object behind the proxy (bound to `target`).

Due to the proxy-based nature of Spring's AOP framework, calls within the target object are by definition *not* intercepted. For JDK proxies, only public interface method calls on the proxy can be intercepted. With CGLIB, public and protected method calls on the proxy will be intercepted, and even package-visible methods if necessary. However, common interactions through proxies should always be designed through public signatures.



Note that pointcut definitions are generally matched against any intercepted method. If a pointcut is strictly meant to be public-only, even in a CGLIB proxy scenario with potential non-public interactions through proxies, it needs to be defined accordingly.

If your interception needs include method calls or even constructors within the target class, consider the use of Spring-driven [native AspectJ weaving](#) instead of Spring's proxy-based AOP framework. This constitutes a different mode of AOP usage with different characteristics, so be sure to make yourself familiar with weaving first before making a decision.

Spring AOP also supports an additional PCD named `bean`. This PCD allows you to limit the matching of join points to a particular named Spring bean, or to a set of named Spring beans (when using wildcards). The `bean` PCD has the following form:

```
bean(idOrNameOfBean)
```

The `idOrNameOfBean` token can be the name of any Spring bean: limited wildcard support using the `*` character is provided, so if you establish some naming conventions for your Spring beans you can quite easily write a `bean` PCD expression to pick them out. As is the case with other pointcut designators, the `bean` PCD can be `&&`'ed, `| |`'ed, and `!` (negated) too.

Please note that the `bean` PCD is *only* supported in Spring AOP - and *not* in native AspectJ weaving. It is a Spring-specific extension to the standard PCDs that AspectJ defines and therefore not available for aspects declared in the `@Aspect` model.



The `bean` PCD operates at the *instance* level (building on the Spring bean name concept) rather than at the type level only (which is what weaving-based AOP is limited to). Instance-based pointcut designators are a special capability of Spring's proxy-based AOP framework and its close integration with the Spring bean factory, where it is natural and straightforward to identify specific beans by name.

## Combining pointcut expressions

Pointcut expressions can be combined using '`&&`', '`| |`' and '`!`'. It is also possible to refer to pointcut expressions by name. The following example shows three pointcut expressions: `anyPublicOperation` (which matches if a method execution join point represents the execution of any public method); `inTrading` (which matches if a method execution is in the trading module), and `tradingOperation` (which matches if a method execution represents any public method in the trading module).

```

@Pointcut("execution(public * *(..))")
private void anyPublicOperation() {}

@Pointcut("within(com.xyz.someapp.trading..*)")
private void inTrading() {}

@Pointcut("anyPublicOperation() && inTrading()")
private void tradingOperation() {}

```

It is a best practice to build more complex pointcut expressions out of smaller named components as shown above. When referring to pointcuts by name, normal Java visibility rules apply (you can see private pointcuts in the same type, protected pointcuts in the hierarchy, public pointcuts anywhere and so on). Visibility does not affect pointcut *matching*.

### Sharing common pointcut definitions

When working with enterprise applications, you often want to refer to modules of the application and particular sets of operations from within several aspects. We recommend defining a "SystemArchitecture" aspect that captures common pointcut expressions for this purpose. A typical such aspect would look as follows:

```

package com.xyz.someapp;

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Pointcut;

@Aspect
public class SystemArchitecture {

    /**
     * A join point is in the web layer if the method is defined
     * in a type in the com.xyz.someapp.web package or any sub-package
     * under that.
     */
    @Pointcut("within(com.xyz.someapp.web..*)")
    public void inWebLayer() {}

    /**
     * A join point is in the service layer if the method is defined
     * in a type in the com.xyz.someapp.service package or any sub-package
     * under that.
     */
    @Pointcut("within(com.xyz.someapp.service..*)")
    public void inServiceLayer() {}

    /**
     * A join point is in the data access layer if the method is defined
     * in a type in the com.xyz.someapp.dao package or any sub-package
     * under that.
     */

```

```

/*
@Pointcut("within(com.xyz.someapp.dao..*)")
public void inDataAccessLayer() {}

/**
 * A business service is the execution of any method defined on a service
 * interface. This definition assumes that interfaces are placed in the
 * "service" package, and that implementation types are in sub-packages.
 *
 * If you group service interfaces by functional area (for example,
 * in packages com.xyz.someapp.abc.service and com.xyz.someapp.def.service) then
 * the pointcut expression "execution(* com.xyz.someapp..service.*.*(..))"
 * could be used instead.
 *
 * Alternatively, you can write the expression using the 'bean'
 * PCD, like so "bean(*Service)". (This assumes that you have
 * named your Spring service beans in a consistent fashion.)
 */
@Pointcut("execution(* com.xyz.someapp..service.*.*(..))")
public void businessService() {}

/**
 * A data access operation is the execution of any method defined on a
 * dao interface. This definition assumes that interfaces are placed in the
 * "dao" package, and that implementation types are in sub-packages.
 */
@Pointcut("execution(* com.xyz.someapp.dao.*.*(..))")
public void dataAccessOperation() {}

}

```

The pointcuts defined in such an aspect can be referred to anywhere that you need a pointcut expression. For example, to make the service layer transactional, you could write:

```

<aop:config>
    <aop:advisor>
        pointcut="com.xyz.someapp.SystemArchitecture.businessService()"
        advice-ref="tx-advice"/>
    </aop:advisor>

    <tx:advice id="tx-advice">
        <tx:attributes>
            <tx:method name="*" propagation="REQUIRED"/>
        </tx:attributes>
    </tx:advice>
</aop:config>

```

The `<aop:config>` and `<aop:advisor>` elements are discussed in [Schema-based AOP support](#). The transaction elements are discussed in [Transaction Management](#).

## Examples

Spring AOP users are likely to use the `execution` pointcut designator the most often. The format of an execution expression is:

```
execution(modifiers-pattern? ret-type-pattern declaring-type-pattern?name-pattern  
(param-pattern)  
throws-pattern?)
```

All parts except the returning type pattern (ret-type-pattern in the snippet above), name pattern, and parameters pattern are optional. The returning type pattern determines what the return type of the method must be in order for a join point to be matched. Most frequently you will use `*` as the returning type pattern, which matches any return type. A fully-qualified type name will match only when the method returns the given type. The name pattern matches the method name. You can use the `*` wildcard as all or part of a name pattern. If specifying a declaring type pattern then include a trailing `.` to join it to the name pattern component. The parameters pattern is slightly more complex: `()` matches a method that takes no parameters, whereas `(..)` matches any number of parameters (zero or more). The pattern `(*)` matches a method taking one parameter of any type, `(* String)` matches a method taking two parameters, the first can be of any type, the second must be a String. Consult the [Language Semantics](#) section of the AspectJ Programming Guide for more information.

Some examples of common pointcut expressions are given below.

- the execution of any public method:

```
execution(public * *(..))
```

- the execution of any method with a name beginning with "set":

```
execution(* set*(..))
```

- the execution of any method defined by the `AccountService` interface:

```
execution(* com.xyz.service.AccountService.*(..))
```

- the execution of any method defined in the service package:

```
execution(* com.xyz.service.*.*(..))
```

- the execution of any method defined in the service package or a sub-package:

```
execution(* com.xyz.service..*.*(..))
```

- any join point (method execution only in Spring AOP) within the service package:

```
within(com.xyz.service.*)
```

- any join point (method execution only in Spring AOP) within the service package or a sub-package:

```
within(com.xyz.service..*)
```

- any join point (method execution only in Spring AOP) where the proxy implements the **AccountService** interface:

```
this(com.xyz.service.AccountService)
```



'this' is more commonly used in a binding form :- see the following section on advice for how to make the proxy object available in the advice body.

- any join point (method execution only in Spring AOP) where the target object implements the **AccountService** interface:

```
target(com.xyz.service.AccountService)
```



'target' is more commonly used in a binding form :- see the following section on advice for how to make the target object available in the advice body.

- any join point (method execution only in Spring AOP) which takes a single parameter, and where the argument passed at runtime is **Serializable**:

```
args(java.io.Serializable)
```



'args' is more commonly used in a binding form :- see the following section on advice for how to make the method arguments available in the advice body.

Note that the pointcut given in this example is different to `execution(* *(java.io.Serializable))`: the args version matches if the argument passed at runtime is Serializable, the execution version matches if the method signature declares a single parameter of type **Serializable**.

- any join point (method execution only in Spring AOP) where the target object has an **@Transactional** annotation:

```
@target(org.springframework.transaction.annotation.Transactional)
```



'@target' can also be used in a binding form :- see the following section on advice for how to make the annotation object available in the advice body.

- any join point (method execution only in Spring AOP) where the declared type of the target object has an **@Transactional** annotation:

```
@within(org.springframework.transaction.annotation.Transactional)
```



'@within' can also be used in a binding form :- see the following section on advice for how to make the annotation object available in the advice body.

- any join point (method execution only in Spring AOP) where the executing method has an **@Transactional** annotation:

```
@annotation(org.springframework.transaction.annotation.Transactional)
```



'@annotation' can also be used in a binding form :- see the following section on advice for how to make the annotation object available in the advice body.

- any join point (method execution only in Spring AOP) which takes a single parameter, and where the runtime type of the argument passed has the **@Classified** annotation:

```
@args(com.xyz.security.Classified)
```



'@args' can also be used in a binding form :- see the following section on advice for how to make the annotation object(s) available in the advice body.

- any join point (method execution only in Spring AOP) on a Spring bean named **tradeService**:

```
bean(tradeService)
```

- any join point (method execution only in Spring AOP) on Spring beans having names that match the wildcard expression **\*Service**:

```
bean(*Service)
```

## Writing good pointcuts

During compilation, AspectJ processes pointcuts in order to try and optimize matching performance. Examining code and determining if each join point matches (statically or dynamically) a given pointcut is a costly process. (A dynamic match means the match cannot be fully determined from static analysis and a test will be placed in the code to determine if there is an

actual match when the code is running). On first encountering a pointcut declaration, AspectJ will rewrite it into an optimal form for the matching process. What does this mean? Basically pointcuts are rewritten in DNF (Disjunctive Normal Form) and the components of the pointcut are sorted such that those components that are cheaper to evaluate are checked first. This means you do not have to worry about understanding the performance of various pointcut designators and may supply them in any order in a pointcut declaration.

However, AspectJ can only work with what it is told, and for optimal performance of matching you should think about what they are trying to achieve and narrow the search space for matches as much as possible in the definition. The existing designators naturally fall into one of three groups: kinded, scoping and context:

- Kinded designators are those which select a particular kind of join point. For example: execution, get, set, call, handler
- Scoping designators are those which select a group of join points of interest (of probably many kinds). For example: within, withincode
- Contextual designators are those that match (and optionally bind) based on context. For example: this, target, @annotation

A well written pointcut should try and include at least the first two types (kinded and scoping), whilst the contextual designators may be included if wishing to match based on join point context, or bind that context for use in the advice. Supplying either just a kinded designator or just a contextual designator will work but could affect weaving performance (time and memory used) due to all the extra processing and analysis. Scoping designators are very fast to match and their usage means AspectJ can very quickly dismiss groups of join points that should not be further processed - that is why a good pointcut should always include one if possible.

#### 5.2.4. Declaring advice

Advice is associated with a pointcut expression, and runs before, after, or around method executions matched by the pointcut. The pointcut expression may be either a simple reference to a named pointcut, or a pointcut expression declared in place.

##### Before advice

Before advice is declared in an aspect using the `@Before` annotation:

```

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Before;

@Aspect
public class BeforeExample {

    @Before("com.xyz.myapp.SystemArchitecture.dataAccessOperation()")
    public void doAccessCheck() {
        // ...
    }

}

```

If using an in-place pointcut expression we could rewrite the above example as:

```

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Before;

@Aspect
public class BeforeExample {

    @Before("execution(* com.xyz.myapp.dao.*.*(..))")
    public void doAccessCheck() {
        // ...
    }

}

```

## After returning advice

After returning advice runs when a matched method execution returns normally. It is declared using the `@AfterReturning` annotation:

```

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.AfterReturning;

@Aspect
public class AfterReturningExample {

    @AfterReturning("com.xyz.myapp.SystemArchitecture.dataAccessOperation()")
    public void doAccessCheck() {
        // ...
    }

}

```



Note: it is of course possible to have multiple advice declarations, and other members as well, all inside the same aspect. We're just showing a single advice declaration in these examples to focus on the issue under discussion at the time.

Sometimes you need access in the advice body to the actual value that was returned. You can use the form of `@AfterReturning` that binds the return value for this:

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.AfterReturning;

@Aspect
public class AfterReturningExample {

    @AfterReturning(
        pointcut="com.xyz.myapp.SystemArchitecture.dataAccessOperation()",
        returning="retVal")
    public void doAccessCheck(Object retVal) {
        // ...
    }

}
```

The name used in the `returning` attribute must correspond to the name of a parameter in the advice method. When a method execution returns, the return value will be passed to the advice method as the corresponding argument value. A `returning` clause also restricts matching to only those method executions that return a value of the specified type (`Object` in this case, which will match any return value).

Please note that it is *not* possible to return a totally different reference when using after-returning advice.

## After throwing advice

After throwing advice runs when a matched method execution exits by throwing an exception. It is declared using the `@AfterThrowing` annotation:

```

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.AfterThrowing;

@Aspect
public class AfterThrowingExample {

    @AfterThrowing("com.xyz.myapp.SystemArchitecture.dataAccessOperation()")
    public void doRecoveryActions() {
        // ...
    }

}

```

Often you want the advice to run only when exceptions of a given type are thrown, and you also often need access to the thrown exception in the advice body. Use the `throwing` attribute to both restrict matching (if desired, use `Throwable` as the exception type otherwise) and bind the thrown exception to an advice parameter.

```

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.AfterThrowing;

@Aspect
public class AfterThrowingExample {

    @AfterThrowing(
        pointcut="com.xyz.myapp.SystemArchitecture.dataAccessOperation()",
        throwing="ex")
    public void doRecoveryActions(DataAccessException ex) {
        // ...
    }

}

```

The name used in the `throwing` attribute must correspond to the name of a parameter in the advice method. When a method execution exits by throwing an exception, the exception will be passed to the advice method as the corresponding argument value. A `throwing` clause also restricts matching to only those method executions that throw an exception of the specified type (`DataAccessException` in this case).

## After (finally) advice

After (finally) advice runs however a matched method execution exits. It is declared using the `@After` annotation. After advice must be prepared to handle both normal and exception return conditions. It is typically used for releasing resources, etc.

```

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.After;

@Aspect
public class AfterFinallyExample {

    @After("com.xyz.myapp.SystemArchitecture.dataAccessOperation()")
    public void doReleaseLock() {
        // ...
    }

}

```

## Around advice

The final kind of advice is around advice. Around advice runs "around" a matched method execution. It has the opportunity to do work both before and after the method executes, and to determine when, how, and even if, the method actually gets to execute at all. Around advice is often used if you need to share state before and after a method execution in a thread-safe manner (starting and stopping a timer for example). Always use the least powerful form of advice that meets your requirements (i.e. don't use around advice if simple before advice would do).

Around advice is declared using the `@Around` annotation. The first parameter of the advice method must be of type `ProceedingJoinPoint`. Within the body of the advice, calling `proceed()` on the `ProceedingJoinPoint` causes the underlying method to execute. The `proceed` method may also be called passing in an `Object[]` - the values in the array will be used as the arguments to the method execution when it proceeds.

The behavior of proceed when called with an `Object[]` is a little different than the behavior of proceed for around advice compiled by the AspectJ compiler. For around advice written using the traditional AspectJ language, the number of arguments passed to proceed must match the number of arguments passed to the around advice (not the number of arguments taken by the underlying join point), and the value passed to proceed in a given argument position supplants the original value at the join point for the entity the value was bound to (Don't worry if this doesn't make sense right now!). The approach taken by Spring is simpler and a better match to its proxy-based, execution only semantics. You only need to be aware of this difference if you are compiling `@AspectJ` aspects written for Spring and using proceed with arguments with the AspectJ compiler and weaver. There is a way to write such aspects that is 100% compatible across both Spring AOP and AspectJ, and this is discussed in the following section on advice parameters.



```

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Around;
import org.aspectj.lang.ProceedingJoinPoint;

@Aspect
public class AroundExample {

    @Around("com.xyz.myapp.SystemArchitecture.businessService()")
    public Object doBasicProfiling(ProceedingJoinPoint pjp) throws Throwable {
        // start stopwatch
        Object retVal = pjp.proceed();
        // stop stopwatch
        return retVal;
    }
}

```

The value returned by the around advice will be the return value seen by the caller of the method. A simple caching aspect for example could return a value from a cache if it has one, and invoke proceed() if it does not. Note that proceed may be invoked once, many times, or not at all within the body of the around advice, all of these are quite legal.

## Advice parameters

Spring offers fully typed advice - meaning that you declare the parameters you need in the advice signature (as we saw for the returning and throwing examples above) rather than work with `Object[]` arrays all the time. We'll see how to make argument and other contextual values available to the advice body in a moment. First let's take a look at how to write generic advice that can find out about the method the advice is currently advising.

### Access to the current JoinPoint

Any advice method may declare as its first parameter, a parameter of type `org.aspectj.lang.JoinPoint` (please note that around advice is *required* to declare a first parameter of type `ProceedingJoinPoint`, which is a subclass of `JoinPoint`). The `JoinPoint` interface provides a number of useful methods such as `getArgs()` (returns the method arguments), `getThis()` (returns the proxy object), `getTarget()` (returns the target object), `getSignature()` (returns a description of the method that is being advised) and `toString()` (prints a useful description of the method being advised). Please do consult the javadocs for full details.

### Passing parameters to advice

We've already seen how to bind the returned value or exception value (using after returning and after throwing advice). To make argument values available to the advice body, you can use the binding form of `args`. If a parameter name is used in place of a type name in an args expression, then the value of the corresponding argument will be passed as the parameter value when the advice is invoked. An example should make this clearer. Suppose you want to advise the execution of dao operations that take an Account object as the first parameter, and you need access to the account in the advice body. You could write the following:

```

@Before("com.xyz.myapp.SystemArchitecture.dataAccessOperation() && args(account,...)")
public void validateAccount(Account account) {
    // ...
}

```

The `args(account,...)` part of the pointcut expression serves two purposes: firstly, it restricts matching to only those method executions where the method takes at least one parameter, and the argument passed to that parameter is an instance of `Account`; secondly, it makes the actual `Account` object available to the advice via the `account` parameter.

Another way of writing this is to declare a pointcut that "provides" the `Account` object value when it matches a join point, and then just refer to the named pointcut from the advice. This would look as follows:

```

@Pointcut("com.xyz.myapp.SystemArchitecture.dataAccessOperation() && args(account,...")
")
private void accountDataAccessOperation(Account account) {}

@Before("accountDataAccessOperation(account)")
public void validateAccount(Account account) {
    // ...
}

```

The interested reader is once more referred to the AspectJ programming guide for more details.

The proxy object (`this`), target object (`target`), and annotations (`@within`, `@target`, `@annotation`, `@args`) can all be bound in a similar fashion. The following example shows how you could match the execution of methods annotated with an `@Auditable` annotation, and extract the audit code.

First the definition of the `@Auditable` annotation:

```

@Retention(RetentionPolicy.RUNTIME)
@Target(ElementType.METHOD)
public @interface Auditable {
    AuditCode value();
}

```

And then the advice that matches the execution of `@Auditable` methods:

```

@Before("com.xyz.lib.Pointcuts.anyPublicMethod() && @annotation(auditable)")
public void audit(Auditable auditable) {
    AuditCode code = auditable.value();
    // ...
}

```

## Advice parameters and generics

Spring AOP can handle generics used in class declarations and method parameters. Suppose you have a generic type like this:

```
public interface Sample<T> {  
    void sampleGenericMethod(T param);  
    void sampleGenericCollectionMethod(Collection<T> param);  
}
```

You can restrict interception of method types to certain parameter types by simply typing the advice parameter to the parameter type you want to intercept the method for:

```
@Before("execution(* ..Sample+.sampleGenericMethod(*)) && args(param)")  
public void beforeSampleMethod(MyType param) {  
    // Advice implementation  
}
```

That this works is pretty obvious as we already discussed above. However, it's worth pointing out that this won't work for generic collections. So you cannot define a pointcut like this:

```
@Before("execution(* ..Sample+.sampleGenericCollectionMethod(*)) && args(param)")  
public void beforeSampleMethod(Collection<MyType> param) {  
    // Advice implementation  
}
```

To make this work we would have to inspect every element of the collection, which is not reasonable as we also cannot decide how to treat `null` values in general. To achieve something similar to this you have to type the parameter to `Collection<?>` and manually check the type of the elements.

## Determining argument names

The parameter binding in advice invocations relies on matching names used in pointcut expressions to declared parameter names in (advice and pointcut) method signatures. Parameter names are *not* available through Java reflection, so Spring AOP uses the following strategies to determine parameter names:

- If the parameter names have been specified by the user explicitly, then the specified parameter names are used: both the advice and the pointcut annotations have an optional "argNames" attribute which can be used to specify the argument names of the annotated method - these argument names *are* available at runtime. For example:

```

@Before(value="com.xyz.lib.Pointcuts.anyPublicMethod() && target(bean) &&
@annotation(auditable)",
       argNames="bean,auditable")
public void audit(Object bean, Auditable auditable) {
    AuditCode code = auditable.value();
    // ... use code and bean
}

```

If the first parameter is of the `JoinPoint`, `ProceedingJoinPoint`, or `JoinPoint.StaticPart` type, you may leave out the name of the parameter from the value of the "argNames" attribute. For example, if you modify the preceding advice to receive the join point object, the "argNames" attribute need not include it:

```

@Before(value="com.xyz.lib.Pointcuts.anyPublicMethod() && target(bean) &&
@annotation(auditable)",
       argNames="bean,auditable")
public void audit(JoinPoint jp, Object bean, Auditable auditable) {
    AuditCode code = auditable.value();
    // ... use code, bean, and jp
}

```

The special treatment given to the first parameter of the `JoinPoint`, `ProceedingJoinPoint`, and `JoinPoint.StaticPart` types is particularly convenient for advice that do not collect any other join point context. In such situations, you may simply omit the "argNames" attribute. For example, the following advice need not declare the "argNames" attribute:

```

@Before("com.xyz.lib.Pointcuts.anyPublicMethod()")
public void audit(JoinPoint jp) {
    // ... use jp
}

```

- Using the '`argNames`' attribute is a little clumsy, so if the '`argNames`' attribute has not been specified, then Spring AOP will look at the debug information for the class and try to determine the parameter names from the local variable table. This information will be present as long as the classes have been compiled with debug information (`'-g:vars'` at a minimum). The consequences of compiling with this flag on are: (1) your code will be slightly easier to understand (reverse engineer), (2) the class file sizes will be very slightly bigger (typically inconsequential), (3) the optimization to remove unused local variables will not be applied by your compiler. In other words, you should encounter no difficulties building with this flag on.



If an `@AspectJ` aspect has been compiled by the `AspectJ` compiler (`ajc`) even without the debug information then there is no need to add the `argNames` attribute as the compiler will retain the needed information.

- If the code has been compiled without the necessary debug information, then Spring AOP will attempt to deduce the pairing of binding variables to parameters (for example, if only one

variable is bound in the pointcut expression, and the advice method only takes one parameter, the pairing is obvious!). If the binding of variables is ambiguous given the available information, then an `AmbiguousBindingException` will be thrown.

- If all of the above strategies fail then an `IllegalArgumentException` will be thrown.

### Proceeding with arguments

We remarked earlier that we would describe how to write a proceed call *with arguments* that works consistently across Spring AOP and AspectJ. The solution is simply to ensure that the advice signature binds each of the method parameters in order. For example:

```
@Around("execution(List<Account> find*(..)) && " +
    "com.xyz.myapp.SystemArchitecture.inDataAccessLayer() && " +
    "args(accountHolderNamePattern)")
public Object preProcessQueryPattern(ProceedingJoinPoint pjp,
    String accountHolderNamePattern) throws Throwable {
    String newPattern = preprocess(accountHolderNamePattern);
    return pjp.proceed(new Object[] {newPattern});
}
```

In many cases you will be doing this binding anyway (as in the example above).

### Advice ordering

What happens when multiple pieces of advice all want to run at the same join point? Spring AOP follows the same precedence rules as AspectJ to determine the order of advice execution. The highest precedence advice runs first "on the way in" (so given two pieces of before advice, the one with highest precedence runs first). "On the way out" from a join point, the highest precedence advice runs last (so given two pieces of after advice, the one with the highest precedence will run second).

When two pieces of advice defined in *different* aspects both need to run at the same join point, unless you specify otherwise the order of execution is undefined. You can control the order of execution by specifying precedence. This is done in the normal Spring way by either implementing the `org.springframework.core.Ordered` interface in the aspect class or annotating it with the `Order` annotation. Given two aspects, the aspect returning the lower value from `Ordered.getValue()` (or the annotation value) has the higher precedence.

When two pieces of advice defined in *the same* aspect both need to run at the same join point, the ordering is undefined (since there is no way to retrieve the declaration order via reflection for javac-compiled classes). Consider collapsing such advice methods into one advice method per join point in each aspect class, or refactor the pieces of advice into separate aspect classes - which can be ordered at the aspect level.

### 5.2.5. Introductions

Introductions (known as inter-type declarations in AspectJ) enable an aspect to declare that advised objects implement a given interface, and to provide an implementation of that interface on behalf

of those objects.

An introduction is made using the `@DeclareParents` annotation. This annotation is used to declare that matching types have a new parent (hence the name). For example, given an interface `UsageTracked`, and an implementation of that interface `DefaultUsageTracked`, the following aspect declares that all implementors of service interfaces also implement the `UsageTracked` interface. (In order to expose statistics via JMX for example.)

```
@Aspect
public class UsageTracking {

    @DeclareParents(value="com.xyz.myapp.service.*+", defaultImpl=DefaultUsageTracked
.class)
    public static UsageTracked mixin;

    @Before("com.xyz.myapp.SystemArchitecture.businessService() && this(usageTracked)
")
    public void recordUsage(UsageTracked usageTracked) {
        usageTracked.incrementUseCount();
    }

}
```

The interface to be implemented is determined by the type of the annotated field. The `value` attribute of the `@DeclareParents` annotation is an AspectJ type pattern :- any bean of a matching type will implement the `UsageTracked` interface. Note that in the before advice of the above example, service beans can be directly used as implementations of the `UsageTracked` interface. If accessing a bean programmatically you would write the following:

```
UsageTracked usageTracked = (UsageTracked) context.getBean("myService");
```

## 5.2.6. Aspect instantiation models



(This is an advanced topic, so if you are just starting out with AOP you can safely skip it until later.)

By default there will be a single instance of each aspect within the application context. AspectJ calls this the singleton instantiation model. It is possible to define aspects with alternate lifecycles :- Spring supports AspectJ's `perthis` and `pertarget` instantiation models (`percflow`, `percflowbelow`, and `pertypewithin` are not currently supported).

A "perthis" aspect is declared by specifying a `perthis` clause in the `@Aspect` annotation. Let's look at an example, and then we'll explain how it works.

```

@Aspect("perthis(com.xyz.myapp.SystemArchitecture.businessService())")
public class MyAspect {

    private int someState;

    @Before(com.xyz.myapp.SystemArchitecture.businessService())
    public void recordServiceUsage() {
        // ...
    }

}

```

The effect of the '`perthis`' clause is that one aspect instance will be created for each unique service object executing a business service (each unique object bound to 'this' at join points matched by the pointcut expression). The aspect instance is created the first time that a method is invoked on the service object. The aspect goes out of scope when the service object goes out of scope. Before the aspect instance is created, none of the advice within it executes. As soon as the aspect instance has been created, the advice declared within it will execute at matched join points, but only when the service object is the one this aspect is associated with. See the AspectJ programming guide for more information on per-clauses.

The '`pertarget`' instantiation model works in exactly the same way as `perthis`, but creates one aspect instance for each unique target object at matched join points.

### 5.2.7. Example

Now that you have seen how all the constituent parts work, let's put them together to do something useful!

The execution of business services can sometimes fail due to concurrency issues (for example, deadlock loser). If the operation is retried, it is quite likely to succeed next time round. For business services where it is appropriate to retry in such conditions (idempotent operations that don't need to go back to the user for conflict resolution), we'd like to transparently retry the operation to avoid the client seeing a `PessimisticLockingFailureException`. This is a requirement that clearly cuts across multiple services in the service layer, and hence is ideal for implementing via an aspect.

Because we want to retry the operation, we will need to use around advice so that we can call proceed multiple times. Here's how the basic aspect implementation looks:

```

@Aspect
public class ConcurrentOperationExecutor implements Ordered {

    private static final int DEFAULT_MAX_RETRIES = 2;

    private int maxRetries = DEFAULT_MAX_RETRIES;
    private int order = 1;

    public void setMaxRetries(int maxRetries) {
        this.maxRetries = maxRetries;
    }

    public int getOrder() {
        return this.order;
    }

    public void setOrder(int order) {
        this.order = order;
    }

    @Around("com.xyz.myapp.SystemArchitecture.businessService()")
    public Object doConcurrentOperation(ProceedingJoinPoint pjp) throws Throwable {
        int numAttempts = 0;
        PessimisticLockingFailureException lockFailureException;
        do {
            numAttempts++;
            try {
                return pjp.proceed();
            }
            catch(PessimisticLockingFailureException ex) {
                lockFailureException = ex;
            }
        } while(numAttempts <= this.maxRetries);
        throw lockFailureException;
    }
}

```

Note that the aspect implements the `Ordered` interface so we can set the precedence of the aspect higher than the transaction advice (we want a fresh transaction each time we retry). The `maxRetries` and `order` properties will both be configured by Spring. The main action happens in the `doConcurrentOperation` around advice. Notice that for the moment we're applying the retry logic to all `businessService()`s. We try to proceed, and if we fail with an `PessimisticLockingFailureException` we simply try again unless we have exhausted all of our retry attempts.

The corresponding Spring configuration is:

```

<aop:aspectj-autoproxy>

<bean id="concurrentOperationExecutor" class=
"com.xyz.myapp.service.impl.ConcurrentOperationExecutor">
    <property name="maxRetries" value="3"/>
    <property name="order" value="100"/>
</bean>

```

To refine the aspect so that it only retries idempotent operations, we might define an `Idempotent` annotation:

```

@Retention(RetentionPolicy.RUNTIME)
public @interface Idempotent {
    // marker annotation
}

```

and use the annotation to annotate the implementation of service operations. The change to the aspect to only retry idempotent operations simply involves refining the pointcut expression so that only `@Idempotent` operations match:

```

@Around("com.xyz.myapp.SystemArchitecture.businessService() && " +
        "@annotation(com.xyz.myapp.service.Idempotent)")
public Object doConcurrentOperation(ProceedingJoinPoint pjp) throws Throwable {
    ...
}

```

## 5.3. Schema-based AOP support

If you prefer an XML-based format, then Spring also offers support for defining aspects using the new "aop" namespace tags. The exact same pointcut expressions and advice kinds are supported as when using the `@AspectJ` style, hence in this section we will focus on the new *syntax* and refer the reader to the discussion in the previous section ([{@AspectJ support}](#)) for an understanding of writing pointcut expressions and the binding of advice parameters.

To use the `aop` namespace tags described in this section, you need to import the `spring-aop` schema as described in [XML Schema-based configuration](#). See [the AOP schema](#) for how to import the tags in the `aop` namespace.

Within your Spring configurations, all aspect and advisor elements must be placed within an `<aop:config>` element (you can have more than one `<aop:config>` element in an application context configuration). An `<aop:config>` element can contain pointcut, advisor, and aspect elements (note these must be declared in that order).



The `<aop:config>` style of configuration makes heavy use of Spring's [auto-proxying](#) mechanism. This can cause issues (such as advice not being woven) if you are already using explicit auto-proxying via the use of `BeanNameAutoProxyCreator` or suchlike. The recommended usage pattern is to use either just the `<aop:config>` style, or just the `AutoProxyCreator` style.

### 5.3.1. Declaring an aspect

Using the schema support, an aspect is simply a regular Java object defined as a bean in your Spring application context. The state and behavior is captured in the fields and methods of the object, and the pointcut and advice information is captured in the XML.

An aspect is declared using the `<aop:aspect>` element, and the backing bean is referenced using the `ref` attribute:

```
<aop:config>
  <aop:aspect id="myAspect" ref="aBean">
    ...
  </aop:aspect>
</aop:config>

<bean id="aBean" class="...">
  ...
</bean>
```

The bean backing the aspect ("`aBean`" in this case) can of course be configured and dependency injected just like any other Spring bean.

### 5.3.2. Declaring a pointcut

A named pointcut can be declared inside an `<aop:config>` element, enabling the pointcut definition to be shared across several aspects and advisors.

A pointcut representing the execution of any business service in the service layer could be defined as follows:

```
<aop:config>
  <aop:pointcut id="businessService"
    expression="execution(* com.xyz.myapp.service.*.*(..))"/>
</aop:config>
```

Note that the pointcut expression itself is using the same AspectJ pointcut expression language as described in [@AspectJ support](#). If you are using the schema based declaration style, you can refer to named pointcuts defined in types (@Aspects) within the pointcut expression. Another way of defining the above pointcut would be:

```

<aop:config>

    <aop:pointcut id="businessService"
        expression="com.xyz.myapp.SystemArchitecture.businessService()"/>

</aop:config>

```

Assuming you have a `SystemArchitecture` aspect as described in [Sharing common pointcut definitions](#).

Declaring a pointcut inside an aspect is very similar to declaring a top-level pointcut:

```

<aop:config>

    <aop:aspect id="myAspect" ref="aBean">

        <aop:pointcut id="businessService"
            expression="execution(* com.xyz.myapp.service.*.*(..))"/>

        ...

    </aop:aspect>

</aop:config>

```

Much the same way in an @AspectJ aspect, pointcuts declared using the schema based definition style may collect join point context. For example, the following pointcut collects the 'this' object as the join point context and passes it to advice:

```

<aop:config>

    <aop:aspect id="myAspect" ref="aBean">

        <aop:pointcut id="businessService"
            expression="execution(* com.xyz.myapp.service.*.*(..)) && this(service)"/>

        <aop:before pointcut-ref="businessService" method="monitor"/>

        ...

    </aop:aspect>

</aop:config>

```

The advice must be declared to receive the collected join point context by including parameters of the matching names:

```
public void monitor(Object service) {  
    ...  
}
```

When combining pointcut sub-expressions, '&&&' is awkward within an XML document, and so the keywords 'and', 'or' and 'not' can be used in place of '&&&', '||' and '!' respectively. For example, the previous pointcut may be better written as:

```
<aop:config>  
  
    <aop:aspect id="myAspect" ref="aBean">  
  
        <aop:pointcut id="businessService"  
            expression="execution(* com.xyz.myapp.service.*.*(..)) **and**  
this(service)" />  
  
        <aop:before pointcut-ref="businessService" method="monitor"/>  
  
        ...  
    </aop:aspect>  
</aop:config>
```

Note that pointcuts defined in this way are referred to by their XML id and cannot be used as named pointcuts to form composite pointcuts. The named pointcut support in the schema based definition style is thus more limited than that offered by the @AspectJ style.

### 5.3.3. Declaring advice

The same five advice kinds are supported as for the @AspectJ style, and they have exactly the same semantics.

#### Before advice

Before advice runs before a matched method execution. It is declared inside an `<aop:aspect>` using the `<aop:before>` element.

```
<aop:aspect id="beforeExample" ref="aBean">  
  
    <aop:before  
        pointcut-ref="dataAccessOperation"  
        method="doAccessCheck"/>  
  
    ...  
  
</aop:aspect>
```

Here `dataAccessOperation` is the id of a pointcut defined at the top (`<aop:config>`) level. To define the

pointcut inline instead, replace the `pointcut-ref` attribute with a `pointcut` attribute:

```
<aop:aspect id="beforeExample" ref="aBean">

    <aop:before
        pointcut="execution(* com.xyz.myapp.dao.*.*(..))"
        method="doAccessCheck"/>

    ...

</aop:aspect>
```

As we noted in the discussion of the @AspectJ style, using named pointcuts can significantly improve the readability of your code.

The method attribute identifies a method (`doAccessCheck`) that provides the body of the advice. This method must be defined for the bean referenced by the aspect element containing the advice. Before a data access operation is executed (a method execution join point matched by the pointcut expression), the "doAccessCheck" method on the aspect bean will be invoked.

### After returning advice

After returning advice runs when a matched method execution completes normally. It is declared inside an `<aop:aspect>` in the same way as before advice. For example:

```
<aop:aspect id="afterReturningExample" ref="aBean">

    <aop:after-returning
        pointcut-ref="dataAccessOperation"
        method="doAccessCheck"/>

    ...

</aop:aspect>
```

Just as in the @AspectJ style, it is possible to get hold of the return value within the advice body. Use the `returning` attribute to specify the name of the parameter to which the return value should be passed:

```

<aop:aspect id="afterReturningExample" ref="aBean">

    <aop:after-returning
        pointcut-ref="dataAccessOperation"
        returning="RetVal"
        method="doAccessCheck"/>

    ...

</aop:aspect>

```

The doAccessCheck method must declare a parameter named `RetVal`. The type of this parameter constrains matching in the same way as described for @AfterReturning. For example, the method signature may be declared as:

```
public void doAccessCheck(Object retVal) { ... }
```

## After throwing advice

After throwing advice executes when a matched method execution exits by throwing an exception. It is declared inside an `<aop:aspect>` using the after-throwing element:

```

<aop:aspect id="afterThrowingExample" ref="aBean">

    <aop:after-throwing
        pointcut-ref="dataAccessOperation"
        method="doRecoveryActions"/>

    ...

</aop:aspect>

```

Just as in the @AspectJ style, it is possible to get hold of the thrown exception within the advice body. Use the `throwing` attribute to specify the name of the parameter to which the exception should be passed:

```

<aop:aspect id="afterThrowingExample" ref="aBean">

    <aop:after-throwing
        pointcut-ref="dataAccessOperation"
        throwing="dataAccessEx"
        method="doRecoveryActions"/>

    ...

</aop:aspect>

```

The doRecoveryActions method must declare a parameter named `dataAccessEx`. The type of this parameter constrains matching in the same way as described for @AfterThrowing. For example, the method signature may be declared as:

```
public void doRecoveryActions(DataAccessException dataAccessEx) {....}
```

## After (finally) advice

After (finally) advice runs however a matched method execution exits. It is declared using the `after` element:

```

<aop:aspect id="afterFinallyExample" ref="aBean">

    <aop:after
        pointcut-ref="dataAccessOperation"
        method="doReleaseLock"/>

    ...

</aop:aspect>

```

## Around advice

The final kind of advice is around advice. Around advice runs "around" a matched method execution. It has the opportunity to do work both before and after the method executes, and to determine when, how, and even if, the method actually gets to execute at all. Around advice is often used if you need to share state before and after a method execution in a thread-safe manner (starting and stopping a timer for example). Always use the least powerful form of advice that meets your requirements; don't use around advice if simple before advice would do.

Around advice is declared using the `aop:around` element. The first parameter of the advice method must be of type `ProceedingJoinPoint`. Within the body of the advice, calling `proceed()` on the `ProceedingJoinPoint` causes the underlying method to execute. The `proceed` method may also be called passing in an `Object[]` - the values in the array will be used as the arguments to the method execution when it proceeds. See [Around advice](#) for notes on calling proceed with an `Object[]`.

```

<aop:aspect id="aroundExample" ref="aBean">

    <aop:around
        pointcut-ref="businessService"
        method="doBasicProfiling"/>

    ...

</aop:aspect>

```

The implementation of the `doBasicProfiling` advice would be exactly the same as in the @AspectJ example (minus the annotation of course):

```

public Object doBasicProfiling(ProceedingJoinPoint pjp) throws Throwable {
    // start stopwatch
    Object retVal = pjp.proceed();
    // stop stopwatch
    return retVal;
}

```

## Advice parameters

The schema based declaration style supports fully typed advice in the same way as described for the @AspectJ support - by matching pointcut parameters by name against advice method parameters. See [Advice parameters](#) for details. If you wish to explicitly specify argument names for the advice methods (not relying on the detection strategies previously described) then this is done using the `arg-names` attribute of the advice element, which is treated in the same manner to the "argNames" attribute in an advice annotation as described in [Determining argument names](#). For example:

```

<aop:before
    pointcut="com.xyz.lib.Pointcuts.anyPublicMethod() and @annotation(auditable)"
    method="audit"
    arg-names="auditable"/>

```

The `arg-names` attribute accepts a comma-delimited list of parameter names.

Find below a slightly more involved example of the XSD-based approach that illustrates some around advice used in conjunction with a number of strongly typed parameters.

```

package x.y.service;

public interface FooService {

    Foo getFoo(String fooName, int age);
}

public class DefaultFooService implements FooService {

    public Foo getFoo(String name, int age) {
        return new Foo(name, age);
    }
}

```

Next up is the aspect. Notice the fact that the `profile(..)` method accepts a number of strongly-typed parameters, the first of which happens to be the join point used to proceed with the method call: the presence of this parameter is an indication that the `profile(..)` is to be used as `around` advice:

```

package x.y;

import org.aspectj.lang.ProceedingJoinPoint;
import org.springframework.util.StopWatch;

public class SimpleProfiler {

    public Object profile(ProceedingJoinPoint call, String name, int age) throws
Throwable {
    StopWatch clock = new StopWatch("Profiling for '" + name + "' and '" + age +
"']");
    try {
        clock.start(call.toShortString());
        return call.proceed();
    } finally {
        clock.stop();
        System.out.println(clock.prettyPrint());
    }
}

```

Finally, here is the XML configuration that is required to effect the execution of the above advice for a particular join point:

```

<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:aop="http://www.springframework.org/schema/aop"
       xsi:schemaLocation="
           http://www.springframework.org/schema/beans
           http://www.springframework.org/schema/beans/spring-beans.xsd
           http://www.springframework.org/schema/aop
           http://www.springframework.org/schema/aop/spring-aop.xsd">

    <!-- this is the object that will be proxied by Spring's AOP infrastructure -->
    <bean id="fooService" class="x.y.service.DefaultFooService"/>

    <!-- this is the actual advice itself -->
    <bean id="profiler" class="x.y.SimpleProfiler"/>

    <aop:config>
        <aop:aspect ref="profiler">

            <aop:pointcut id="theExecutionOfSomeFooServiceMethod"
                           expression="execution(* x.y.service.FooService.getFoo(String,int))
                           and args(name, age)"/>

            <aop:around pointcut-ref="theExecutionOfSomeFooServiceMethod"
                         method="profile"/>

        </aop:aspect>
    </aop:config>

</beans>

```

If we had the following driver script, we would get output something like this on standard output:

```

import org.springframework.beans.factory.BeanFactory;
import org.springframework.context.support.ClassPathXmlApplicationContext;
import x.y.service.FooService;

public final class Boot {

    public static void main(final String[] args) throws Exception {
        BeanFactory ctx = new ClassPathXmlApplicationContext("x/y/plain.xml");
        FooService foo = (FooService) ctx.getBean("fooService");
        foo.getFoo("Pengo", 12);
    }
}

```

```

StopWatch 'Profiling for 'Pengo' and '12''': running time (millis) = 0
-----
ms      %      Task name
-----
00000  ?  execution(getFoo)

```

## Advice ordering

When multiple advice needs to execute at the same join point (executing method) the ordering rules are as described in [Advice ordering](#). The precedence between aspects is determined by either adding the `Order` annotation to the bean backing the aspect or by having the bean implement the `Ordered` interface.

### 5.3.4. Introductions

Introductions (known as inter-type declarations in AspectJ) enable an aspect to declare that advised objects implement a given interface, and to provide an implementation of that interface on behalf of those objects.

An introduction is made using the `aop:declare-parents` element inside an `aop:aspect`. This element is used to declare that matching types have a new parent (hence the name). For example, given an interface `UsageTracked`, and an implementation of that interface `DefaultUsageTracked`, the following aspect declares that all implementors of service interfaces also implement the `UsageTracked` interface. (In order to expose statistics via JMX for example.)

```

<aop:aspect id="usageTrackerAspect" ref="usageTracking">

    <aop:declare-parents
        types-matching="com.xyz.myapp.service.*+"
        implement-interface="com.xyz.myapp.service.tracking.UsageTracked"
        default-impl="com.xyz.myapp.service.tracking.DefaultUsageTracked"/>

    <aop:before
        pointcut="com.xyz.myapp.SystemArchitecture.businessService()
            and this(usageTracked)"
        method="recordUsage"/>

</aop:aspect>

```

The class backing the `usageTracking` bean would contain the method:

```

public void recordUsage(UsageTracked usageTracked) {
    usageTracked.incrementUseCount();
}

```

The interface to be implemented is determined by `implement-interface` attribute. The value of the

`types-matching` attribute is an AspectJ type pattern :- any bean of a matching type will implement the `UsageTracked` interface. Note that in the before advice of the above example, service beans can be directly used as implementations of the `UsageTracked` interface. If accessing a bean programmatically you would write the following:

```
UsageTracked usageTracked = (UsageTracked) context.getBean("myService");
```

### 5.3.5. Aspect instantiation models

The only supported instantiation model for schema-defined aspects is the singleton model. Other instantiation models may be supported in future releases.

### 5.3.6. Advisors

The concept of "advisors" is brought forward from the AOP support defined in Spring and does not have a direct equivalent in AspectJ. An advisor is like a small self-contained aspect that has a single piece of advice. The advice itself is represented by a bean, and must implement one of the advice interfaces described in [Advice types in Spring](#). Advisors can take advantage of AspectJ pointcut expressions though.

Spring supports the advisor concept with the `<aop:advisor>` element. You will most commonly see it used in conjunction with transactional advice, which also has its own namespace support in Spring. Here's how it looks:

```
<aop:config>

    <aop:pointcut id="businessService"
        expression="execution(* com.xyz.myapp.service.*.*(..))"/>

    <aop:advisor
        pointcut-ref="businessService"
        advice-ref="tx-advice"/>

</aop:config>

<tx:advice id="tx-advice">
    <tx:attributes>
        <tx:method name="*" propagation="REQUIRED"/>
    </tx:attributes>
</tx:advice>
```

As well as the `pointcut-ref` attribute used in the above example, you can also use the `pointcut` attribute to define a pointcut expression inline.

To define the precedence of an advisor so that the advice can participate in ordering, use the `order` attribute to define the `Ordered` value of the advisor.

### 5.3.7. Example

Let's see how the concurrent locking failure retry example from [Example](#) looks when rewritten using the schema support.

The execution of business services can sometimes fail due to concurrency issues (for example, deadlock loser). If the operation is retried, it is quite likely it will succeed next time round. For business services where it is appropriate to retry in such conditions (idempotent operations that don't need to go back to the user for conflict resolution), we'd like to transparently retry the operation to avoid the client seeing a [PessimisticLockingFailureException](#). This is a requirement that clearly cuts across multiple services in the service layer, and hence is ideal for implementing via an aspect.

Because we want to retry the operation, we'll need to use around advice so that we can call proceed multiple times. Here's how the basic aspect implementation looks (it's just a regular Java class using the schema support):

```

public class ConcurrentOperationExecutor implements Ordered {

    private static final int DEFAULT_MAX_RETRIES = 2;

    private int maxRetries = DEFAULT_MAX_RETRIES;
    private int order = 1;

    public void setMaxRetries(int maxRetries) {
        this.maxRetries = maxRetries;
    }

    public int getOrder() {
        return this.order;
    }

    public void setOrder(int order) {
        this.order = order;
    }

    public Object doConcurrentOperation(ProceedingJoinPoint pjp) throws Throwable {
        int numAttempts = 0;
        PessimisticLockingFailureException lockFailureException;
        do {
            numAttempts++;
            try {
                return pjp.proceed();
            }
            catch(PessimisticLockingFailureException ex) {
                lockFailureException = ex;
            }
        } while(numAttempts <= this.maxRetries);
        throw lockFailureException;
    }
}

```

Note that the aspect implements the `Ordered` interface so we can set the precedence of the aspect higher than the transaction advice (we want a fresh transaction each time we retry). The `maxRetries` and `order` properties will both be configured by Spring. The main action happens in the `doConcurrentOperation` around advice method. We try to proceed, and if we fail with a `PessimisticLockingFailureException` we simply try again unless we have exhausted all of our retry attempts.



This class is identical to the one used in the @AspectJ example, but with the annotations removed.

The corresponding Spring configuration is:

```

<aop:config>

    <aop:aspect id="concurrentOperationRetry" ref="concurrentOperationExecutor">

        <aop:pointcut id="idempotentOperation"
            expression="execution(* com.xyz.myapp.service.*.*(..))"/>

        <aop:around
            pointcut-ref="idempotentOperation"
            method="doConcurrentOperation"/>

    </aop:aspect>

</aop:config>

<bean id="concurrentOperationExecutor"
    class="com.xyz.myapp.service.impl.ConcurrentOperationExecutor">
    <property name="maxRetries" value="3"/>
    <property name="order" value="100"/>
</bean>

```

Notice that for the time being we assume that all business services are idempotent. If this is not the case we can refine the aspect so that it only retries genuinely idempotent operations, by introducing an **Idempotent** annotation:

```

@Retention(RetentionPolicy.RUNTIME)
public @interface Idempotent {
    // marker annotation
}

```

and using the annotation to annotate the implementation of service operations. The change to the aspect to retry only idempotent operations simply involves refining the pointcut expression so that only **@Idempotent** operations match:

```

<aop:pointcut id="idempotentOperation"
    expression="execution(* com.xyz.myapp.service.*.*(..)) and
    @annotation(com.xyz.myapp.service.Idempotent)"/>

```

## 5.4. Choosing which AOP declaration style to use

Once you have decided that an aspect is the best approach for implementing a given requirement, how do you decide between using Spring AOP or AspectJ, and between the Aspect language (code) style, `@AspectJ` annotation style, or the Spring XML style? These decisions are influenced by a number of factors including application requirements, development tools, and team familiarity with AOP.

### 5.4.1. Spring AOP or full AspectJ?

Use the simplest thing that can work. Spring AOP is simpler than using full AspectJ as there is no requirement to introduce the AspectJ compiler / weaver into your development and build processes. If you only need to advise the execution of operations on Spring beans, then Spring AOP is the right choice. If you need to advise objects not managed by the Spring container (such as domain objects typically), then you will need to use AspectJ. You will also need to use AspectJ if you wish to advise join points other than simple method executions (for example, field get or set join points, and so on).

When using AspectJ, you have the choice of the AspectJ language syntax (also known as the "code style") or the @AspectJ annotation style. Clearly, if you are not using Java 5+ then the choice has been made for you... use the code style. If aspects play a large role in your design, and you are able to use the [AspectJ Development Tools \(AJDT\)](#) plugin for Eclipse, then the AspectJ language syntax is the preferred option: it is cleaner and simpler because the language was purposefully designed for writing aspects. If you are not using Eclipse, or have only a few aspects that do not play a major role in your application, then you may want to consider using the @AspectJ style and sticking with a regular Java compilation in your IDE, and adding an aspect weaving phase to your build script.

### 5.4.2. @AspectJ or XML for Spring AOP?

If you have chosen to use Spring AOP, then you have a choice of @AspectJ or XML style. There are various tradeoffs to consider.

The XML style will be most familiar to existing Spring users and it is backed by genuine POJOs. When using AOP as a tool to configure enterprise services then XML can be a good choice (a good test is whether you consider the pointcut expression to be a part of your configuration you might want to change independently). With the XML style arguably it is clearer from your configuration what aspects are present in the system.

The XML style has two disadvantages. Firstly it does not fully encapsulate the implementation of the requirement it addresses in a single place. The DRY principle says that there should be a single, unambiguous, authoritative representation of any piece of knowledge within a system. When using the XML style, the knowledge of *how* a requirement is implemented is split across the declaration of the backing bean class, and the XML in the configuration file. When using the @AspectJ style there is a single module - the aspect - in which this information is encapsulated. Secondly, the XML style is slightly more limited in what it can express than the @AspectJ style: only the "singleton" aspect instantiation model is supported, and it is not possible to combine named pointcuts declared in XML. For example, in the @AspectJ style you can write something like:

```
@Pointcut(execution(* get*()))
public void propertyAccess() {}

@Pointcut(execution(org.xyz.Account+ *(..)))
public void operationReturningAnAccount() {}

@Pointcut(propertyAccess() && operationReturningAnAccount())
public void accountPropertyAccess() {}
```

In the XML style I can declare the first two pointcuts:

```
<aop:pointcut id="propertyAccess"
    expression="execution(* get*())"/>

<aop:pointcut id="operationReturningAnAccount"
    expression="execution(org.xyz.Account+ *(..))"/>
```

The downside of the XML approach is that you cannot define the `accountPropertyAccess` pointcut by combining these definitions.

The `@AspectJ` style supports additional instantiation models, and richer pointcut composition. It has the advantage of keeping the aspect as a modular unit. It also has the advantage the `@AspectJ` aspects can be understood (and thus consumed) both by Spring AOP and by AspectJ - so if you later decide you need the capabilities of AspectJ to implement additional requirements then it is very easy to migrate to an AspectJ-based approach. On balance the Spring team prefer the `@AspectJ` style whenever you have aspects that do more than simple "configuration" of enterprise services.

## 5.5. Mixing aspect types

It is perfectly possible to mix `@AspectJ` style aspects using the autoproxying support, schema-defined `<aop:aspect>` aspects, `<aop:advisor>` declared advisors and even proxies and interceptors defined using the Spring 1.2 style in the same configuration. All of these are implemented using the same underlying support mechanism and will co-exist without any difficulty.

## 5.6. Proxying mechanisms

Spring AOP uses either JDK dynamic proxies or CGLIB to create the proxy for a given target object. (JDK dynamic proxies are preferred whenever you have a choice).

If the target object to be proxied implements at least one interface then a JDK dynamic proxy will be used. All of the interfaces implemented by the target type will be proxied. If the target object does not implement any interfaces then a CGLIB proxy will be created.

If you want to force the use of CGLIB proxying (for example, to proxy every method defined for the target object, not just those implemented by its interfaces) you can do so. However, there are some issues to consider:

- `final` methods cannot be advised, as they cannot be overridden.
- As of Spring 3.2, it is no longer necessary to add CGLIB to your project classpath, as CGLIB classes are repackaged under `org.springframework` and included directly in the `spring-core` JAR. This means that CGLIB-based proxy support 'just works' in the same way that JDK dynamic proxies always have.
- As of Spring 4.0, the constructor of your proxied object will NOT be called twice anymore since the CGLIB proxy instance will be created via Objenesis. Only if your JVM does not allow for constructor bypassing, you might see double invocations and corresponding debug log entries from Spring's AOP support.

To force the use of CGLIB proxies set the value of the `proxy-target-class` attribute of the `<aop:config>` element to true:

```
<aop:config proxy-target-class="true">
    <!-- other beans defined here... -->
</aop:config>
```

To force CGLIB proxying when using the @AspectJ autoproxy support, set the '`proxy-target-class`' attribute of the `<aop:aspectj-autoproxy>` element to `true`:

```
<aop:aspectj-autoproxy proxy-target-class="true"/>
```

Multiple `<aop:config>` sections are collapsed into a single unified auto-proxy creator at runtime, which applies the *strongest* proxy settings that any of the `<aop:config>` sections (typically from different XML bean definition files) specified. This also applies to the `<tx:annotation-driven/>` and `<aop:aspectj-autoproxy/>` elements.



To be clear: using `proxy-target-class="true"` on `<tx:annotation-driven/>`, `<aop:aspectj-autoproxy/>` or `<aop:config/>` elements will force the use of CGLIB proxies *for all three of them*.

### 5.6.1. Understanding AOP proxies

Spring AOP is *proxy-based*. It is vitally important that you grasp the semantics of what that last statement actually means before you write your own aspects or use any of the Spring AOP-based aspects supplied with the Spring Framework.

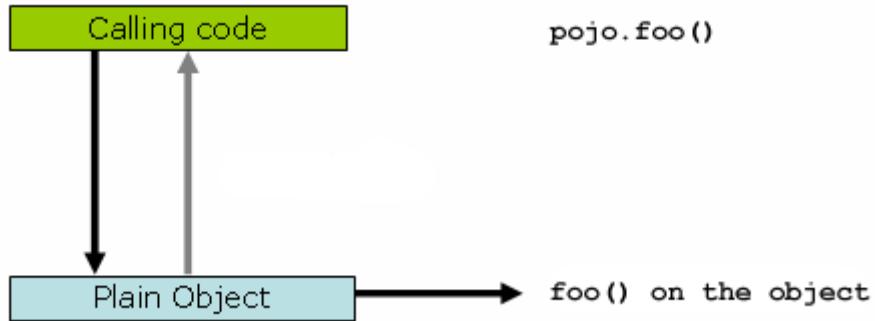
Consider first the scenario where you have a plain-vanilla, unproxied, nothing-special-about-it, straight object reference, as illustrated by the following code snippet.

```
public class SimplePojo implements Pojo {

    public void foo() {
        // this next method invocation is a direct call on the 'this' reference
        this.bar();
    }

    public void bar() {
        // some logic...
    }
}
```

If you invoke a method on an object reference, the method is invoked *directly* on that object reference, as can be seen below.



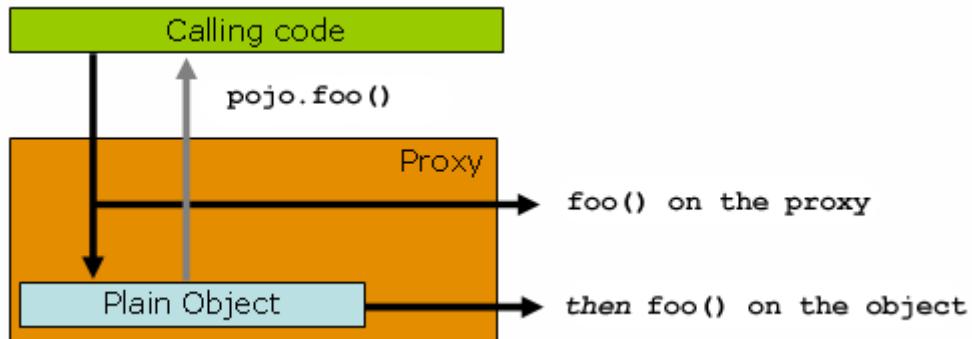
```
public class Main {

    public static void main(String[] args) {

        Pojo pojo = new SimplePojo();

        // this is a direct method call on the 'pojo' reference
        pojo.foo();
    }
}
```

Things change slightly when the reference that client code has is a proxy. Consider the following diagram and code snippet.



```

public class Main {

    public static void main(String[] args) {

        ProxyFactory factory = new ProxyFactory(new SimplePojo());
        factory.addInterface(Pojo.class);
        factory.addAdvice(new RetryAdvice());

        Pojo pojo = (Pojo) factory.getProxy();

        // this is a method call on the proxy!
        pojo.foo();
    }
}

```

The key thing to understand here is that the client code inside the `main(..)` of the `Main` class *has a reference to the proxy*. This means that method calls on that object reference will be calls on the proxy, and as such the proxy will be able to delegate to all of the interceptors (advice) that are relevant to that particular method call. However, once the call has finally reached the target object, the `SimplePojo` reference in this case, any method calls that it may make on itself, such as `this.bar()` or `this.foo()`, are going to be invoked against the `this` reference, and *not* the proxy. This has important implications. It means that self-invocation is *not* going to result in the advice associated with a method invocation getting a chance to execute.

Okay, so what is to be done about this? The best approach (the term best is used loosely here) is to refactor your code such that the self-invocation does not happen. For sure, this does entail some work on your part, but it is the best, least-invasive approach. The next approach is absolutely horrendous, and I am almost reticent to point it out precisely because it is so horrendous. You can (choke!) totally tie the logic within your class to Spring AOP by doing this:

```

public class SimplePojo implements Pojo {

    public void foo() {
        // this works, but... gah!
        ((Pojo) AopContext.currentProxy()).bar();
    }

    public void bar() {
        // some logic...
    }
}

```

This totally couples your code to Spring AOP, *and* it makes the class itself aware of the fact that it is being used in an AOP context, which flies in the face of AOP. It also requires some additional configuration when the proxy is being created:

```

public class Main {

    public static void main(String[] args) {

        ProxyFactory factory = new ProxyFactory(new SimplePojo());
        factory.addInterface(Pojo.class);
        factory.addAdvice(new RetryAdvice());
        factory.setExposeProxy(true);

        Pojo pojo = (Pojo) factory.getProxy();

        // this is a method call on the proxy!
        pojo.foo();
    }
}

```

Finally, it must be noted that AspectJ does not have this self-invocation issue because it is not a proxy-based AOP framework.

## 5.7. Programmatic creation of @AspectJ Proxies

In addition to declaring aspects in your configuration using either `<aop:config>` or `<aop:aspectj-autoproxy>`, it is also possible programmatically to create proxies that advise target objects. For the full details of Spring's AOP API, see the next chapter. Here we want to focus on the ability to automatically create proxies using @AspectJ aspects.

The class `org.springframework.aop.aspectj.annotation.AspectJProxyFactory` can be used to create a proxy for a target object that is advised by one or more @AspectJ aspects. Basic usage for this class is very simple, as illustrated below. See the javadocs for full information.

```

// create a factory that can generate a proxy for the given target object
AspectJProxyFactory factory = new AspectJProxyFactory(targetObject);

// add an aspect, the class must be an @AspectJ aspect
// you can call this as many times as you need with different aspects
factory.addAspect(SecurityManager.class);

// you can also add existing aspect instances, the type of the object supplied must be
// an @AspectJ aspect
factory.addAspect(usageTracker);

// now get the proxy object...
MyInterfaceType proxy = factory.getProxy();

```

## 5.8. Using AspectJ with Spring applications

Everything we've covered so far in this chapter is pure Spring AOP. In this section, we're going to

look at how you can use the AspectJ compiler/weaver instead of, or in addition to, Spring AOP if your needs go beyond the facilities offered by Spring AOP alone.

Spring ships with a small AspectJ aspect library, which is available standalone in your distribution as `spring-aspects.jar`; you'll need to add this to your classpath in order to use the aspects in it. [Using AspectJ to dependency inject domain objects with Spring](#) and [Other Spring aspects for AspectJ](#) discuss the content of this library and how you can use it. [Configuring AspectJ aspects using Spring IoC](#) discusses how to dependency inject AspectJ aspects that are woven using the AspectJ compiler. Finally, [Load-time weaving with AspectJ in the Spring Framework](#) provides an introduction to load-time weaving for Spring applications using AspectJ.

### 5.8.1. Using AspectJ to dependency inject domain objects with Spring

The Spring container instantiates and configures beans defined in your application context. It is also possible to ask a bean factory to configure a *pre-existing* object given the name of a bean definition containing the configuration to be applied. The `spring-aspects.jar` contains an annotation-driven aspect that exploits this capability to allow dependency injection of *any object*. The support is intended to be used for objects created *outside of the control of any container*. Domain objects often fall into this category because they are often created programmatically using the `new` operator, or by an ORM tool as a result of a database query.

The `@Configurable` annotation marks a class as eligible for Spring-driven configuration. In the simplest case it can be used just as a marker annotation:

```
package com.xyz.myapp.domain;

import org.springframework.beans.factory.annotation.Configurable;

@Configuration
public class Account {
    // ...
}
```

When used as a marker interface in this way, Spring will configure new instances of the annotated type (`Account` in this case) using a bean definition (typically prototype-scoped) with the same name as the fully-qualified type name (`com.xyz.myapp.domain.Account`). Since the default name for a bean is the fully-qualified name of its type, a convenient way to declare the prototype definition is simply to omit the `id` attribute:

```
<bean class="com.xyz.myapp.domain.Account" scope="prototype">
    <property name="fundsTransferService" ref="fundsTransferService"/>
</bean>
```

If you want to explicitly specify the name of the prototype bean definition to use, you can do so directly in the annotation:

```

package com.xyz.myapp.domain;

import org.springframework.beans.factory.annotation.Configurable;

@Configurable("account")
public class Account {
    // ...
}

```

Spring will now look for a bean definition named "account" and use that as the definition to configure new `Account` instances.

You can also use autowiring to avoid having to specify a dedicated bean definition at all. To have Spring apply autowiring use the `autowire` property of the `@Configurable` annotation: specify either `@Configurable(autowire=Autowire.BY_TYPE)` or `@Configurable(autowire=Autowire.BY_NAME)` for autowiring by type or by name respectively. As an alternative, as of Spring 2.5 it is preferable to specify explicit, annotation-driven dependency injection for your `@Configurable` beans by using `@Autowired` or `@Inject` at the field or method level (see [Annotation-based container configuration](#) for further details).

Finally you can enable Spring dependency checking for the object references in the newly created and configured object by using the `dependencyCheck` attribute (for example: `@Configurable(autowire=Autowire.BY_NAME, dependencyCheck=true)`). If this attribute is set to true, then Spring will validate after configuration that all properties (*which are not primitives or collections*) have been set.

Using the annotation on its own does nothing of course. It is the `AnnotationBeanConfigurerAspect` in `spring-aspects.jar` that acts on the presence of the annotation. In essence the aspect says "after returning from the initialization of a new object of a type annotated with `@Configurable`, configure the newly created object using Spring in accordance with the properties of the annotation". In this context, *initialization* refers to newly instantiated objects (e.g., objects instantiated with the `new` operator) as well as to `Serializable` objects that are undergoing deserialization (e.g., via `readResolve()`).

One of the key phrases in the above paragraph is '*in essence*'. For most cases, the exact semantics of '*after returning from the initialization of a new object*' will be fine... in this context, '*after initialization*' means that the dependencies will be injected *after* the object has been constructed - this means that the dependencies will not be available for use in the constructor bodies of the class. If you want the dependencies to be injected *before* the constructor bodies execute, and thus be available for use in the body of the constructors, then you need to define this on the `@Configurable` declaration like so:

```
@Configurable(preConstruction=true)
```

You can find out more information about the language semantics of the various pointcut types in AspectJ [in this appendix](#) of the [AspectJ Programming Guide](#).

For this to work the annotated types must be woven with the AspectJ weaver - you can either use a build-time Ant or Maven task to do this (see for example the [AspectJ Development Environment Guide](#)) or load-time weaving (see [Load-time weaving with AspectJ in the Spring Framework](#)). The `AnnotationBeanConfigurerAspect` itself needs configuring by Spring (in order to obtain a reference to the bean factory that is to be used to configure new objects). If you are using Java based configuration simply add `@EnableSpringConfigured` to any `@Configuration` class.

```
@Configuration  
@EnableSpringConfigured  
public class AppConfig {  
  
}
```

If you prefer XML based configuration, the Spring `context namespace` defines a convenient `context:spring-configured` element:

```
<context:spring-configured/>
```

Instances of `@Configurable` objects created *before* the aspect has been configured will result in a message being issued to the debug log and no configuration of the object taking place. An example might be a bean in the Spring configuration that creates domain objects when it is initialized by Spring. In this case you can use the "depends-on" bean attribute to manually specify that the bean depends on the configuration aspect.

```

<bean id="myService"
      class="com.xzy.myapp.service.MyService"
      depends-on=
"org.springframework.beans.factory.aspectj.AnnotationBeanConfigurerAspect">

    <!-- ... -->

</bean>

```



Do not activate `@Configurable` processing through the bean configurer aspect unless you really mean to rely on its semantics at runtime. In particular, make sure that you do not use `@Configurable` on bean classes which are registered as regular Spring beans with the container: You would get double initialization otherwise, once through the container and once through the aspect.

## Unit testing `@Configurable` objects

One of the goals of the `@Configurable` support is to enable independent unit testing of domain objects without the difficulties associated with hard-coded lookups. If `@Configurable` types have not been woven by AspectJ then the annotation has no affect during unit testing, and you can simply set mock or stub property references in the object under test and proceed as normal. If `@Configurable` types *have* been woven by AspectJ then you can still unit test outside of the container as normal, but you will see a warning message each time that you construct an `@Configurable` object indicating that it has not been configured by Spring.

## Working with multiple application contexts

The `AnnotationBeanConfigurerAspect` used to implement the `@Configurable` support is an AspectJ singleton aspect. The scope of a singleton aspect is the same as the scope of `static` members, that is to say there is one aspect instance per classloader that defines the type. This means that if you define multiple application contexts within the same classloader hierarchy you need to consider where to define the `@EnableSpringConfigured` bean and where to place `spring-aspects.jar` on the classpath.

Consider a typical Spring web-app configuration with a shared parent application context defining common business services and everything needed to support them, and one child application context per servlet containing definitions particular to that servlet. All of these contexts will co-exist within the same classloader hierarchy, and so the `AnnotationBeanConfigurerAspect` can only hold a reference to one of them. In this case we recommend defining the `@EnableSpringConfigured` bean in the shared (parent) application context: this defines the services that you are likely to want to inject into domain objects. A consequence is that you cannot configure domain objects with references to beans defined in the child (servlet-specific) contexts using the `@Configurable` mechanism (probably not something you want to do anyway!).

When deploying multiple web-apps within the same container, ensure that each web-application loads the types in `spring-aspects.jar` using its own classloader (for example, by placing `spring-aspects.jar` in '`WEB-INF/lib`'). If `spring-aspects.jar` is only added to the container wide classpath (and hence loaded by the shared parent classloader), all web applications will share the same

aspect instance which is probably not what you want.

### 5.8.2. Other Spring aspects for AspectJ

In addition to the `@Configurable` aspect, `spring-aspects.jar` contains an AspectJ aspect that can be used to drive Spring's transaction management for types and methods annotated with the `@Transactional` annotation. This is primarily intended for users who want to use the Spring Framework's transaction support outside of the Spring container.

The aspect that interprets `@Transactional` annotations is the `AnnotationTransactionAspect`. When using this aspect, you must annotate the *implementation* class (and/or methods within that class), *not* the interface (if any) that the class implements. AspectJ follows Java's rule that annotations on interfaces are *not inherited*.

A `@Transactional` annotation on a class specifies the default transaction semantics for the execution of any *public* operation in the class.

A `@Transactional` annotation on a method within the class overrides the default transaction semantics given by the class annotation (if present). Methods of any visibility may be annotated, including private methods. Annotating non-public methods directly is the only way to get transaction demarcation for the execution of such methods.



Since Spring Framework 4.2, `spring-aspects` provides a similar aspect that offers the exact same features for the standard `javax.transaction.Transactional` annotation. Check `JtaAnnotationTransactionAspect` for more details.

For AspectJ programmers that want to use the Spring configuration and transaction management support but don't want to (or cannot) use annotations, `spring-aspects.jar` also contains `abstract` aspects you can extend to provide your own pointcut definitions. See the sources for the `AbstractBeanConfigurerAspect` and `AbstractTransactionAspect` aspects for more information. As an example, the following excerpt shows how you could write an aspect to configure all instances of objects defined in the domain model using prototype bean definitions that match the fully-qualified class names:

```
public aspect DomainObjectConfiguration extends AbstractBeanConfigurerAspect {

    public DomainObjectConfiguration() {
        setBeanWiringInfoResolver(new ClassNameBeanWiringInfoResolver());
    }

    // the creation of a new bean (any object in the domain model)
    protected pointcut beanCreation(Object beanInstance) :
        initialization(new(..)) &&
        SystemArchitecture.inDomainModel() &&
        this(beanInstance);

}
```

### 5.8.3. Configuring AspectJ aspects using Spring IoC

When using AspectJ aspects with Spring applications, it is natural to both want and expect to be able to configure such aspects using Spring. The AspectJ runtime itself is responsible for aspect creation, and the means of configuring the AspectJ created aspects via Spring depends on the AspectJ instantiation model (the `per-xxx` clause) used by the aspect.

The majority of AspectJ aspects are *singleton* aspects. Configuration of these aspects is very easy: simply create a bean definition referencing the aspect type as normal, and include the bean attribute `'factory-method="aspectOf"'`. This ensures that Spring obtains the aspect instance by asking AspectJ for it rather than trying to create an instance itself. For example:

```
<bean id="profiler" class="com.xyz.profiler.Profiler"
    <strong>factory-method="aspectOf"</strong>>

    <property name="profilingStrategy" ref="jamonProfilingStrategy"/>
</bean>
```

Non-singleton aspects are harder to configure: however it is possible to do so by creating prototype bean definitions and using the `@Configurable` support from `spring-aspects.jar` to configure the aspect instances once they have been created by the AspectJ runtime.

If you have some `@AspectJ` aspects that you want to weave with AspectJ (for example, using load-time weaving for domain model types) and other `@AspectJ` aspects that you want to use with Spring AOP, and these aspects are all configured using Spring, then you will need to tell the Spring AOP `@AspectJ` autoproxying support which exact subset of the `@AspectJ` aspects defined in the configuration should be used for autoproxying. You can do this by using one or more `<include>` elements inside the `<aop:aspectj-autoproxy>` declaration. Each `<include>` element specifies a name pattern, and only beans with names matched by at least one of the patterns will be used for Spring AOP autoproxy configuration:

```
<aop:aspectj-autoproxy>
    <aop:include name="thisBean"/>
    <aop:include name="thatBean"/>
</aop:aspectj-autoproxy>
```

 Do not be misled by the name of the `<aop:aspectj-autoproxy>` element: using it will result in the creation of *Spring AOP proxies*. The `@AspectJ` style of aspect declaration is just being used here, but the AspectJ runtime is *not* involved.

### 5.8.4. Load-time weaving with AspectJ in the Spring Framework

Load-time weaving (LTW) refers to the process of weaving AspectJ aspects into an application's class files as they are being loaded into the Java virtual machine (JVM). The focus of this section is on configuring and using LTW in the specific context of the Spring Framework: this section is not an introduction to LTW though. For full details on the specifics of LTW and configuring LTW with just AspectJ (with Spring not being involved at all), see the [LTW section of the AspectJ Development](#)

## Environment Guide.

The value-add that the Spring Framework brings to AspectJ LTW is in enabling much finer-grained control over the weaving process. 'Vanilla' AspectJ LTW is effected using a Java (5+) agent, which is switched on by specifying a VM argument when starting up a JVM. It is thus a JVM-wide setting, which may be fine in some situations, but often is a little too coarse. Spring-enabled LTW enables you to switch on LTW on a *per-ClassLoader* basis, which obviously is more fine-grained and which can make more sense in a 'single-JVM-multiple-application' environment (such as is found in a typical application server environment).

Further, [in certain environments](#), this support enables load-time weaving *without making any modifications to the application server's launch script* that will be needed to add `-javaagent:path/to/aspectjweaver.jar` or (as we describe later in this section) `-javaagent:path/to/org.springframework.instrument-{version}.jar` (previously named `spring-agent.jar`). Developers simply modify one or more files that form the application context to enable load-time weaving instead of relying on administrators who typically are in charge of the deployment configuration such as the launch script.

Now that the sales pitch is over, let us first walk through a quick example of AspectJ LTW using Spring, followed by detailed specifics about elements introduced in the following example. For a complete example, please see the [Petclinic sample application](#).

### A first example

Let us assume that you are an application developer who has been tasked with diagnosing the cause of some performance problems in a system. Rather than break out a profiling tool, what we are going to do is switch on a simple profiling aspect that will enable us to very quickly get some performance metrics, so that we can then apply a finer-grained profiling tool to that specific area immediately afterwards.



The example presented here uses XML style configuration, it is also possible to configure and use `@AspectJ` with [Java Configuration](#). Specifically the `@EnableLoadTimeWeaving` annotation can be used as an alternative to `<context:load-time-weaver/>` (see [below](#) for details).

Here is the profiling aspect. Nothing too fancy, just a quick-and-dirty time-based profiler, using the `@AspectJ`-style of aspect declaration.

```

package foo;

import org.aspectj.lang.ProceedingJoinPoint;
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Around;
import org.aspectj.lang.annotation.Pointcut;
import org.springframework.util.StopWatch;
import org.springframework.core.annotation.Order;

@Aspect
public class ProfilingAspect {

    @Around("methodsToBeProfiled()")
    public Object profile(ProceedingJoinPoint pjp) throws Throwable {
        StopWatch sw = new StopWatch(getClass().getSimpleName());
        try {
            sw.start(pjp.getSignature().getName());
            return pjp.proceed();
        } finally {
            sw.stop();
            System.out.println(sw.prettyPrint());
        }
    }

    @Pointcut("execution(public * foo..*.*(..))")
    public void methodsToBeProfiled(){}
}

```

We will also need to create an `META-INF/aop.xml` file, to inform the AspectJ weaver that we want to weave our `ProfilingAspect` into our classes. This file convention, namely the presence of a file (or files) on the Java classpath called `META-INF/aop.xml` is standard AspectJ.

```

<!DOCTYPE aspectj PUBLIC "-//AspectJ//DTD//EN"
"http://www.eclipse.org/aspectj/dtd/aspectj.dtd">
<aspectj>

    <weaver>
        <!-- only weave classes in our application-specific packages -->
        <include within="foo.*"/>
    </weaver>

    <aspects>
        <!-- weave in just this aspect -->
        <aspect name="foo.ProfilingAspect"/>
    </aspects>

</aspectj>

```

Now to the Spring-specific portion of the configuration. We need to configure a `LoadTimeWeaver` (all explained later, just take it on trust for now). This load-time weaver is the essential component responsible for weaving the aspect configuration in one or more `META-INF/aop.xml` files into the classes in your application. The good thing is that it does not require a lot of configuration, as can be seen below (there are some more options that you can specify, but these are detailed later).

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:context="http://www.springframework.org/schema/context"
       xsi:schemaLocation="
           http://www.springframework.org/schema/beans
           http://www.springframework.org/schema/beans/spring-beans.xsd
           http://www.springframework.org/schema/context
           http://www.springframework.org/schema/context/spring-context.xsd">

    <!-- a service object; we will be profiling its methods -->
    <bean id="entitlementCalculationService"
          class="foo.StubEntitlementCalculationService"/>

    <!-- this switches on the load-time weaving -->
    <strong><context:load-time-weaver/></strong>
</beans>
```

Now that all the required artifacts are in place - the aspect, the `META-INF/aop.xml` file, and the Spring configuration -, let us create a simple driver class with a `main(..)` method to demonstrate the LTW in action.

```
package foo;

import org.springframework.context.support.ClassPathXmlApplicationContext;

public final class Main {

    public static void main(String[] args) {

        ApplicationContext ctx = new ClassPathXmlApplicationContext("beans.xml", Main.class);

        EntitlementCalculationService entitlementCalculationService
            = (EntitlementCalculationService) ctx.getBean(
                "entitlementCalculationService");

        // the profiling aspect is 'woven' around this method execution
        entitlementCalculationService.calculateEntitlement();
    }
}
```

There is one last thing to do. The introduction to this section did say that one could switch on LTW selectively on a per- `ClassLoader` basis with Spring, and this is true. However, just for this example, we are going to use a Java agent (supplied with Spring) to switch on the LTW. This is the command line we will use to run the above `Main` class:

```
java -javaagent:C:/projects/foo/lib/global/spring-instrument.jar foo.Main
```

The `-javaagent` is a flag for specifying and enabling [agents to instrument programs running on the JVM](#). The Spring Framework ships with such an agent, the `InstrumentationSavingAgent`, which is packaged in the `spring-instrument.jar` that was supplied as the value of the `-javaagent` argument in the above example.

The output from the execution of the `Main` program will look something like that below. (I have introduced a `Thread.sleep(..)` statement into the `calculateEntitlement()` implementation so that the profiler actually captures something other than 0 milliseconds - the `01234` milliseconds is *not* an overhead introduced by the AOP :))

Calculating entitlement

```
StopWatch 'ProfilingAspect': running time (millis) = 1234
-----
ms      %      Task name
-----
01234  100%  calculateEntitlement
```

Since this LTW is effected using full-blown AspectJ, we are not just limited to advising Spring beans; the following slight variation on the `Main` program will yield the same result.

```
package foo;

import org.springframework.context.support.ClassPathXmlApplicationContext;

public final class Main {

    public static void main(String[] args) {

        new ClassPathXmlApplicationContext("beans.xml", Main.class);

        EntitlementCalculationService entitlementCalculationService =
            new StubEntitlementCalculationService();

        // the profiling aspect will be 'woven' around this method execution
        entitlementCalculationService.calculateEntitlement();
    }
}
```

Notice how in the above program we are simply bootstrapping the Spring container, and then

creating a new instance of the `StubEntitlementCalculationService` totally outside the context of Spring... the profiling advice still gets woven in.

The example admittedly is simplistic... however the basics of the LTW support in Spring have all been introduced in the above example, and the rest of this section will explain the 'why' behind each bit of configuration and usage in detail.



The `ProfilingAspect` used in this example may be basic, but it is quite useful. It is a nice example of a development-time aspect that developers can use during development (of course), and then quite easily exclude from builds of the application being deployed into UAT or production.

## Aspects

The aspects that you use in LTW have to be AspectJ aspects. They can be written in either the AspectJ language itself or you can write your aspects in the @AspectJ-style. It means that your aspects are then both valid AspectJ *and* Spring AOP aspects. Furthermore, the compiled aspect classes need to be available on the classpath.

### 'META-INF/aop.xml'

The AspectJ LTW infrastructure is configured using one or more `META-INF/aop.xml` files, that are on the Java classpath (either directly, or more typically in jar files).

The structure and contents of this file is detailed in the main AspectJ reference documentation, and the interested reader is [referred to that resource](#). (I appreciate that this section is brief, but the `aop.xml` file is 100% AspectJ - there is no Spring-specific information or semantics that apply to it, and so there is no extra value that I can contribute either as a result), so rather than rehash the quite satisfactory section that the AspectJ developers wrote, I am just directing you there.)

## Required libraries (JARS)

At a minimum you will need the following libraries to use the Spring Framework's support for AspectJ LTW:

- `spring-aop.jar` (version 2.5 or later, plus all mandatory dependencies)
- `aspectjweaver.jar` (version 1.6.8 or later)

If you are using the [Spring-provided agent to enable instrumentation](#), you will also need:

- `spring-instrument.jar`

## Spring configuration

The key component in Spring's LTW support is the `LoadTimeWeaver` interface (in the `org.springframework.instrument.classloading` package), and the numerous implementations of it that ship with the Spring distribution. A `LoadTimeWeaver` is responsible for adding one or more `java.lang.instrument.ClassFileTransformers` to a `ClassLoader` at runtime, which opens the door to all manner of interesting applications, one of which happens to be the LTW of aspects.



If you are unfamiliar with the idea of runtime class file transformation, you are encouraged to read the javadoc API documentation for the `java.lang.instrument` package before continuing. This is not a huge chore because there is - rather annoyingly - precious little documentation there... the key interfaces and classes will at least be laid out in front of you for reference as you read through this section.

Configuring a `LoadTimeWeaver` for a particular `ApplicationContext` can be as easy as adding one line. (Please note that you almost certainly will need to be using an `ApplicationContext` as your Spring container - typically a `BeanFactory` will not be enough because the LTW support makes use of `BeanFactoryPostProcessors`.)

To enable the Spring Framework's LTW support, you need to configure a `LoadTimeWeaver`, which typically is done using the `@EnableLoadTimeWeaving` annotation.

```
@Configuration  
@EnableLoadTimeWeaving  
public class AppConfig {  
}
```

Alternatively, if you prefer XML based configuration, use the `<context:load-time-weaver/>` element. Note that the element is defined in the `context` namespace.

```
<?xml version="1.0" encoding="UTF-8"?>  
<beans xmlns="http://www.springframework.org/schema/beans"  
       xmlns: xsi="http://www.w3.org/2001/XMLSchema-instance"  
       xmlns: context="http://www.springframework.org/schema/context"  
       xsi:schemaLocation="  
           http://www.springframework.org/schema/beans  
           http://www.springframework.org/schema/beans/spring-beans.xsd  
           http://www.springframework.org/schema/context  
           http://www.springframework.org/schema/context/spring-context.xsd">  
  
    <context:load-time-weaver/>  
  
</beans>
```

The above configuration will define and register a number of LTW-specific infrastructure beans for you automatically, such as a `LoadTimeWeaver` and an `AspectJWeavingEnabler`. The default `LoadTimeWeaver` is the `DefaultContextLoadTimeWeaver` class, which attempts to decorate an automatically detected `LoadTimeWeaver`: the exact type of `LoadTimeWeaver` that will be 'automatically detected' is dependent upon your runtime environment (summarized in the following table).

*Table 13. DefaultContextLoadTimeWeaver LoadTimeWeavers*

Runtime Environment	LoadTimeWeaver implementation
Running in Oracle's <a href="#">WebLogic</a>	<a href="#">WebLogicLoadTimeWeaver</a>
Running in Oracle's <a href="#">GlassFish</a>	<a href="#">GlassFishLoadTimeWeaver</a>
Running in <a href="#">Apache Tomcat</a>	<a href="#">TomcatLoadTimeWeaver</a>
Running in Red Hat's <a href="#">JBoss AS</a> or <a href="#">WildFly</a>	<a href="#">JBossLoadTimeWeaver</a>
Running in IBM's <a href="#">WebSphere</a>	<a href="#">WebSphereLoadTimeWeaver</a>
JVM started with Spring <a href="#">InstrumentationSavingAgent</a> ( <i>java -javaagent:path/to/spring-instrument.jar</i> )	<a href="#">InstrumentationLoadTimeWeaver</a>
Fallback, expecting the underlying ClassLoader to follow common conventions (e.g. applicable to <a href="#">TomcatInstrumentableClassLoader</a> and <a href="#">Resin</a> )	<a href="#">ReflectiveLoadTimeWeaver</a>

Note that these are just the [LoadTimeWeavers](#) that are autodetected when using the [DefaultContextLoadTimeWeaver](#): it is of course possible to specify exactly which [LoadTimeWeaver](#) implementation that you wish to use.

To specify a specific [LoadTimeWeaver](#) with Java configuration implement the [LoadTimeWeavingConfigurer](#) interface and override the [getLoadTimeWeaver\(\)](#) method:

```
@Configuration
@EnableLoadTimeWeaving
public class AppConfig implements LoadTimeWeavingConfigurer {

    @Override
    public LoadTimeWeaver getLoadTimeWeaver() {
        return new ReflectiveLoadTimeWeaver();
    }
}
```

If you are using XML based configuration you can specify the fully-qualified classname as the value of the [weaver-class](#) attribute on the [`<context:load-time-weaver/>`](#) element:

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:load-time-weaver
        weaver-class=
    "org.springframework.instrument.classloading.ReflectiveLoadTimeWeaver"/>

</beans>

```

The `LoadTimeWeaver` that is defined and registered by the configuration can be later retrieved from the Spring container using the well-known name `loadTimeWeaver`. Remember that the `LoadTimeWeaver` exists just as a mechanism for Spring's LTW infrastructure to add one or more `ClassFileTransformers`. The actual `ClassFileTransformer` that does the LTW is the `ClassPreProcessorAgentAdapter` (from the `org.aspectj.weaver.loadtime` package) class. See the class-level javadocs of the `ClassPreProcessorAgentAdapter` class for further details, because the specifics of how the weaving is actually effected is beyond the scope of this section.

There is one final attribute of the configuration left to discuss: the `aspectjWeaving` attribute (or `aspectj-weaving` if you are using XML). This is a simple attribute that controls whether LTW is enabled or not; it is as simple as that. It accepts one of three possible values, summarized below, with the default value being `autodetect` if the attribute is not present.

*Table 14. AspectJ weaving attribute values*

Annotation Value	XML Value	Explanation
ENABLED	on	AspectJ weaving is on, and aspects will be woven at load-time as appropriate.
DISABLED	off	LTW is off... no aspect will be woven at load-time.
AUTODETECT	autodetect	If the Spring LTW infrastructure can find at least one <code>META-INF/aop.xml</code> file, then AspectJ weaving is on, else it is off. This is the default value.

## Environment-specific configuration

This last section contains any additional settings and configuration that you will need when using Spring's LTW support in environments such as application servers and web containers.

## Tomcat

Historically, [Apache Tomcat](#)'s default class loader did not support class transformation which is why Spring provides an enhanced implementation that addresses this need. Named [TomcatInstrumentableClassLoader](#), the loader works on Tomcat 6.0 and above.



Do not define [TomcatInstrumentableClassLoader](#) anymore on Tomcat 8.0 and higher. Instead, let Spring automatically use Tomcat's new native [InstrumentableClassLoader](#) facility through the [TomcatLoadTimeWeaver](#) strategy.

If you still need to use [TomcatInstrumentableClassLoader](#), it can be registered individually for *each* web application as follows:

- Copy `org.springframework.instrument.tomcat.jar` into `$CATALINA_HOME/lib`, where `$CATALINA_HOME` represents the root of the Tomcat installation)
- Instruct Tomcat to use the custom class loader (instead of the default) by editing the web application context file:

```
<Context path="/myWebApp" docBase="/my/webApp/location">
    <Loader
        loaderClass=
"org.springframework.instrument.classloading.tomcat.TomcatInstrumentableClassLoader"/>
</Context>
```

Apache Tomcat (6.0+) supports several context locations:

- server configuration file - `$CATALINA_HOME/conf/server.xml`
- default context configuration - `$CATALINA_HOME/conf/context.xml` - that affects all deployed web applications
- per-web application configuration which can be deployed either on the server-side at `$CATALINA_HOME/conf/[enginename]/[hostname]/[webapp]-context.xml` or embedded inside the web-app archive at `META-INF/context.xml`

For efficiency, the embedded per-web-app configuration style is recommended because it will impact only applications that use the custom class loader and does not require any changes to the server configuration. See the [Tomcat 6.0.x documentation](#) for more details about available context locations.

Alternatively, consider the use of the Spring-provided generic VM agent, to be specified in Tomcat's launch script (see above). This will make instrumentation available to all deployed web applications, no matter what ClassLoader they happen to run on.

## WebLogic, WebSphere, Resin, GlassFish, JBoss

Recent versions of WebLogic Server (version 10 and above), IBM WebSphere Application Server (version 7 and above), Resin (3.1 and above) and JBoss (6.x or above) provide a ClassLoader that is capable of local instrumentation. Spring's native LTW leverages such ClassLoaders to enable AspectJ weaving. You can enable LTW by simply activating load-time weaving as described earlier.

Specifically, you do *not* need to modify the launch script to add `-javaagent:path/to/spring-instrument.jar`.

Note that GlassFish instrumentation-capable ClassLoader is available only in its EAR environment. For GlassFish web applications, follow the Tomcat setup instructions as outlined above.

Note that on JBoss 6.x, the app server scanning needs to be disabled to prevent it from loading the classes before the application actually starts. A quick workaround is to add to your artifact a file named `WEB-INF/jboss-scanning.xml` with the following content:

```
<scanning xmlns="urn:jboss:scanning:1.0"/>
```

### Generic Java applications

When class instrumentation is required in environments that do not support or are not supported by the existing `LoadTimeWeaver` implementations, a JDK agent can be the only solution. For such cases, Spring provides `InstrumentationLoadTimeWeaver`, which requires a Spring-specific (but very general) VM agent, `org.springframework.instrument-{version}.jar` (previously named `spring-agent.jar`).

To use it, you must start the virtual machine with the Spring agent, by supplying the following JVM options:

```
-javaagent:/path/to/org.springframework.instrument-{version}.jar
```

Note that this requires modification of the VM launch script which may prevent you from using this in application server environments (depending on your operation policies). Additionally, the JDK agent will instrument the *entire* VM which can prove expensive.

For performance reasons, it is recommended to use this configuration only if your target environment (such as `Jetty`) does not have (or does not support) a dedicated LTW.

## 5.9. Further Resources

More information on AspectJ can be found on the [AspectJ website](#).

The book *Eclipse AspectJ* by Adrian Colyer et. al. (Addison-Wesley, 2005) provides a comprehensive introduction and reference for the AspectJ language.

The book *AspectJ in Action, Second Edition* by Ramnivas Laddad (Manning, 2009) comes highly recommended; the focus of the book is on AspectJ, but a lot of general AOP themes are explored (in some depth).

# Chapter 6. Spring AOP APIs

## 6.1. Introduction

The previous chapter described the Spring's support for AOP using `@AspectJ` and schema-based aspect definitions. In this chapter we discuss the lower-level Spring AOP APIs and the AOP support typically used in Spring 1.2 applications. For new applications, we recommend the use of the Spring 2.0 and later AOP support described in the previous chapter, but when working with existing applications, or when reading books and articles, you may come across Spring 1.2 style examples. Spring 5 remains backwards compatible with Spring 1.2 and everything described in this chapter is fully supported in Spring 5.

## 6.2. Pointcut API in Spring

Let's look at how Spring handles the crucial pointcut concept.

### 6.2.1. Concepts

Spring's pointcut model enables pointcut reuse independent of advice types. It's possible to target different advice using the same pointcut.

The `org.springframework.aop.Pointcut` interface is the central interface, used to target advices to particular classes and methods. The complete interface is shown below:

```
public interface Pointcut {  
    ClassFilter getClassFilter();  
  
    MethodMatcher getMethodMatcher();  
}
```

Splitting the `Pointcut` interface into two parts allows reuse of class and method matching parts, and fine-grained composition operations (such as performing a "union" with another method matcher).

The `ClassFilter` interface is used to restrict the pointcut to a given set of target classes. If the `matches()` method always returns true, all target classes will be matched:

```
public interface ClassFilter {  
    boolean matches(Class clazz);  
}
```

The `MethodMatcher` interface is normally more important. The complete interface is shown below:

```

public interface MethodMatcher {

    boolean matches(Method m, Class targetClass);

    boolean isRuntime();

    boolean matches(Method m, Class targetClass, Object[] args);
}

```

The `matches(Method, Class)` method is used to test whether this pointcut will ever match a given method on a target class. This evaluation can be performed when an AOP proxy is created, to avoid the need for a test on every method invocation. If the 2-argument `matches` method returns true for a given method, and the `isRuntime()` method for the `MethodMatcher` returns true, the 3-argument `matches` method will be invoked on every method invocation. This enables a pointcut to look at the arguments passed to the method invocation immediately before the target advice is to execute.

Most `MethodMatchers` are static, meaning that their `isRuntime()` method returns false. In this case, the 3-argument `matches` method will never be invoked.



If possible, try to make pointcuts static, allowing the AOP framework to cache the results of pointcut evaluation when an AOP proxy is created.

### 6.2.2. Operations on pointcuts

Spring supports operations on pointcuts: notably, *union* and *intersection*.

- Union means the methods that either pointcut matches.
- Intersection means the methods that both pointcuts match.
- Union is usually more useful.
- Pointcuts can be composed using the static methods in the `org.springframework.aop.support.Pointcuts` class, or using the `ComposablePointcut` class in the same package. However, using AspectJ pointcut expressions is usually a simpler approach.

### 6.2.3. AspectJ expression pointcuts

Since 2.0, the most important type of pointcut used by Spring is `org.springframework.aop.aspectj.AspectJExpressionPointcut`. This is a pointcut that uses an AspectJ supplied library to parse an AspectJ pointcut expression string.

See the previous chapter for a discussion of supported AspectJ pointcut primitives.

### 6.2.4. Convenience pointcut implementations

Spring provides several convenient pointcut implementations. Some can be used out of the box; others are intended to be subclassed in application-specific pointcuts.

## Static pointcuts

Static pointcuts are based on method and target class, and cannot take into account the method's arguments. Static pointcuts are sufficient - *and best* - for most usages. It's possible for Spring to evaluate a static pointcut only once, when a method is first invoked: after that, there is no need to evaluate the pointcut again with each method invocation.

Let's consider some static pointcut implementations included with Spring.

### Regular expression pointcuts

One obvious way to specify static pointcuts is regular expressions. Several AOP frameworks besides Spring make this possible. `org.springframework.aop.support.JdkRegexpMethodPointcut` is a generic regular expression pointcut, using the regular expression support in the JDK.

Using the `JdkRegexpMethodPointcut` class, you can provide a list of pattern Strings. If any of these is a match, the pointcut will evaluate to true. (So the result is effectively the union of these pointcuts.)

The usage is shown below:

```
<bean id="settersAndAbsquatulatePointcut"
      class="org.springframework.aop.support.JdkRegexpMethodPointcut">
    <property name="patterns">
      <list>
        <value>.*set.*</value>
        <value>.*absquatulate</value>
      </list>
    </property>
</bean>
```

Spring provides a convenience class, `RegexpMethodPointcutAdvisor`, that allows us to also reference an Advice (remember that an Advice can be an interceptor, before advice, throws advice etc.). Behind the scenes, Spring will use a `JdkRegexpMethodPointcut`. Using `RegexpMethodPointcutAdvisor` simplifies wiring, as the one bean encapsulates both pointcut and advice, as shown below:

```
<bean id="settersAndAbsquatulateAdvisor"
      class="org.springframework.aop.support.RegexpMethodPointcutAdvisor">
    <property name="advice">
      <ref bean="beanNameOfAopAllianceInterceptor"/>
    </property>
    <property name="patterns">
      <list>
        <value>.*set.*</value>
        <value>.*absquatulate</value>
      </list>
    </property>
</bean>
```

`RegexpMethodPointcutAdvisor` can be used with any Advice type.

## Attribute-driven pointcuts

An important type of static pointcut is a *metadata-driven* pointcut. This uses the values of metadata attributes: typically, source-level metadata.

## Dynamic pointcuts

Dynamic pointcuts are costlier to evaluate than static pointcuts. They take into account method *arguments*, as well as static information. This means that they must be evaluated with every method invocation; the result cannot be cached, as arguments will vary.

The main example is the `control flow` pointcut.

### Control flow pointcuts

Spring control flow pointcuts are conceptually similar to AspectJ `cflow` pointcuts, although less powerful. (There is currently no way to specify that a pointcut executes below a join point matched by another pointcut.) A control flow pointcut matches the current call stack. For example, it might fire if the join point was invoked by a method in the `com.mycompany.web` package, or by the `SomeCaller` class. Control flow pointcuts are specified using the `org.springframework.aop.support.ControlFlowPointcut` class.



Control flow pointcuts are significantly more expensive to evaluate at runtime than even other dynamic pointcuts. In Java 1.4, the cost is about 5 times that of other dynamic pointcuts.

### 6.2.5. Pointcut superclasses

Spring provides useful pointcut superclasses to help you to implement your own pointcuts.

Because static pointcuts are most useful, you'll probably subclass `StaticMethodMatcherPointcut`, as shown below. This requires implementing just one abstract method (although it's possible to override other methods to customize behavior):

```
class TestStaticPointcut extends StaticMethodMatcherPointcut {  
  
    public boolean matches(Method m, Class targetClass) {  
        // return true if custom criteria match  
    }  
}
```

There are also superclasses for dynamic pointcuts.

You can use custom pointcuts with any advice type in Spring 1.0 RC2 and above.

### 6.2.6. Custom pointcuts

Because pointcuts in Spring AOP are Java classes, rather than language features (as in AspectJ) it's possible to declare custom pointcuts, whether static or dynamic. Custom pointcuts in Spring can be

arbitrarily complex. However, using the AspectJ pointcut expression language is recommended if possible.



Later versions of Spring may offer support for "semantic pointcuts" as offered by JAC: for example, "all methods that change instance variables in the target object."

## 6.3. Advice API in Spring

Let's now look at how Spring AOP handles advice.

### 6.3.1. Advice lifecycles

Each advice is a Spring bean. An advice instance can be shared across all advised objects, or unique to each advised object. This corresponds to *per-class* or *per-instance* advice.

Per-class advice is used most often. It is appropriate for generic advice such as transaction advisors. These do not depend on the state of the proxied object or add new state; they merely act on the method and arguments.

Per-instance advice is appropriate for introductions, to support mixins. In this case, the advice adds state to the proxied object.

It's possible to use a mix of shared and per-instance advice in the same AOP proxy.

### 6.3.2. Advice types in Spring

Spring provides several advice types out of the box, and is extensible to support arbitrary advice types. Let us look at the basic concepts and standard advice types.

#### Interception around advice

The most fundamental advice type in Spring is *interception around advice*.

Spring is compliant with the AOP Alliance interface for around advice using method interception. MethodInterceptors implementing around advice should implement the following interface:

```
public interface MethodInterceptor extends Interceptor {  
    Object invoke(MethodInvocation invocation) throws Throwable;  
}
```

The `MethodInvocation` argument to the `invoke()` method exposes the method being invoked; the target join point; the AOP proxy; and the arguments to the method. The `invoke()` method should return the invocation's result: the return value of the join point.

A simple `MethodInterceptor` implementation looks as follows:

```

public class DebugInterceptor implements MethodInterceptor {

    public Object invoke(MethodInvocation invocation) throws Throwable {
        System.out.println("Before: invocation=[" + invocation + "]");
        Object rval = invocation.proceed();
        System.out.println("Invocation returned");
        return rval;
    }
}

```

Note the call to the MethodInvocation's `proceed()` method. This proceeds down the interceptor chain towards the join point. Most interceptors will invoke this method, and return its return value. However, a MethodInterceptor, like any around advice, can return a different value or throw an exception rather than invoke the proceed method. However, you don't want to do this without good reason!



MethodInterceptors offer interoperability with other AOP Alliance-compliant AOP implementations. The other advice types discussed in the remainder of this section implement common AOP concepts, but in a Spring-specific way. While there is an advantage in using the most specific advice type, stick with MethodInterceptor around advice if you are likely to want to run the aspect in another AOP framework. Note that pointcuts are not currently interoperable between frameworks, and the AOP Alliance does not currently define pointcut interfaces.

## Before advice

A simpler advice type is a *before advice*. This does not need a `MethodInvocation` object, since it will only be called before entering the method.

The main advantage of a before advice is that there is no need to invoke the `proceed()` method, and therefore no possibility of inadvertently failing to proceed down the interceptor chain.

The `MethodBeforeAdvice` interface is shown below. (Spring's API design would allow for field before advice, although the usual objects apply to field interception and it's unlikely that Spring will ever implement it).

```

public interface MethodBeforeAdvice extends BeforeAdvice {

    void before(Method m, Object[] args, Object target) throws Throwable;
}

```

Note the return type is `void`. Before advice can insert custom behavior before the join point executes, but cannot change the return value. If a before advice throws an exception, this will abort further execution of the interceptor chain. The exception will propagate back up the interceptor chain. If it is unchecked, or on the signature of the invoked method, it will be passed directly to the client; otherwise it will be wrapped in an unchecked exception by the AOP proxy.

An example of a before advice in Spring, which counts all method invocations:

```
public class CountingBeforeAdvice implements MethodBeforeAdvice {  
  
    private int count;  
  
    public void before(Method m, Object[] args, Object target) throws Throwable {  
        ++count;  
    }  
  
    public int getCount() {  
        return count;  
    }  
}
```



Before advice can be used with any pointcut.

## Throws advice

*Throws advice* is invoked after the return of the join point if the join point threw an exception. Spring offers typed throws advice. Note that this means that the `org.springframework.aop.ThrowsAdvice` interface does not contain any methods: It is a tag interface identifying that the given object implements one or more typed throws advice methods. These should be in the form of:

```
afterThrowing([Method, args, target], subclassOfThrowable)
```

Only the last argument is required. The method signatures may have either one or four arguments, depending on whether the advice method is interested in the method and arguments. The following classes are examples of throws advice.

The advice below is invoked if a `RemoteException` is thrown (including subclasses):

```
public class RemoteThrowsAdvice implements ThrowsAdvice {  
  
    public void afterThrowing(RemoteException ex) throws Throwable {  
        // Do something with remote exception  
    }  
}
```

The following advice is invoked if a `ServletException` is thrown. Unlike the above advice, it declares 4 arguments, so that it has access to the invoked method, method arguments and target object:

```

public class ServletThrowsAdviceWithArguments implements ThrowsAdvice {

    public void afterThrowing(Method m, Object[] args, Object target, ServletException ex) {
        // Do something with all arguments
    }
}

```

The final example illustrates how these two methods could be used in a single class, which handles both `RemoteException` and `ServletException`. Any number of throws advice methods can be combined in a single class.

```

public static class CombinedThrowsAdvice implements ThrowsAdvice {

    public void afterThrowing(RemoteException ex) throws Throwable {
        // Do something with remote exception
    }

    public void afterThrowing(Method m, Object[] args, Object target, ServletException ex) {
        // Do something with all arguments
    }
}

```

If a throws-advice method throws an exception itself, it will override the original exception (i.e. change the exception thrown to the user). The overriding exception will typically be a `RuntimeException`; this is compatible with any method signature. However, if a throws-advice method throws a checked exception, it will have to match the declared exceptions of the target method and is hence to some degree coupled to specific target method signatures. *Do not throw an undeclared checked exception that is incompatible with the target method's signature!*



Throws advice can be used with any pointcut.

## After Returning advice

An after returning advice in Spring must implement the `org.springframework.aop.AfterReturningAdvice` interface, shown below:

```

public interface AfterReturningAdvice extends Advice {

    void afterReturning(Object returnValue, Method m, Object[] args, Object target)
        throws Throwable;
}

```

An after returning advice has access to the return value (which it cannot modify), invoked method,

methods arguments and target.

The following after returning advice counts all successful method invocations that have not thrown exceptions:

```
public class CountingAfterReturningAdvice implements AfterReturningAdvice {  
  
    private int count;  
  
    public void afterReturning(Object returnValue, Method m, Object[] args, Object  
target)  
        throws Throwable {  
        ++count;  
    }  
  
    public int getCount() {  
        return count;  
    }  
}
```

This advice doesn't change the execution path. If it throws an exception, this will be thrown up the interceptor chain instead of the return value.



After returning advice can be used with any pointcut.

## Introduction advice

Spring treats introduction advice as a special kind of interception advice.

Introduction requires an [IntroductionAdvisor](#), and an [IntroductionInterceptor](#), implementing the following interface:

```
public interface IntroductionInterceptor extends MethodInterceptor {  
  
    boolean implementsInterface(Class intf);  
}
```

The [invoke\(\)](#) method inherited from the AOP Alliance [MethodInterceptor](#) interface must implement the introduction: that is, if the invoked method is on an introduced interface, the introduction interceptor is responsible for handling the method call - it cannot invoke [proceed\(\)](#).

Introduction advice cannot be used with any pointcut, as it applies only at class, rather than method, level. You can only use introduction advice with the [IntroductionAdvisor](#), which has the following methods:

```

public interface IntroductionAdvisor extends Advisor, IntroductionInfo {

    ClassFilter getClassFilter();

    void validateInterfaces() throws IllegalArgumentException;
}

public interface IntroductionInfo {
    Class[] getInterfaces();
}

```

There is no `MethodMatcher`, and hence no `Pointcut`, associated with introduction advice. Only class filtering is logical.

The `getInterfaces()` method returns the interfaces introduced by this advisor.

The `validateInterfaces()` method is used internally to see whether or not the introduced interfaces can be implemented by the configured `IntroductionInterceptor`.

Let's look at a simple example from the Spring test suite. Let's suppose we want to introduce the following interface to one or more objects:

```

public interface Lockable {
    void lock();
    void unlock();
    boolean locked();
}

```

This illustrates a *mixin*. We want to be able to cast advised objects to `Lockable`, whatever their type, and call `lock` and `unlock` methods. If we call the `lock()` method, we want all setter methods to throw a `LockedException`. Thus we can add an aspect that provides the ability to make objects immutable, without them having any knowledge of it: a good example of AOP.

Firstly, we'll need an `IntroductionInterceptor` that does the heavy lifting. In this case, we extend the `org.springframework.aop.support.DelegatingIntroductionInterceptor` convenience class. We could implement `IntroductionInterceptor` directly, but using `DelegatingIntroductionInterceptor` is best for most cases.

The `DelegatingIntroductionInterceptor` is designed to delegate an introduction to an actual implementation of the introduced interface(s), concealing the use of interception to do so. The delegate can be set to any object using a constructor argument; the default delegate (when the no-arg constructor is used) is this. Thus in the example below, the delegate is the `LockMixin` subclass of `DelegatingIntroductionInterceptor`. Given a delegate (by default itself), a `DelegatingIntroductionInterceptor` instance looks for all interfaces implemented by the delegate (other than `IntroductionInterceptor`), and will support introductions against any of them. It's possible for subclasses such as `LockMixin` to call the `suppressInterface(Class intf)` method to suppress interfaces that should not be exposed. However, no matter how many interfaces an

`IntroductionInterceptor` is prepared to support, the `IntroductionAdvisor` used will control which interfaces are actually exposed. An introduced interface will conceal any implementation of the same interface by the target.

Thus `LockMixin` extends `DelegatingIntroductionInterceptor` and implements `Lockable` itself. The superclass automatically picks up that `Lockable` can be supported for introduction, so we don't need to specify that. We could introduce any number of interfaces in this way.

Note the use of the `locked` instance variable. This effectively adds additional state to that held in the target object.

```
public class LockMixin extends DelegatingIntroductionInterceptor implements Lockable {

    private boolean locked;

    public void lock() {
        this.locked = true;
    }

    public void unlock() {
        this.locked = false;
    }

    public boolean locked() {
        return this.locked;
    }

    public Object invoke(MethodInvocation invocation) throws Throwable {
        if (locked() && invocation.getMethod().getName().indexOf("set") == 0) {
            throw new LockedException();
        }
        return super.invoke(invocation);
    }
}
```

Often it isn't necessary to override the `invoke()` method: the `DelegatingIntroductionInterceptor` implementation - which calls the delegate method if the method is introduced, otherwise proceeds towards the join point - is usually sufficient. In the present case, we need to add a check: no setter method can be invoked if in locked mode.

The introduction advisor required is simple. All it needs to do is hold a distinct `LockMixin` instance, and specify the introduced interfaces - in this case, just `Lockable`. A more complex example might take a reference to the introduction interceptor (which would be defined as a prototype): in this case, there's no configuration relevant for a `LockMixin`, so we simply create it using `new`.

```

public class LockMixinAdvisor extends DefaultIntroductionAdvisor {

    public LockMixinAdvisor() {
        super(new LockMixin(), Lockable.class);
    }
}

```

We can apply this advisor very simply: it requires no configuration. (However, it is necessary: It's impossible to use an `IntroductionInterceptor` without an `IntroductionAdvisor`.) As usual with introductions, the advisor must be per-instance, as it is stateful. We need a different instance of `LockMixinAdvisor`, and hence `LockMixin`, for each advised object. The advisor comprises part of the advised object's state.

We can apply this advisor programmatically, using the `Advised.addAdvisor()` method, or (the recommended way) in XML configuration, like any other advisor. All proxy creation choices discussed below, including "auto proxy creators," correctly handle introductions and stateful mixins.

## 6.4. Advisor API in Spring

In Spring, an Advisor is an aspect that contains just a single advice object associated with a pointcut expression.

Apart from the special case of introductions, any advisor can be used with any advice. `org.springframework.aop.support.DefaultPointcutAdvisor` is the most commonly used advisor class. For example, it can be used with a `MethodInterceptor`, `BeforeAdvice` or `ThrowsAdvice`.

It is possible to mix advisor and advice types in Spring in the same AOP proxy. For example, you could use a interception around advice, throws advice and before advice in one proxy configuration: Spring will automatically create the necessary interceptor chain.

## 6.5. Using the ProxyFactoryBean to create AOP proxies

If you're using the Spring IoC container (an `ApplicationContext` or `BeanFactory`) for your business objects - and you should be! - you will want to use one of Spring's AOP FactoryBeans. (Remember that a factory bean introduces a layer of indirection, enabling it to create objects of a different type.)



The Spring AOP support also uses factory beans under the covers.

The basic way to create an AOP proxy in Spring is to use the `org.springframework.aop.framework.ProxyFactoryBean`. This gives complete control over the pointcuts and advice that will apply, and their ordering. However, there are simpler options that are preferable if you don't need such control.

### 6.5.1. Basics

The `ProxyFactoryBean`, like other Spring `FactoryBean` implementations, introduces a level of indirection. If you define a `ProxyFactoryBean` with name `foo`, what objects referencing `foo` see is not the `ProxyFactoryBean` instance itself, but an object created by the `ProxyFactoryBean`'s implementation of the `getObject()` method. This method will create an AOP proxy wrapping a target object.

One of the most important benefits of using a `ProxyFactoryBean` or another IoC-aware class to create AOP proxies, is that it means that advices and pointcuts can also be managed by IoC. This is a powerful feature, enabling certain approaches that are hard to achieve with other AOP frameworks. For example, an advice may itself reference application objects (besides the target, which should be available in any AOP framework), benefiting from all the pluggability provided by Dependency Injection.

### 6.5.2. JavaBean properties

In common with most `FactoryBean` implementations provided with Spring, the `ProxyFactoryBean` class is itself a JavaBean. Its properties are used to:

- Specify the target you want to proxy.
- Specify whether to use CGLIB (see below and also [JDK- and CGLIB-based proxies](#)).

Some key properties are inherited from `org.springframework.aop.framework.ProxyConfig` (the superclass for all AOP proxy factories in Spring). These key properties include:

- `proxyTargetClass`: `true` if the target class is to be proxied, rather than the target class' interfaces. If this property value is set to `true`, then CGLIB proxies will be created (but see also [JDK- and CGLIB-based proxies](#)).
- `optimize`: controls whether or not aggressive optimizations are applied to proxies *created via CGLIB*. One should not blithely use this setting unless one fully understands how the relevant AOP proxy handles optimization. This is currently used only for CGLIB proxies; it has no effect with JDK dynamic proxies.
- `frozen`: if a proxy configuration is `frozen`, then changes to the configuration are no longer allowed. This is useful both as a slight optimization and for those cases when you don't want callers to be able to manipulate the proxy (via the `Advised` interface) after the proxy has been created. The default value of this property is `false`, so changes such as adding additional advice are allowed.
- `exposeProxy`: determines whether or not the current proxy should be exposed in a `ThreadLocal` so that it can be accessed by the target. If a target needs to obtain the proxy and the `exposeProxy` property is set to `true`, the target can use the `AopContext.currentProxy()` method.

Other properties specific to `ProxyFactoryBean` include:

- `proxyInterfaces`: array of String interface names. If this isn't supplied, a CGLIB proxy for the target class will be used (but see also [JDK- and CGLIB-based proxies](#)).
- `interceptorNames`: String array of `Advisor`, interceptor or other advice names to apply. Ordering is significant, on a first come-first served basis. That is to say that the first interceptor in the list

will be the first to be able to intercept the invocation.

The names are bean names in the current factory, including bean names from ancestor factories. You can't mention bean references here since doing so would result in the `ProxyFactoryBean` ignoring the singleton setting of the advice.

You can append an interceptor name with an asterisk (\*). This will result in the application of all advisor beans with names starting with the part before the asterisk to be applied. An example of using this feature can be found in [Using 'global' advisors](#).

- singleton: whether or not the factory should return a single object, no matter how often the `getObject()` method is called. Several `FactoryBean` implementations offer such a method. The default value is `true`. If you want to use stateful advice - for example, for stateful mixins - use prototype advices along with a singleton value of `false`.

### 6.5.3. JDK- and CGLIB-based proxies

This section serves as the definitive documentation on how the `ProxyFactoryBean` chooses to create one of either a JDK- and CGLIB-based proxy for a particular target object (that is to be proxied).



The behavior of the `ProxyFactoryBean` with regard to creating JDK- or CGLIB-based proxies changed between versions 1.2.x and 2.0 of Spring. The `ProxyFactoryBean` now exhibits similar semantics with regard to auto-detecting interfaces as those of the `TransactionProxyFactoryBean` class.

If the class of a target object that is to be proxied (hereafter simply referred to as the target class) doesn't implement any interfaces, then a CGLIB-based proxy will be created. This is the easiest scenario, because JDK proxies are interface based, and no interfaces means JDK proxying isn't even possible. One simply plugs in the target bean, and specifies the list of interceptors via the `interceptorNames` property. Note that a CGLIB-based proxy will be created even if the `proxyTargetClass` property of the `ProxyFactoryBean` has been set to `false`. (Obviously this makes no sense, and is best removed from the bean definition because it is at best redundant, and at worst confusing.)

If the target class implements one (or more) interfaces, then the type of proxy that is created depends on the configuration of the `ProxyFactoryBean`.

If the `proxyTargetClass` property of the `ProxyFactoryBean` has been set to `true`, then a CGLIB-based proxy will be created. This makes sense, and is in keeping with the principle of least surprise. Even if the `proxyInterfaces` property of the `ProxyFactoryBean` has been set to one or more fully qualified interface names, the fact that the `proxyTargetClass` property is set to `true` will cause CGLIB-based proxying to be in effect.

If the `proxyInterfaces` property of the `ProxyFactoryBean` has been set to one or more fully qualified interface names, then a JDK-based proxy will be created. The created proxy will implement all of the interfaces that were specified in the `proxyInterfaces` property; if the target class happens to implement a whole lot more interfaces than those specified in the `proxyInterfaces` property, that is all well and good but those additional interfaces will not be implemented by the returned proxy.

If the `proxyInterfaces` property of the `ProxyFactoryBean` has *not* been set, but the target class *does implement one (or more)* interfaces, then the `ProxyFactoryBean` will auto-detect the fact that the target class does actually implement at least one interface, and a JDK-based proxy will be created. The interfaces that are actually proxied will be *all* of the interfaces that the target class implements; in effect, this is the same as simply supplying a list of each and every interface that the target class implements to the `proxyInterfaces` property. However, it is significantly less work, and less prone to typos.

### 6.5.4. Proxying interfaces

Let's look at a simple example of `ProxyFactoryBean` in action. This example involves:

- A *target bean* that will be proxied. This is the "personTarget" bean definition in the example below.
- An Advisor and an Interceptor used to provide advice.
- An AOP proxy bean definition specifying the target object (the personTarget bean) and the interfaces to proxy, along with the advices to apply.

```
<bean id="personTarget" class="com.mycompany.PersonImpl">
    <property name="name" value="Tony"/>
    <property name="age" value="51"/>
</bean>

<bean id="myAdvisor" class="com.mycompany.MyAdvisor">
    <property name="someProperty" value="Custom string property value"/>
</bean>

<bean id="debugInterceptor" class=
"org.springframework.aop.interceptor.DebugInterceptor">
</bean>

<bean id="person"
    class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="proxyInterfaces" value="com.mycompany.Person"/>

    <property name="target" ref="personTarget"/>
    <property name="interceptorNames">
        <list>
            <value>myAdvisor</value>
            <value>debugInterceptor</value>
        </list>
    </property>
</bean>
```

Note that the `interceptorNames` property takes a list of String: the bean names of the interceptor or advisors in the current factory. Advisors, interceptors, before, after returning and throws advice objects can be used. The ordering of advisors is significant.

 You might be wondering why the list doesn't hold bean references. The reason for this is that if the `ProxyFactoryBean`'s `singleton` property is set to false, it must be able to return independent proxy instances. If any of the advisors is itself a prototype, an independent instance would need to be returned, so it's necessary to be able to obtain an instance of the prototype from the factory; holding a reference isn't sufficient.

The "person" bean definition above can be used in place of a Person implementation, as follows:

```
Person person = (Person) factory.getBean("person");
```

Other beans in the same IoC context can express a strongly typed dependency on it, as with an ordinary Java object:

```
<bean id="personUser" class="com.mycompany.PersonUser">
    <property name="person"><ref bean="person"/></property>
</bean>
```

The `PersonUser` class in this example would expose a property of type `Person`. As far as it's concerned, the AOP proxy can be used transparently in place of a "real" person implementation. However, its class would be a dynamic proxy class. It would be possible to cast it to the `Advised` interface (discussed below).

It's possible to conceal the distinction between target and proxy using an anonymous *inner bean*, as follows. Only the `ProxyFactoryBean` definition is different; the advice is included only for completeness:

```

<bean id="myAdvisor" class="com.mycompany.MyAdvisor">
    <property name="someProperty" value="Custom string property value"/>
</bean>

<bean id="debugInterceptor" class=
"org.springframework.aop.interceptor.DebugInterceptor"/>

<bean id="person" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="proxyInterfaces" value="com.mycompany.Person"/>
    <!-- Use inner bean, not local reference to target -->
    <property name="target">
        <bean class="com.mycompany.PersonImpl">
            <property name="name" value="Tony"/>
            <property name="age" value="51"/>
        </bean>
    </property>
    <property name="interceptorNames">
        <list>
            <value>myAdvisor</value>
            <value>debugInterceptor</value>
        </list>
    </property>
</bean>

```

This has the advantage that there's only one object of type `Person`: useful if we want to prevent users of the application context from obtaining a reference to the un-advised object, or need to avoid any ambiguity with Spring IoC *autowiring*. There's also arguably an advantage in that the `ProxyFactoryBean` definition is self-contained. However, there are times when being able to obtain the un-advised target from the factory might actually be an *advantage*: for example, in certain test scenarios.

### 6.5.5. Proxying classes

What if you need to proxy a class, rather than one or more interfaces?

Imagine that in our example above, there was no `Person` interface: we needed to advise a class called `Person` that didn't implement any business interface. In this case, you can configure Spring to use CGLIB proxying, rather than dynamic proxies. Simply set the `proxyTargetClass` property on the `ProxyFactoryBean` above to true. While it's best to program to interfaces, rather than classes, the ability to advise classes that don't implement interfaces can be useful when working with legacy code. (In general, Spring isn't prescriptive. While it makes it easy to apply good practices, it avoids forcing a particular approach.)

If you want to, you can force the use of CGLIB in any case, even if you do have interfaces.

CGLIB proxying works by generating a subclass of the target class at runtime. Spring configures this generated subclass to delegate method calls to the original target: the subclass is used to implement the *Decorator* pattern, weaving in the advice.

CGLIB proxying should generally be transparent to users. However, there are some issues to consider:

- **Final** methods can't be advised, as they can't be overridden.
- There is no need to add CGLIB to your classpath. As of Spring 3.2, CGLIB is repackaged and included in the spring-core JAR. In other words, CGLIB-based AOP will work "out of the box" just as do JDK dynamic proxies.

There's little performance difference between CGLIB proxying and dynamic proxies. As of Spring 1.0, dynamic proxies are slightly faster. However, this may change in the future. Performance should not be a decisive consideration in this case.

### 6.5.6. Using 'global' advisors

By appending an asterisk to an interceptor name, all advisors with bean names matching the part before the asterisk, will be added to the advisor chain. This can come in handy if you need to add a standard set of 'global' advisors:

```
<bean id="proxy" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="target" ref="service"/>
    <property name="interceptorNames">
        <list>
            <value>global*</value>
        </list>
    </property>
</bean>

<bean id="global_debug" class="org.springframework.aop.interceptor.DebugInterceptor"/>
<bean id="global_performance" class=
"org.springframework.aop.interceptor.PerformanceMonitorInterceptor"/>
```

## 6.6. Concise proxy definitions

Especially when defining transactional proxies, you may end up with many similar proxy definitions. The use of parent and child bean definitions, along with inner bean definitions, can result in much cleaner and more concise proxy definitions.

First a parent, *template*, bean definition is created for the proxy:

```

<bean id="txProxyTemplate" abstract="true"
      class="org.springframework.transaction.interceptor.TransactionProxyFactoryBean">
    <property name="transactionManager" ref="transactionManager"/>
    <property name="transactionAttributes">
      <props>
        <prop key="*">PROPAGATION_REQUIRED</prop>
      </props>
    </property>
</bean>

```

This will never be instantiated itself, so may actually be incomplete. Then each proxy which needs to be created is just a child bean definition, which wraps the target of the proxy as an inner bean definition, since the target will never be used on its own anyway.

```

<bean id="myService" parent="txProxyTemplate">
  <property name="target">
    <bean class="org.springframework.samples.MyServiceImpl">
    </bean>
  </property>
</bean>

```

It is of course possible to override properties from the parent template, such as in this case, the transaction propagation settings:

```

<bean id="mySpecialService" parent="txProxyTemplate">
  <property name="target">
    <bean class="org.springframework.samples.MySpecialServiceImpl">
    </bean>
  </property>
  <property name="transactionAttributes">
    <props>
      <prop key="get*">PROPAGATION_REQUIRED,readonly</prop>
      <prop key="find*">PROPAGATION_REQUIRED,readonly</prop>
      <prop key="load*">PROPAGATION_REQUIRED,readonly</prop>
      <prop key="store*">PROPAGATION_REQUIRED</prop>
    </props>
  </property>
</bean>

```

Note that in the example above, we have explicitly marked the parent bean definition as *abstract* by using the *abstract* attribute, as described [previously](#), so that it may not actually ever be instantiated. Application contexts (but not simple bean factories) will by default pre-instantiate all singletons. It is therefore important (at least for singleton beans) that if you have a (parent) bean definition which you intend to use only as a template, and this definition specifies a class, you must make sure to set the *abstract* attribute to *true*, otherwise the application context will actually try to pre-instantiate it.

## 6.7. Creating AOP proxies programmatically with the ProxyFactory

It's easy to create AOP proxies programmatically using Spring. This enables you to use Spring AOP without dependency on Spring IoC.

The following listing shows creation of a proxy for a target object, with one interceptor and one advisor. The interfaces implemented by the target object will automatically be proxied:

```
ProxyFactory factory = new ProxyFactory(myBusinessInterfaceImpl);
factory.addAdvice(myMethodInterceptor);
factory.addAdvisor(myAdvisor);
MyBusinessInterface tb = (MyBusinessInterface) factory.getProxy();
```

The first step is to construct an object of type `org.springframework.aop.framework.ProxyFactory`. You can create this with a target object, as in the above example, or specify the interfaces to be proxied in an alternate constructor.

You can add advices (with interceptors as a specialized kind of advice) and/or advisors, and manipulate them for the life of the `ProxyFactory`. If you add an `IntroductionInterceptionAroundAdvisor`, you can cause the proxy to implement additional interfaces.

There are also convenience methods on `ProxyFactory` (inherited from `AdvisedSupport`) which allow you to add other advice types such as before and throws advice. `AdvisedSupport` is the superclass of both `ProxyFactory` and `ProxyFactoryBean`.



Integrating AOP proxy creation with the IoC framework is best practice in most applications. We recommend that you externalize configuration from Java code with AOP, as in general.

## 6.8. Manipulating advised objects

However you create AOP proxies, you can manipulate them using the `org.springframework.aop.framework.Advised` interface. Any AOP proxy can be cast to this interface, whichever other interfaces it implements. This interface includes the following methods:

```
Advisor[] getAdvisors();

void addAdvice(Advice advice) throws AopConfigException;

void addAdvice(int pos, Advice advice) throws AopConfigException;

void addAdvisor(Advisor advisor) throws AopConfigException;

void addAdvisor(int pos, Advisor advisor) throws AopConfigException;

int indexOf(Advisor advisor);

boolean removeAdvisor(Advisor advisor) throws AopConfigException;

void removeAdvisor(int index) throws AopConfigException;

boolean replaceAdvisor(Advisor a, Advisor b) throws AopConfigException;

boolean isFrozen();
```

The `getAdvisors()` method will return an Advisor for every advisor, interceptor or other advice type that has been added to the factory. If you added an Advisor, the returned advisor at this index will be the object that you added. If you added an interceptor or other advice type, Spring will have wrapped this in an advisor with a pointcut that always returns true. Thus if you added a `MethodInterceptor`, the advisor returned for this index will be an `DefaultPointcutAdvisor` returning your `MethodInterceptor` and a pointcut that matches all classes and methods.

The `addAdvisor()` methods can be used to add any Advisor. Usually the advisor holding pointcut and advice will be the generic `DefaultPointcutAdvisor`, which can be used with any advice or pointcut (but not for introductions).

By default, it's possible to add or remove advisors or interceptors even once a proxy has been created. The only restriction is that it's impossible to add or remove an introduction advisor, as existing proxies from the factory will not show the interface change. (You can obtain a new proxy from the factory to avoid this problem.)

A simple example of casting an AOP proxy to the `Advised` interface and examining and manipulating its advice:

```

Advised advised = (Advised) myObject;
Advisor[] advisors = advised.getAdvisors();
int oldAdvisorCount = advisors.length;
System.out.println(oldAdvisorCount + " advisors");

// Add an advice like an interceptor without a pointcut
// Will match all proxied methods
// Can use for interceptors, before, after returning or throws advice
advised.addAdvice(new DebugInterceptor());

// Add selective advice using a pointcut
advised.addAdvisor(new DefaultPointcutAdvisor(mySpecialPointcut, myAdvice));

assertEquals("Added two advisors", oldAdvisorCount + 2, advised.getAdvisors().length);

```



It's questionable whether it's advisable (no pun intended) to modify advice on a business object in production, although there are no doubt legitimate usage cases. However, it can be very useful in development: for example, in tests. I have sometimes found it very useful to be able to add test code in the form of an interceptor or other advice, getting inside a method invocation I want to test. (For example, the advice can get inside a transaction created for that method: for example, to run SQL to check that a database was correctly updated, before marking the transaction for roll back.)

Depending on how you created the proxy, you can usually set a `frozen` flag, in which case the `Advised isFrozen()` method will return true, and any attempts to modify advice through addition or removal will result in an `AopConfigException`. The ability to freeze the state of an advised object is useful in some cases, for example, to prevent calling code removing a security interceptor. It may also be used in Spring 1.1 to allow aggressive optimization if runtime advice modification is known not to be required.

## 6.9. Using the "auto-proxy" facility

So far we've considered explicit creation of AOP proxies using a `ProxyFactoryBean` or similar factory bean.

Spring also allows us to use "auto-proxy" bean definitions, which can automatically proxy selected bean definitions. This is built on Spring "bean post processor" infrastructure, which enables modification of any bean definition as the container loads.

In this model, you set up some special bean definitions in your XML bean definition file to configure the auto proxy infrastructure. This allows you just to declare the targets eligible for auto-proxying: you don't need to use `ProxyFactoryBean`.

There are two ways to do this:

- Using an auto-proxy creator that refers to specific beans in the current context.

- A special case of auto-proxy creation that deserves to be considered separately; auto-proxy creation driven by source-level metadata attributes.

## 6.9.1. Autoproxy bean definitions

The `org.springframework.aop.framework.autoproxy` package provides the following standard auto-proxy creators.

### BeanNameAutoProxyCreator

The `BeanNameAutoProxyCreator` class is a `BeanPostProcessor` that automatically creates AOP proxies for beans with names matching literal values or wildcards.

```
<bean class="org.springframework.aop.framework.autoproxy.BeanNameAutoProxyCreator">
    <property name="beanNames" value="jdk*,onlyJdk"/>
    <property name="interceptorNames">
        <list>
            <value>myInterceptor</value>
        </list>
    </property>
</bean>
```

As with `ProxyFactoryBean`, there is an `interceptorNames` property rather than a list of interceptors, to allow correct behavior for prototype advisors. Named "interceptors" can be advisors or any advice type.

As with auto proxying in general, the main point of using `BeanNameAutoProxyCreator` is to apply the same configuration consistently to multiple objects, with minimal volume of configuration. It is a popular choice for applying declarative transactions to multiple objects.

Bean definitions whose names match, such as "jdkMyBean" and "onlyJdk" in the above example, are plain old bean definitions with the target class. An AOP proxy will be created automatically by the `BeanNameAutoProxyCreator`. The same advice will be applied to all matching beans. Note that if advisors are used (rather than the interceptor in the above example), the pointcuts may apply differently to different beans.

### DefaultAdvisorAutoProxyCreator

A more general and extremely powerful auto proxy creator is `DefaultAdvisorAutoProxyCreator`. This will automagically apply eligible advisors in the current context, without the need to include specific bean names in the auto-proxy advisor's bean definition. It offers the same merit of consistent configuration and avoidance of duplication as `BeanNameAutoProxyCreator`.

Using this mechanism involves:

- Specifying a `DefaultAdvisorAutoProxyCreator` bean definition.
- Specifying any number of Advisors in the same or related contexts. Note that these *must* be Advisors, not just interceptors or other advices. This is necessary because there must be a pointcut to evaluate, to check the eligibility of each advice to candidate bean definitions.

The `DefaultAdvisorAutoProxyCreator` will automatically evaluate the pointcut contained in each advisor, to see what (if any) advice it should apply to each business object (such as "businessObject1" and "businessObject2" in the example).

This means that any number of advisors can be applied automatically to each business object. If no pointcut in any of the advisors matches any method in a business object, the object will not be proxied. As bean definitions are added for new business objects, they will automatically be proxied if necessary.

Autoproxying in general has the advantage of making it impossible for callers or dependencies to obtain an un-advised object. Calling `getBean("businessObject1")` on this `ApplicationContext` will return an AOP proxy, not the target business object. (The "inner bean" idiom shown earlier also offers this benefit.)

```
<bean class=
"org.springframework.aop.framework.autoproxy.DefaultAdvisorAutoProxyCreator"/>

<bean class=
"org.springframework.transaction.interceptor.TransactionAttributeSourceAdvisor">
    <property name="transactionInterceptor" ref="transactionInterceptor"/>
</bean>

<bean id="customAdvisor" class="com.mycompany.MyAdvisor"/>

<bean id="businessObject1" class="com.mycompany.BusinessObject1">
    <!-- Properties omitted -->
</bean>

<bean id="businessObject2" class="com.mycompany.BusinessObject2"/>
```

The `DefaultAdvisorAutoProxyCreator` is very useful if you want to apply the same advice consistently to many business objects. Once the infrastructure definitions are in place, you can simply add new business objects without including specific proxy configuration. You can also drop in additional aspects very easily - for example, tracing or performance monitoring aspects - with minimal change to configuration.

The `DefaultAdvisorAutoProxyCreator` offers support for filtering (using a naming convention so that only certain advisors are evaluated, allowing use of multiple, differently configured, `AdvisorAutoProxyCreators` in the same factory) and ordering. Advisors can implement the `org.springframework.core.Ordered` interface to ensure correct ordering if this is an issue. The `TransactionAttributeSourceAdvisor` used in the above example has a configurable order value; the default setting is `unordered`.

## 6.10. Using TargetSources

Spring offers the concept of a *TargetSource*, expressed in the `org.springframework.aop.TargetSource` interface. This interface is responsible for returning the "target object" implementing the join point. The `TargetSource` implementation is asked for a target instance each time the AOP proxy handles a

method invocation.

Developers using Spring AOP don't normally need to work directly with TargetSources, but this provides a powerful means of supporting pooling, hot swappable and other sophisticated targets. For example, a pooling TargetSource can return a different target instance for each invocation, using a pool to manage instances.

If you do not specify a TargetSource, a default implementation is used that wraps a local object. The same target is returned for each invocation (as you would expect).

Let's look at the standard target sources provided with Spring, and how you can use them.



When using a custom target source, your target will usually need to be a prototype rather than a singleton bean definition. This allows Spring to create a new target instance when required.

### 6.10.1. Hot swappable target sources

The `org.springframework.aop.target.HotSwappableTargetSource` exists to allow the target of an AOP proxy to be switched while allowing callers to keep their references to it.

Changing the target source's target takes effect immediately. The `HotSwappableTargetSource` is threadsafe.

You can change the target via the `swap()` method on `HotSwappableTargetSource` as follows:

```
HotSwappableTargetSource swapper = (HotSwappableTargetSource) beanFactory.getBean("swapper");
Object oldTarget = swapper.swap(newTarget);
```

The XML definitions required look as follows:

```
<bean id="initialTarget" class="mycompany.OldTarget"/>

<bean id="swapper" class="org.springframework.aop.target.HotSwappableTargetSource">
    <constructor-arg ref="initialTarget"/>
</bean>

<bean id="swappable" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="targetSource" ref="swapper"/>
</bean>
```

The above `swap()` call changes the target of the swappable bean. Clients who hold a reference to that bean will be unaware of the change, but will immediately start hitting the new target.

Although this example doesn't add any advice - and it's not necessary to add advice to use a `TargetSource` - of course any `TargetSource` can be used in conjunction with arbitrary advice.

## 6.10.2. Pooling target sources

Using a pooling target source provides a similar programming model to stateless session EJBs, in which a pool of identical instances is maintained, with method invocations going to free objects in the pool.

A crucial difference between Spring pooling and SLSB pooling is that Spring pooling can be applied to any POJO. As with Spring in general, this service can be applied in a non-invasive way.

Spring provides out-of-the-box support for Commons Pool 2.2, which provides a fairly efficient pooling implementation. You'll need the commons-pool Jar on your application's classpath to use this feature. It's also possible to subclass `org.springframework.aop.target.AbstractPoolingTargetSource` to support any other pooling API.



Commons Pool 1.5+ is also supported but deprecated as of Spring Framework 4.2.

Sample configuration is shown below:

```
<bean id="businessObjectTarget" class="com.mycompany.MyBusinessObject"
      scope="prototype">
    ... properties omitted
</bean>

<bean id="poolTargetSource" class=
"org.springframework.aop.target.CommonsPool2TargetSource">
    <property name="targetBeanName" value="businessObjectTarget"/>
    <property name="maxSize" value="25"/>
</bean>

<bean id="businessObject" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="targetSource" ref="poolTargetSource"/>
    <property name="interceptorNames" value="myInterceptor"/>
</bean>
```

Note that the target object - "businessObjectTarget" in the example - *must* be a prototype. This allows the `PoolingTargetSource` implementation to create new instances of the target to grow the pool as necessary. See the javadocs of `AbstractPoolingTargetSource` and the concrete subclass you wish to use for information about its properties: "maxSize" is the most basic, and always guaranteed to be present.

In this case, "myInterceptor" is the name of an interceptor that would need to be defined in the same IoC context. However, it isn't necessary to specify interceptors to use pooling. If you want only pooling, and no other advice, don't set the interceptorNames property at all.

It's possible to configure Spring so as to be able to cast any pooled object to the `org.springframework.aop.target.PoolingConfig` interface, which exposes information about the configuration and current size of the pool through an introduction. You'll need to define an advisor like this:

```

<bean id="poolConfigAdvisor" class=
"org.springframework.beans.factory.config.MethodInvokingFactoryBean">
    <property name="targetObject" ref="poolTargetSource"/>
    <property name="targetMethod" value="getPoolingConfigMixin"/>
</bean>

```

This advisor is obtained by calling a convenience method on the `AbstractPoolingTargetSource` class, hence the use of `MethodInvokingFactoryBean`. This advisor's name ("poolConfigAdvisor" here) must be in the list of interceptors names in the `ProxyFactoryBean` exposing the pooled object.

The cast will look as follows:

```

PoolingConfig conf = (PoolingConfig) beanFactory.getBean("businessObject");
System.out.println("Max pool size is " + conf.getMaxSize());

```



Pooling stateless service objects is not usually necessary. We don't believe it should be the default choice, as most stateless objects are naturally thread safe, and instance pooling is problematic if resources are cached.

Simpler pooling is available using auto-proxying. It's possible to set the `TargetSources` used by any auto-proxy creator.

### 6.10.3. Prototype target sources

Setting up a "prototype" target source is similar to a pooling `TargetSource`. In this case, a new instance of the target will be created on every method invocation. Although the cost of creating a new object isn't high in a modern JVM, the cost of wiring up the new object (satisfying its IoC dependencies) may be more expensive. Thus you shouldn't use this approach without very good reason.

To do this, you could modify the `poolTargetSource` definition shown above as follows. (I've also changed the name, for clarity.)

```

<bean id="prototypeTargetSource" class=
"org.springframework.aop.target.PrototypeTargetSource">
    <property name="targetBeanName" ref="businessObjectTarget"/>
</bean>

```

There's only one property: the name of the target bean. Inheritance is used in the `TargetSource` implementations to ensure consistent naming. As with the pooling target source, the target bean must be a prototype bean definition.

### 6.10.4. ThreadLocal target sources

`ThreadLocal` target sources are useful if you need an object to be created for each incoming request (per thread that is). The concept of a `ThreadLocal` provide a JDK-wide facility to transparently store

resource alongside a thread. Setting up a `ThreadLocalTargetSource` is pretty much the same as was explained for the other types of target source:

```
<bean id="threadlocalTargetSource" class="org.springframework.aop.target.ThreadLocalTargetSource">
    <property name="targetBeanName" value="businessObjectTarget"/>
</bean>
```

 ThreadLocals come with serious issues (potentially resulting in memory leaks) when incorrectly using them in a multi-threaded and multi-classloader environments. One should always consider wrapping a threadlocal in some other class and never directly use the `ThreadLocal` itself (except of course in the wrapper class). Also, one should always remember to correctly set and unset (where the latter simply involved a call to `ThreadLocal.set(null)`) the resource local to the thread. Unsetting should be done in any case since not unsetting it might result in problematic behavior. Spring's ThreadLocal support does this for you and should always be considered in favor of using ThreadLocals without other proper handling code.

## 6.11. Defining new Advice types

Spring AOP is designed to be extensible. While the interception implementation strategy is presently used internally, it is possible to support arbitrary advice types in addition to the out-of-the-box interception around advice, before, throws advice and after returning advice.

The `org.springframework.aop.framework.adapter` package is an SPI package allowing support for new custom advice types to be added without changing the core framework. The only constraint on a custom `Advice` type is that it must implement the `org.aopalliance.aop.Advice` marker interface.

Please refer to the `org.springframework.aop.framework.adapter` javadocs for further information.

# Chapter 7. Null-safety

Although Java does not allow to express null-safety with its type system, Spring Framework now provides following annotations in the `org.springframework.lang` package to declare nullability of APIs and fields:

- `@NotNull` annotation where specific parameter, return value or field cannot be `null` (not needed on parameter and return value where `@NotNullApi` and `@NotNullFields` apply).
- `@Nullable` annotation where specific parameter, return value or field can be `null`.
- `@NotNullApi` annotation at package level declares non-null as the default behavior for parameters and return values.
- `@NotNullFields` annotation at package level declares non-null as the default behavior for fields.

Spring Framework leverages itself these annotations, but they can also be used in any Spring based Java project to declare null-safe APIs and optionally null-safe fields. Generic type arguments, varargs and array elements nullability are not supported yet, but should be in an upcoming release, see [SPR-15942](#) for up-to-date information. Nullability declaration are expected to be fine-tuned between Spring Framework release, including minor ones. Nullability of types used inside method bodies is outside of the scope of this feature.



Libraries like Reactor or Spring Data provide null-safe APIs leveraging this feature.

## 7.1. Use cases

In addition to providing an explicit declaration for Spring Framework API nullability, these annotation can be used by IDE (such as IDEA or Eclipse) to provide useful warnings to Java developers related to null-safety in order to avoid `NullPointerException` at runtime.

They are also used to make Spring API null-safe in Kotlin projects since Kotlin natively supports [null-safety](#). More details are available in [Kotlin support documentation](#).

## 7.2. JSR 305 meta-annotations

Spring annotations are meta-annotated with [JSR 305](#) annotations (a dormant but widely spread JSR). JSR 305 meta-annotations allows tooling vendors like IDEA or Kotlin to provide null-safety support in a generic way, without having to hard-code support for Spring annotations.

It is not necessary nor recommended to add JSR 305 dependency in project classpath to take advantage of Spring null-safe API. Only projects like Spring-based libraries using null-safety annotations in their codebase should add `com.google.code.findbugs:jsr305:3.0.2` with `compileOnly` Gradle configuration or Maven `provided` scope to avoid compile warnings.

# Chapter 8. Data Buffers and Codecs

## 8.1. Introduction

The `DataBuffer` interface defines an abstraction over byte buffers. The main reason for introducing it, and not use the standard `java.nio.ByteBuffer` instead, is Netty. Netty does not use `ByteBuffer`, but instead offers `ByteBuf` as an alternative. Spring's `DataBuffer` is a simple abstraction over `ByteBuf` that can also be used on non-Netty platforms (i.e. Servlet 3.1+).

## 8.2. DataBufferFactory

The `DataBufferFactory` offers functionality to allocate new data buffers, as well as to wrap existing data. The `allocate` methods allocate a new data buffer, with a default or given capacity. Though `DataBuffer` implementation grow and shrink on demand, it is more efficient to give the capacity upfront, if known. The `wrap` methods decorate an existing `ByteBuffer` or byte array. Wrapping does not involve allocation: it simply decorates the given data with a `DataBuffer` implementation.

There are two implementation of `DataBufferFactory`: the `NettyDataBufferFactory` which is meant to be used on Netty platforms, such as Reactor Netty. The other implementation, the `DefaultDataBufferFactory`, is used on other platforms, such as Servlet 3.1+ servers.

## 8.3. The DataBuffer interface

The `DataBuffer` interface is similar to `ByteBuffer`, but offers a number of advantages. Similar to Netty's `ByteBuf`, the `DataBuffer` abstraction offers independent read and write positions. This is different from the JDK's `ByteBuffer`, which only exposes one position for both reading and writing, and a separate `flip()` operation to switch between the two I/O operations. In general, the following invariant holds for the read position, write position, and the capacity:

```
'0' <= _read position_ <= _write position_ <= _capacity_
```

When reading bytes from the `DataBuffer`, the read position is automatically updated in accordance with the amount of data read from the buffer. Similarly, when writing bytes to the `DataBuffer`, the write position is updated with the amount of data written to the buffer. Also, when writing data, the capacity of a `DataBuffer` is automatically expanded, just like `StringBuilder`, `ArrayList`, and similar types.

Besides the reading and writing functionality mentioned above, the `DataBuffer` also has methods to view a (slice of a) buffer as `ByteBuffer`, `InputStream`, or `OutputStream`. Additionally, it offers methods to determine the index of a given byte.

There are two implementation of `DataBuffer`: the `NettyDataBuffer` which is meant to be used on Netty platforms, such as Reactor Netty. The other implementation, the `DefaultDataBuffer`, is used on other platforms, such as Servlet 3.1+ servers.

### 8.3.1. PooledDataBuffer

The `PooledDataBuffer` is an extension to `DataBuffer` that adds methods for reference counting. The `retain` method increases the reference count by one. The `release` method decreases the count by one, and releases the buffer's memory when the count reaches 0. Both of these methods are related to *reference counting*, a mechanism that is explained below.

Note that `DataBufferUtils` offers useful utility methods for releasing and retaining pooled data buffers. These methods take a plain `DataBuffer` as parameter, but only call `retain` or `release` if the passed data buffer is an instance of `PooledDataBuffer`.

#### Reference Counting

Reference counting is not a common technique in Java; it is much more common in other programming languages such as Object C and C++. In and of itself, reference counting is not complex: it basically involves tracking the number of references that apply to an object. The reference count of a `PooledDataBuffer` starts at 1, is incremented by calling `retain`, and decremented by calling `release`. As long as the buffer's reference count is larger than 0 the buffer will not be released. When the number decreases to 0, the instance will be released. In practice, this means that the reserved memory captured by the buffer will be returned back to the memory pool, ready to be used for future allocations.

In general, *the last component to access a `DataBuffer` is responsible for releasing it*. Within Spring, there are two sorts of components that release buffers: decoders and transports. Decoders are responsible for transforming a stream of buffers into other types (see [Codecs](#) below), and transports are responsible for sending buffers across a network boundary, typically as an HTTP message. This means that if you allocate data buffers for the purpose of putting them into an outbound HTTP message (i.e. client-side request or server-side response), they do not have to be released. The other consequence of this rule is that if you allocate data buffers that do not end up in the body, for instance because of a thrown exception, you will have to release them yourself. The following snippet shows a typical `DataBuffer` usage scenario when dealing with methods that throw exceptions:

```

DataBufferFactory factory = ...
DataBuffer buffer = factory.allocateBuffer(); ①
boolean release = true; ②
try {
    writeDataToBuffer(buffer); ③
    putBufferInHttpBody(buffer);
    release = false; ④
}
finally {
    if (release) {
        DataBufferUtils.release(buffer); ⑤
    }
}

private void writeDataToBuffer(DataBuffer buffer) throws IOException { ③
    ...
}

```

- ① A new buffer is allocated.
- ② A boolean flag indicates whether the allocated buffer should be released.
- ③ This example method loads data into the buffer. Note that the method can throw an `IOException`, and therefore a `finally` block to release the buffer is required.
- ④ If no exception occurred, we switch the `release` flag to `false` as the buffer will now be released as part of sending the HTTP body across the wire.
- ⑤ If an exception did occur, the flag is still set to `true`, and the buffer will be released here.

### 8.3.2. DataBufferUtils

`DataBufferUtils` contains various utility methods that operate on data buffers. It contains methods for reading a `Flux` of `DataBuffer` objects from an `InputStream` or NIO `Channel`, and methods for writing a data buffer `Flux` to an `OutputStream` or `Channel`. `DataBufferUtils` also exposes `retain` and `release` methods that operate on plain `DataBuffer` instances (so that casting to a `PooledDataBuffer` is not required).

Additionally, `DataBufferUtils` exposes `compose`, which merges a stream of data buffers into one. For instance, this method can be used to convert the entire HTTP body into a single buffer (and from that, a `String`, or `InputStream`). This is particularly useful when dealing with older, blocking APIs. Note, however, that this puts the entire body in memory, and therefore uses more memory than a pure streaming solution would.

## Codecs

The `org.springframework.core.codec` package contains the two main abstractions for converting a stream of bytes into a stream of objects, or vice-versa. The `Encoder` is a strategy interface that encodes a stream of objects into an output stream of data buffers. The `Decoder` does the reverse: it turns a stream of data buffers into a stream of objects. Note that a decoder instance needs to

consider [reference counting](#).

Spring comes with a wide array of default codecs, capable of converting from/to `String`, `ByteBuffer`, byte arrays, and also codecs that support marshalling libraries such as JAXB and Jackson (with [Jackson 2.9+ support for non-blocking parsing](#)). Within the context of Spring WebFlux, codecs are used to convert the request body into a `@RequestMapping` parameter, or to convert the return type into the response body that is sent back to the client. The default codecs are configured in the `WebFluxConfigurationSupport` class, and can easily be changed by overriding the `configureHttpMessageCodecs` when inheriting from that class. For more information about using codecs in WebFlux, see [this section](#).

# Chapter 9. Appendix

## 9.1. XML Schemas

This part of the appendix lists XML schemas related to the core container.

### 9.1.1. The util schema

As the name implies, the `util` tags deal with common, *utility* configuration issues, such as configuring collections, referencing constants, and suchlike. To use the tags in the `util` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the snippet below references the correct schema so that the tags in the `util` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    <em>xmns:util="http://www.springframework.org/schema/util"</em>
xsi:schemaLocation="
    http://www.springframework.org/schema/beans
    http://www.springframework.org/schema/beans/spring-beans.xsd
        <em>http://www.springframework.org/schema/util
    http://www.springframework.org/schema/util/spring-util.xsd"</em>> <!-- bean
definitions here -->

</beans>
```

`<util:constant/>`

Before...

```
<bean id="..." class="...">
    <property name="isolation">
        <bean id="java.sql.Connection.TRANSACTION_SERIALIZABLE"
            class=
"org.springframework.beans.factory.config.FieldRetrievingFactoryBean" />
    </property>
</bean>
```

The above configuration uses a Spring `FactoryBean` implementation, the `FieldRetrievingFactoryBean`, to set the value of the `isolation` property on a bean to the value of the `java.sql.Connection.TRANSACTION_SERIALIZABLE` constant. This is all well and good, but it is a tad verbose and (unnecessarily) exposes Spring's internal plumbing to the end user.

The following XML Schema-based version is more concise and clearly expresses the developer's intent (*'inject this constant value'*), and it just reads better.

```

<bean id="..." class="...">
    <property name="isolation">
        <util:constant static-field="java.sql.Connection.TRANSACTION_SERIALIZABLE"/>
    </property>
</bean>

```

### Setting a bean property or constructor arg from a field value

`FieldRetrievingFactoryBean` is a `FactoryBean` which retrieves a `static` or non-static field value. It is typically used for retrieving `public static final` constants, which may then be used to set a property value or constructor arg for another bean.

Find below an example which shows how a `static` field is exposed, by using the `staticField` property:

```

<bean id="myField"
      class="org.springframework.beans.factory.config.FieldRetrievingFactoryBean">
    <property name="staticField" value="java.sql.Connection.TRANSACTION_SERIALIZABLE"
  "/>
</bean>

```

There is also a convenience usage form where the `static` field is specified as the bean name:

```

<bean id="java.sql.Connection.TRANSACTION_SERIALIZABLE"
      class="org.springframework.beans.factory.config.FieldRetrievingFactoryBean"/>

```

This does mean that there is no longer any choice in what the bean id is (so any other bean that refers to it will also have to use this longer name), but this form is very concise to define, and very convenient to use as an inner bean since the id doesn't have to be specified for the bean reference:

```

<bean id="..." class="...">
    <property name="isolation">
        <bean id="java.sql.Connection.TRANSACTION_SERIALIZABLE"
              class=
"org.springframework.beans.factory.config.FieldRetrievingFactoryBean" />
    </property>
</bean>

```

It is also possible to access a non-static (instance) field of another bean, as described in the API documentation for the `FieldRetrievingFactoryBean` class.

Injecting enum values into beans as either property or constructor arguments is very easy to do in Spring, in that you don't actually have to *do* anything or know anything about the Spring internals (or even about classes such as the `FieldRetrievingFactoryBean`). Let's look at an example to see how easy injecting an enum value is; consider this enum:

```

package javax.persistence;

public enum PersistenceContextType {
    TRANSACTION,
    EXTENDED
}

```

Now consider a setter of type `PersistenceContextType`:

```

package example;

public class Client {

    private PersistenceContextType persistenceContextType;

    public void setPersistenceContextType(PersistenceContextType type) {
        this.persistenceContextType = type;
    }
}

```

a. and the corresponding bean definition:

```

<bean class="example.Client">
    <property name="persistenceContextType" value="TRANSACTION"/>
</bean>

```

`<util:property-path/>`

Before...

```

<!-- target bean to be referenced by name -->
<bean id="testBean" class="org.springframework.beans.TestBean" scope="prototype">
    <property name="age" value="10"/>
    <property name="spouse">
        <bean class="org.springframework.beans.TestBean">
            <property name="age" value="11"/>
        </bean>
    </property>
</bean>

<!-- will result in 10, which is the value of property 'age' of bean 'testBean' -->
<bean id="testBean.age" class=
"org.springframework.beans.factory.config.PropertyPathFactoryBean"/>

```

The above configuration uses a Spring `FactoryBean` implementation, the `PropertyPathFactoryBean`, to

create a bean (of type `int`) called `testBean.age` that has a value equal to the `age` property of the `testBean` bean.

After...

```
<!-- target bean to be referenced by name -->
<bean id="testBean" class="org.springframework.beans.TestBean" scope="prototype">
    <property name="age" value="10"/>
    <property name="spouse">
        <bean class="org.springframework.beans.TestBean">
            <property name="age" value="11"/>
        </bean>
    </property>
</bean>

<!-- will result in 10, which is the value of property 'age' of bean 'testBean' -->
<util:property-path id="name" path="testBean.age"/>
```

The value of the `path` attribute of the `<property-path/>` tag follows the form `beanName.beanProperty`.

#### Using `<util:property-path/>` to set a bean property or constructor-argument

`PropertyPathFactoryBean` is a `FactoryBean` that evaluates a property path on a given target object. The target object can be specified directly or via a bean name. This value may then be used in another bean definition as a property value or constructor argument.

Here's an example where a path is used against another bean, by name:

```
// target bean to be referenced by name
<bean id="person" class="org.springframework.beans.TestBean" scope="prototype">
    <property name="age" value="10"/>
    <property name="spouse">
        <bean class="org.springframework.beans.TestBean">
            <property name="age" value="11"/>
        </bean>
    </property>
</bean>

// will result in 11, which is the value of property 'spouse.age' of bean 'person'
<bean id="theAge"
      class="org.springframework.beans.factory.config.PropertyPathFactoryBean">
    <property name="targetBeanName" value="person"/>
    <property name="propertyPath" value="spouse.age"/>
</bean>
```

In this example, a path is evaluated against an inner bean:

```

<!-- will result in 12, which is the value of property 'age' of the inner bean -->
<bean id="theAge"
      class="org.springframework.beans.factory.config.PropertyPathFactoryBean">
    <property name="targetObject">
      <bean class="org.springframework.beans.TestBean">
        <property name="age" value="12"/>
      </bean>
    </property>
    <property name="propertyPath" value="age"/>
</bean>

```

There is also a shortcut form, where the bean name is the property path.

```

<!-- will result in 10, which is the value of property 'age' of bean 'person' -->
<bean id="person.age"
      class="org.springframework.beans.factory.config.PropertyPathFactoryBean"/>

```

This form does mean that there is no choice in the name of the bean. Any reference to it will also have to use the same id, which is the path. Of course, if used as an inner bean, there is no need to refer to it at all:

```

<bean id="..." class="...">
  <property name="age">
    <bean id="person.age"
          class=
"org.springframework.beans.factory.config.PropertyPathFactoryBean"/>
  </property>
</bean>

```

The result type may be specifically set in the actual definition. This is not necessary for most use cases, but can be of use for some. Please see the Javadocs for more info on this feature.

<util:properties/>

Before...

```

<!-- creates a java.util.Properties instance with values loaded from the supplied
location -->
<bean id="jdbcConfiguration" class=
"org.springframework.beans.factory.config.PropertiesFactoryBean">
  <property name="location" value="classpath:com/foo/jdbc-production.properties"/>
</bean>

```

The above configuration uses a Spring **FactoryBean** implementation, the **PropertiesFactoryBean**, to instantiate a **java.util.Properties** instance with values loaded from the supplied **Resource** location).

After...

```
<!-- creates a java.util.Properties instance with values loaded from the supplied  
location -->  
<util:properties id="jdbcConfiguration" location="classpath:com/foo/jdbc-  
production.properties"/>
```

<util:list/>

Before...

```
<!-- creates a java.util.List instance with values loaded from the supplied  
'sourceList' -->  
<bean id="emails" class="org.springframework.beans.factory.config.ListFactoryBean">  
    <property name="sourceList">  
        <list>  
            <value>pechorin@hero.org</value>  
            <value>raskolnikov@slums.org</value>  
            <value>stavrogin@gov.org</value>  
            <value>porfiry@gov.org</value>  
        </list>  
    </property>  
</bean>
```

The above configuration uses a Spring **FactoryBean** implementation, the **ListFactoryBean**, to create a **java.util.List** instance initialized with values taken from the supplied **sourceList**.

After...

```
<!-- creates a java.util.List instance with the supplied values -->  
<util:list id="emails">  
    <value>pechorin@hero.org</value>  
    <value>raskolnikov@slums.org</value>  
    <value>stavrogin@gov.org</value>  
    <value>porfiry@gov.org</value>  
</util:list>
```

You can also explicitly control the exact type of **List** that will be instantiated and populated via the use of the **list-class** attribute on the **<util:list/>** element. For example, if we really need a **java.util.LinkedList** to be instantiated, we could use the following configuration:

```

<util:list id="emails" list-class="java.util.LinkedList">
    <value>jackshaftoe@vagabond.org</value>
    <value>eliza@thinkingmanscrumpect.org</value>
    <value>vanhoek@pirate.org</value>
    <value>d'Arcachon@nemesis.org</value>
</util:list>

```

If no `list-class` attribute is supplied, a `List` implementation will be chosen by the container.

`<util:map/>`

Before...

```

<!-- creates a java.util.Map instance with values loaded from the supplied 'sourceMap'
-->
<bean id="emails" class="org.springframework.beans.factory.config.MapFactoryBean">
    <property name="sourceMap">
        <map>
            <entry key="pechorin" value="pechorin@hero.org"/>
            <entry key="raskolnikov" value="raskolnikov@slums.org"/>
            <entry key="stavrogin" value="stavrogin@gov.org"/>
            <entry key="porfiry" value="porfiry@gov.org"/>
        </map>
    </property>
</bean>

```

The above configuration uses a Spring `FactoryBean` implementation, the `MapFactoryBean`, to create a `java.util.Map` instance initialized with key-value pairs taken from the supplied '`sourceMap`'.

After...

```

<!-- creates a java.util.Map instance with the supplied key-value pairs -->
<util:map id="emails">
    <entry key="pechorin" value="pechorin@hero.org"/>
    <entry key="raskolnikov" value="raskolnikov@slums.org"/>
    <entry key="stavrogin" value="stavrogin@gov.org"/>
    <entry key="porfiry" value="porfiry@gov.org"/>
</util:map>

```

You can also explicitly control the exact type of `Map` that will be instantiated and populated via the use of the '`map-class`' attribute on the `<util:map/>` element. For example, if we really need a `java.util.TreeMap` to be instantiated, we could use the following configuration:

```

<util:map id="emails" map-class="java.util.TreeMap">
    <entry key="pechorin" value="pechorin@hero.org"/>
    <entry key="raskolnikov" value="raskolnikov@slums.org"/>
    <entry key="stavrogin" value="stavrogin@gov.org"/>
    <entry key="porfiry" value="porfiry@gov.org"/>
</util:map>

```

If no '`map-class`' attribute is supplied, a `Map` implementation will be chosen by the container.

<`util:set`>

Before...

```

<!-- creates a java.util.Set instance with values loaded from the supplied 'sourceSet'
-->
<bean id="emails" class="org.springframework.beans.factory.config.SetFactoryBean">
    <property name="sourceSet">
        <set>
            <value>pechorin@hero.org</value>
            <value>raskolnikov@slums.org</value>
            <value>stavrogin@gov.org</value>
            <value>porfiry@gov.org</value>
        </set>
    </property>
</bean>

```

The above configuration uses a Spring `FactoryBean` implementation, the `SetFactoryBean`, to create a `java.util.Set` instance initialized with values taken from the supplied '`sourceSet`'.

After...

```

<!-- creates a java.util.Set instance with the supplied values -->
<util:set id="emails">
    <value>pechorin@hero.org</value>
    <value>raskolnikov@slums.org</value>
    <value>stavrogin@gov.org</value>
    <value>porfiry@gov.org</value>
</util:set>

```

You can also explicitly control the exact type of `Set` that will be instantiated and populated via the use of the '`set-class`' attribute on the `<util:set/>` element. For example, if we really need a `java.util.TreeSet` to be instantiated, we could use the following configuration:

```

<util:set id="emails" set-class="java.util.TreeSet">
    <value>pechorin@hero.org</value>
    <value>raskolnikov@slums.org</value>
    <value>stavrogin@gov.org</value>
    <value>porfiry@gov.org</value>
</util:set>

```

If no '`set-class`' attribute is supplied, a `Set` implementation will be chosen by the container.

### 9.1.2. The aop schema

The `aop` tags deal with configuring all things AOP in Spring: this includes Spring's own proxy-based AOP framework and Spring's integration with the AspectJ AOP framework. These tags are comprehensively covered in the chapter entitled [Aspect Oriented Programming with Spring](#).

In the interest of completeness, to use the tags in the `aop` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the following snippet references the correct schema so that the tags in the `aop` namespace are available to you.

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    <em>xm&lins:aop="http://www.springframework.org/schema/aop"</em>
xsi:schemaLocation="
    http://www.springframework.org/schema/beans
    http://www.springframework.org/schema/beans/spring-beans.xsd
        <em>http://www.springframework.org/schema/aop
    http://www.springframework.org/schema/aop/spring-aop.xsd"</em>> <!-- bean definitions
here -->

</beans>

```

### 9.1.3. The context schema

The `context` tags deal with `ApplicationContext` configuration that relates to plumbing - that is, not usually beans that are important to an end-user but rather beans that do a lot of grunt work in Spring, such as `BeanfactoryPostProcessors`. The following snippet references the correct schema so that the tags in the `context` namespace are available to you.

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    <em>xm&lt;ns:context="http://www.springframework.org/schema/context"</em>
xsi:schemaLocation="
    http://www.springframework.org/schema/beans
    http://www.springframework.org/schema/beans/spring-beans.xsd
    <em>http://www.springframework.org/schema/context
    http://www.springframework.org/schema/context/spring-context.xsd"</em>> <!-- bean
definitions here -->

</beans>

```

### <property-placeholder/>

This element activates the replacement of `{}…` placeholders, resolved against the specified properties file (as a [Spring resource location](#)). This element is a convenience mechanism that sets up a `PropertyPlaceholderConfigurer` for you; if you need more control over the `PropertyPlaceholderConfigurer`, just define one yourself explicitly.

### <annotation-config/>

Activates the Spring infrastructure for various annotations to be detected in bean classes: Spring's `@Required` and `@Autowired`, as well as JSR 250's `@PostConstruct`, `@PreDestroy` and `@Resource` (if available), and JPA's `@PersistenceContext` and `@PersistenceUnit` (if available). Alternatively, you can choose to activate the individual `BeanPostProcessors` for those annotations explicitly.



This element does *not* activate processing of Spring's `@Transactional` annotation. Use the `<tx:annotation-driven/>` element for that purpose.

### <component-scan/>

This element is detailed in [Annotation-based container configuration](#).

### <load-time-weaver/>

This element is detailed in [Load-time weaving with AspectJ in the Spring Framework](#).

### <spring-configured/>

This element is detailed in [Using AspectJ to dependency inject domain objects with Spring](#).

### <mbean-export/>

This element is detailed in [Configuring annotation based MBean export](#).

## 9.1.4. The beans schema

Last but not least we have the tags in the `beans` schema. These are the same tags that have been in

Spring since the very dawn of the framework. Examples of the various tags in the `beans` schema are not shown here because they are quite comprehensively covered in [Dependencies and configuration in detail](#) (and indeed in that entire [chapter](#)).

Note that it is possible to add zero or more key / value pairs to `<bean/>` XML definitions. What, if anything, is done with this extra metadata is totally up to your own custom logic (and so is typically only of use if you are writing your own custom tags as described in the appendix entitled [XML Schema Authoring](#)).

Find below an example of the `<meta/>` tag in the context of a surrounding `<bean/>` (please note that without any logic to interpret it the metadata is effectively useless as-is).

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="
           http://www.springframework.org/schema/beans
           http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="foo" class="x.y.Foo">
        <em><meta key="cacheName" value="foo"/></em>
        <property name="name" value="Rick"/>
    </bean>

</beans>
```

In the case of the above example, you would assume that there is some logic that will consume the bean definition and set up some caching infrastructure using the supplied metadata.

## 9.2. XML Schema Authoring

### 9.2.1. Introduction

Since version 2.0, Spring has featured a mechanism for schema-based extensions to the basic Spring XML format for defining and configuring beans. This section is devoted to detailing how you would go about writing your own custom XML bean definition parsers and integrating such parsers into the Spring IoC container.

To facilitate the authoring of configuration files using a schema-aware XML editor, Spring's extensible XML configuration mechanism is based on XML Schema. If you are not familiar with Spring's current XML configuration extensions that come with the standard Spring distribution, please first read the appendix entitled [\[xsd-config\]](#).

Creating new XML configuration extensions can be done by following these (relatively) simple steps:

- [Authoring](#) an XML schema to describe your custom element(s).
- [Coding](#) a custom `NamespaceHandler` implementation (this is an easy step, don't worry).

- **Coding** one or more `BeanDefinitionParser` implementations (this is where the real work is done).
- **Registering** the above artifacts with Spring (this too is an easy step).

What follows is a description of each of these steps. For the example, we will create an XML extension (a custom XML element) that allows us to configure objects of the type `SimpleDateFormat` (from the `java.text` package) in an easy manner. When we are done, we will be able to define bean definitions of type `SimpleDateFormat` like this:

```
<myns:dateFormat id="dateFormat"
    pattern="yyyy-MM-dd HH:mm"
    lenient="true"/>
```

*(Don't worry about the fact that this example is very simple; much more detailed examples follow afterwards. The intent in this first simple example is to walk you through the basic steps involved.)*

### 9.2.2. Authoring the schema

Creating an XML configuration extension for use with Spring's IoC container starts with authoring an XML Schema to describe the extension. What follows is the schema we'll use to configure `SimpleDateFormat` objects.

```
<!-- myns.xsd (inside package org/springframework/samples/xml) -->

<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns="http://www.mycompany.com/schema/myns"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns:beans="http://www.springframework.org/schema/beans"
    targetNamespace="http://www.mycompany.com/schema/myns"
    elementFormDefault="qualified"
    attributeFormDefault="unqualified">

    <xsd:import namespace="http://www.springframework.org/schema/beans"/>

    <xsd:element name="dateFormat">
        <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="beans:identifiedType">
                    <xsd:attribute name="lenient" type="xsd:boolean"/>
                    <xsd:attribute name="pattern" type="xsd:string" use="required"/>
                </xsd:extension>
            </xsd:complexContent>
        </xsd:complexType>
    </xsd:element>
</xsd:schema>
```

(The emphasized line contains an extension base for all tags that will be identifiable (meaning they have an `id` attribute that will be used as the bean identifier in the container). We are able to use this

attribute because we imported the Spring-provided '`beans`' namespace.)

The above schema will be used to configure `SimpleDateFormat` objects, directly in an XML application context file using the `<myns:dateFormat/>` element.

```
<myns:dateFormat id="dateFormat"
    pattern="yyyy-MM-dd HH:mm"
    lenient="true"/>
```

Note that after we've created the infrastructure classes, the above snippet of XML will essentially be exactly the same as the following XML snippet. In other words, we're just creating a bean in the container, identified by the name '`dateFormat`' of type `SimpleDateFormat`, with a couple of properties set.

```
<bean id="dateFormat" class="java.text.SimpleDateFormat">
    <constructor-arg value="yyyy-MM-dd HH:mm"/>
    <property name="lenient" value="true"/>
</bean>
```



The schema-based approach to creating configuration format allows for tight integration with an IDE that has a schema-aware XML editor. Using a properly authored schema, you can use autocompletion to have a user choose between several configuration options defined in the enumeration.

### 9.2.3. Coding a NamespaceHandler

In addition to the schema, we need a `NamespaceHandler` that will parse all elements of this specific namespace Spring encounters while parsing configuration files. The `NamespaceHandler` should in our case take care of the parsing of the `myns:dateFormat` element.

The `NamespaceHandler` interface is pretty simple in that it features just three methods:

- `init()` - allows for initialization of the `NamespaceHandler` and will be called by Spring before the handler is used
- `BeanDefinition parse(Element, ParserContext)` - called when Spring encounters a top-level element (not nested inside a bean definition or a different namespace). This method can register bean definitions itself and/or return a bean definition.
- `BeanDefinitionHolder decorate(Node, BeanDefinitionHolder, ParserContext)` - called when Spring encounters an attribute or nested element of a different namespace. The decoration of one or more bean definitions is used for example with the [out-of-the-box scopes Spring supports](#). We'll start by highlighting a simple example, without using decoration, after which we will show decoration in a somewhat more advanced example.

Although it is perfectly possible to code your own `NamespaceHandler` for the entire namespace (and hence provide code that parses each and every element in the namespace), it is often the case that each top-level XML element in a Spring XML configuration file results in a single bean definition (as

in our case, where a single `<myns:format/>` element results in a single `SimpleDateFormat` bean definition). Spring features a number of convenience classes that support this scenario. In this example, we'll make use of the `NamespaceHandlerSupport` class:

```
package org.springframework.samples.xml;

import org.springframework.beans.factory.xml.NamespaceHandlerSupport;

public class MyNamespaceHandler extends NamespaceHandlerSupport {

    public void init() {
        <strong>registerBeanDefinitionParser("format", new
SimpleDateFormatBeanDefinitionParser());</strong>
    }

}
```

The observant reader will notice that there isn't actually a whole lot of parsing logic in this class. Indeed... the `NamespaceHandlerSupport` class has a built-in notion of delegation. It supports the registration of any number of `BeanDefinitionParser` instances, to which it will delegate to when it needs to parse an element in its namespace. This clean separation of concerns allows a `NamespaceHandler` to handle the orchestration of the parsing of *all* of the custom elements in its namespace, while delegating to `BeanDefinitionParsers` to do the grunt work of the XML parsing; this means that each `BeanDefinitionParser` will contain just the logic for parsing a single custom element, as we can see in the next step.

#### 9.2.4. BeanDefinitionParser

A `BeanDefinitionParser` will be used if the `NamespaceHandler` encounters an XML element of the type that has been mapped to the specific bean definition parser (which is '`format`' in this case). In other words, the `BeanDefinitionParser` is responsible for parsing *one* distinct top-level XML element defined in the schema. In the parser, we'll have access to the XML element (and thus its subelements too) so that we can parse our custom XML content, as can be seen in the following example:

```

package org.springframework.samples.xml;

import org.springframework.beans.factory.support.BeanDefinitionBuilder;
import org.springframework.beans.factory.xml.AbstractSingleBeanDefinitionParser;
import org.springframework.util.StringUtils;
import org.w3c.dom.Element;

import java.text.SimpleDateFormat;

public class SimpleDateFormatBeanDefinitionParser extends
AbstractSingleBeanDefinitionParser { ①

    protected Class<?> getBeanClass(Element element) {
        return SimpleDateFormat.class; ②
    }

    protected void doParse(Element element, BeanDefinitionBuilder bean) {
        // this will never be null since the schema explicitly requires that a value
        be supplied
        String pattern = element.getAttribute("pattern");
        bean.addConstructorArg(pattern);

        // this however is an optional property
        String lenient = element.getAttribute("lenient");
        if (StringUtils.hasText(lenient)) {
            bean.addPropertyValue("lenient", Boolean.valueOf(lenient));
        }
    }
}

```

- ① We use the Spring-provided `AbstractSingleBeanDefinitionParser` to handle a lot of the basic grunt work of creating a *single BeanDefinition*.
- ② We supply the `AbstractSingleBeanDefinitionParser` superclass with the type that our single `BeanDefinition` will represent.

In this simple case, this is all that we need to do. The creation of our single `BeanDefinition` is handled by the `AbstractSingleBeanDefinitionParser` superclass, as is the extraction and setting of the bean definition's unique identifier.

### 9.2.5. Registering the handler and the schema

The coding is finished! All that remains to be done is to somehow make the Spring XML parsing infrastructure aware of our custom element; we do this by registering our custom `namespaceHandler` and custom XSD file in two special purpose properties files. These properties files are both placed in a '`META-INF`' directory in your application, and can, for example, be distributed alongside your binary classes in a JAR file. The Spring XML parsing infrastructure will automatically pick up your new extension by consuming these special properties files, the formats of which are detailed below.

## 'META-INF/spring.handlers'

The properties file called '`spring.handlers`' contains a mapping of XML Schema URIs to namespace handler classes. So for our example, we need to write the following:

```
http\://www.mycompany.com/schema/myns=org.springframework.samples.xml.MyNamespaceHandler
```

(The ':' character is a valid delimiter in the Java properties format, and so the ':' character in the URI needs to be escaped with a backslash.)

The first part (the key) of the key-value pair is the URI associated with your custom namespace extension, and needs to *match exactly* the value of the '`targetNamespace`' attribute as specified in your custom XSD schema.

## 'META-INF/spring.schemas'

The properties file called '`spring.schemas`' contains a mapping of XML Schema locations (referred to along with the schema declaration in XML files that use the schema as part of the '`xsi:schemaLocation`' attribute) to *classpath* resources. This file is needed to prevent Spring from absolutely having to use a default `EntityResolver` that requires Internet access to retrieve the schema file. If you specify the mapping in this properties file, Spring will search for the schema on the classpath (in this case '`myns.xsd`' in the '`org.springframework.samples.xml`' package):

```
http\://www.mycompany.com/schema/myns/myns.xsd=org/springframework/samples/xml/myns.xsd
```

The upshot of this is that you are encouraged to deploy your XSD file(s) right alongside the `NamespaceHandler` and `BeanDefinitionParser` classes on the classpath.

### 9.2.6. Using a custom extension in your Spring XML configuration

Using a custom extension that you yourself have implemented is no different from using one of the 'custom' extensions that Spring provides straight out of the box. Find below an example of using the custom `<dateformat/>` element developed in the previous steps in a Spring XML configuration file.

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:myns="http://www.mycompany.com/schema/myns"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.mycompany.com/schema/myns
        http://www.mycompany.com/schema/myns/myns.xsd">

    <!-- as a top-level bean -->
    <myns:dateFormat id="defaultDateFormat" pattern="yyyy-MM-dd HH:mm" lenient="true"
    "/>

    <bean id="jobDetailTemplate" abstract="true">
        <property name="dateFormat">
            <!-- as an inner bean -->
            <myns:dateFormat pattern="HH:mm MM-dd-yyyy"/>
        </property>
    </bean>

</beans>

```

## 9.2.7. Meatier examples

Find below some much meatier examples of custom XML extensions.

### Nesting custom tags within custom tags

This example illustrates how you might go about writing the various artifacts required to satisfy a target of the following configuration:

```

<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:foo="http://www.foo.com/schema/component"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.foo.com/schema/component
        http://www.foo.com/schema/component/component.xsd">

    <foo:component id="bionic-family" name="Bionic-1">
        <foo:component name="Mother-1">
            <foo:component name="Karate-1"/>
            <foo:component name="Sport-1"/>
        </foo:component>
        <foo:component name="Rock-1"/>
    </foo:component>

</beans>

```

The above configuration actually nests custom extensions within each other. The class that is actually configured by the above `<foo:component/>` element is the `Component` class (shown directly below). Notice how the `Component` class does *not* expose a setter method for the '`components`' property; this makes it hard (or rather impossible) to configure a bean definition for the `Component` class using setter injection.

```
package com.foo;

import java.util.ArrayList;
import java.util.List;

public class Component {

    private String name;
    private List<Component> components = new ArrayList<Component>();

    // mmm, there is no setter method for the 'components'
    public void addComponent(Component component) {
        this.components.add(component);
    }

    public List<Component> getComponents() {
        return components;
    }

    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

}
```

The typical solution to this issue is to create a custom **FactoryBean** that exposes a setter property for the '**components**' property.

```

package com.foo;

import org.springframework.beans.factory.FactoryBean;

import java.util.List;

public class ComponentFactoryBean implements FactoryBean<Component> {

    private Component parent;
    private List<Component> children;

    public void setParent(Component parent) {
        this.parent = parent;
    }

    public void setChildren(List<Component> children) {
        this.children = children;
    }

    public Component getObject() throws Exception {
        if (this.children != null && this.children.size() > 0) {
            for (Component child : children) {
                this.parent.addComponent(child);
            }
        }
        return this.parent;
    }

    public Class<Component> getObjectType() {
        return Component.class;
    }

    public boolean isSingleton() {
        return true;
    }

}

```

This is all very well, and does work nicely, but exposes a lot of Spring plumbing to the end user. What we are going to do is write a custom extension that hides away all of this Spring plumbing. If we stick to [the steps described previously](#), we'll start off by creating the XSD schema to define the structure of our custom tag.

```

<?xml version="1.0" encoding="UTF-8" standalone="no"?>

<xsd:schema xmlns="http://www.foo.com/schema/component"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://www.foo.com/schema/component"
    elementFormDefault="qualified"
    attributeFormDefault="unqualified">

    <xsd:element name="component">
        <xsd:complexType>
            <xsd:choice minOccurs="0" maxOccurs="unbounded">
                <xsd:element ref="component"/>
            </xsd:choice>
            <xsd:attribute name="id" type="xsd:ID"/>
            <xsd:attribute name="name" use="required" type="xsd:string"/>
        </xsd:complexType>
    </xsd:element>

</xsd:schema>

```

We'll then create a custom `NamespaceHandler`.

```

package com.foo;

import org.springframework.beans.factory.xml.NamespaceHandlerSupport;

public class ComponentNamespaceHandler extends NamespaceHandlerSupport {

    public void init() {
        registerBeanDefinitionParser("component", new ComponentBeanDefinitionParser()
    );
    }

}

```

Next up is the custom `BeanDefinitionParser`. Remember that what we are creating is a `BeanDefinition` describing a `ComponentFactoryBean`.

```

package com.foo;

import org.springframework.beans.factory.config.BeanDefinition;
import org.springframework.beans.factory.support.AbstractBeanDefinition;
import org.springframework.beans.factory.support.BeanDefinitionBuilder;
import org.springframework.beans.factory.support.ManagedList;
import org.springframework.beans.factory.xml.AbstractBeanDefinitionParser;
import org.springframework.beans.factory.xml.ParserContext;
import org.springframework.util.xml.DomUtils;
import org.w3c.dom.Element;

```

```

import java.util.List;

public class ComponentBeanDefinitionParser extends AbstractBeanDefinitionParser {

    protected AbstractBeanDefinition parseInternal(Element element, ParserContext parserContext) {
        return parseComponentElement(element);
    }

    private static AbstractBeanDefinition parseComponentElement(Element element) {
        BeanDefinitionBuilder factory = BeanDefinitionBuilder.rootBeanDefinition(ComponentFactoryBean.class);
        factory.addPropertyValue("parent", parseComponent(element));

        List<Element> childElements = DomUtils.getChildElementsByTagName(element, "component");
        if (childElements != null && childElements.size() > 0) {
            parseChildComponents(childElements, factory);
        }

        return factory.getBeanDefinition();
    }

    private static BeanDefinition parseComponent(Element element) {
        BeanDefinitionBuilder component = BeanDefinitionBuilder.rootBeanDefinition(Component.class);
        component.addPropertyValue("name", element.getAttribute("name"));
        return component.getBeanDefinition();
    }

    private static void parseChildComponents(List<Element> childElements, BeanDefinitionBuilder factory) {
        ManagedList<BeanDefinition> children = new ManagedList<BeanDefinition>(childElements.size());
        for (Element element : childElements) {
            children.add(parseComponentElement(element));
        }
        factory.addPropertyValue("children", children);
    }
}

```

Lastly, the various artifacts need to be registered with the Spring XML infrastructure.

```
# in 'META-INF/spring.handlers'
http\://www.foo.com/schema/component=com.foo.ComponentNamespaceHandler
```

```
# in 'META-INF/spring.schemas'  
http\://www.foo.com/schema/component/component.xsd=com/foo/component.xsd
```

## Custom attributes on 'normal' elements

Writing your own custom parser and the associated artifacts isn't hard, but sometimes it is not the right thing to do. Consider the scenario where you need to add metadata to already existing bean definitions. In this case you certainly don't want to have to go off and write your own entire custom extension; rather you just want to add an additional attribute to the existing bean definition element.

By way of another example, let's say that the service class that you are defining a bean definition for a service object that will (unknown to it) be accessing a clustered JCache, and you want to ensure that the named JCache instance is eagerly started within the surrounding cluster:

```
<bean id="checkingAccountService" class="com.foo.DefaultCheckingAccountService"  
      jcache:cache-name="checking.account">  
    <!-- other dependencies here... -->  
</bean>
```

What we are going to do here is create another `BeanDefinition` when the '`jcache:cache-name`' attribute is parsed; this `BeanDefinition` will then initialize the named JCache for us. We will also modify the existing `BeanDefinition` for the '`checkingAccountService`' so that it will have a dependency on this new JCache-initializing `BeanDefinition`.

```
package com.foo;  
  
public class JCacheInitializer {  
  
    private String name;  
  
    public JCacheInitializer(String name) {  
        this.name = name;  
    }  
  
    public void initialize() {  
        // lots of JCache API calls to initialize the named cache...  
    }  
}
```

Now onto the custom extension. Firstly, the authoring of the XSD schema describing the custom attribute (quite easy in this case).

```

<?xml version="1.0" encoding="UTF-8" standalone="no"?>

<xsd:schema xmlns="http://www.foo.com/schema/jcache"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://www.foo.com/schema/jcache"
    elementFormDefault="qualified">

    <xsd:attribute name="cache-name" type="xsd:string"/>

</xsd:schema>

```

Next, the associated `NamespaceHandler`.

```

package com.foo;

import org.springframework.beans.factory.xml.NamespaceHandlerSupport;

public class JCacheNamespaceHandler extends NamespaceHandlerSupport {

    public void init() {
        super.registerBeanDefinitionDecoratorForAttribute("cache-name",
            new JCacheInitializingBeanDefinitionDecorator());
    }

}

```

Next, the parser. Note that in this case, because we are going to be parsing an XML attribute, we write a `BeanDefinitionDecorator` rather than a `BeanDefinitionParser`.

```

package com.foo;

import org.springframework.beans.factory.config.BeanDefinitionHolder;
import org.springframework.beans.factory.support.AbstractBeanDefinition;
import org.springframework.beans.factory.support.BeanDefinitionBuilder;
import org.springframework.beans.factory.xml.BeanDefinitionDecorator;
import org.springframework.beans.factory.xml.ParserContext;
import org.w3c.dom.Attr;
import org.w3c.dom.Node;

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

public class JCacheInitializingBeanDefinitionDecorator implements
BeanDefinitionDecorator {

    private static final String[] EMPTY_STRING_ARRAY = new String[0];

```

```

public BeanDefinitionHolder decorate(Node source, BeanDefinitionHolder holder,
    ParserContext ctx) {
    String initializerBeanName = registerJCacheInitializer(source, ctx);
    createDependencyOnJCacheInitializer(holder, initializerBeanName);
    return holder;
}

private void createDependencyOnJCacheInitializer(BeanDefinitionHolder holder,
    String initializerBeanName) {
    AbstractBeanDefinition definition = ((AbstractBeanDefinition) holder
        .getBeanDefinition());
    String[] dependsOn = definition.getDependsOn();
    if (dependsOn == null) {
        dependsOn = new String[]{initializerBeanName};
    } else {
        List dependencies = new ArrayList(Arrays.asList(dependsOn));
        dependencies.add(initializerBeanName);
        dependsOn = (String[]) dependencies.toArray(EMPTY_STRING_ARRAY);
    }
    definition.setDependsOn(dependsOn);
}

private String registerJCacheInitializer(Node source, ParserContext ctx) {
    String cacheName = ((Attr) source).getValue();
    String beanName = cacheName + "-initializer";
    if (!ctx.getRegistry().containsBeanDefinition(beanName)) {
        BeanDefinitionBuilder initializer = BeanDefinitionBuilder
            .rootBeanDefinition(JCacheInitializer.class);
        initializer.addConstructorArg(cacheName);
        ctx.getRegistry().registerBeanDefinition(beanName, initializer
            .getBeanDefinition());
    }
    return beanName;
}

}

```

Lastly, the various artifacts need to be registered with the Spring XML infrastructure.

```
# in 'META-INF/spring.handlers'
http://www.foo.com/schema/jcache=com.foo.JCacheNamespaceHandler
```

```
# in 'META-INF/spring.schemas'
http://www.foo.com/schema/jcache/jcache.xsd=com/foo/jcache.xsd
```