SPRING BOOT

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1. Introduction to Spring Boot

1.1 What is Spring Boot?

Spring Boot is an **open-source, Java-based framework** used to create stand-alone, production-ready Spring applications with minimal configuration. Built on top of the Spring Framework, it simplifies bootstrapping and development by offering default settings and reducing boilerplate code.

1.2 Features of Spring Boot

- **Auto-Configuration**: Automatically configures your application based on the dependencies declared in the project.
- **Standalone Applications**: Enables creating applications that can run independently using embedded servers like Tomcat or Jetty.
- **Production-Ready**: Includes built-in features like metrics, health checks, and external configuration via Spring Boot Actuator.

- **Opinionated Defaults**: Reduces the need for manual configurations with pre-defined, best-practice defaults.
- **No XML Configuration**: Encourages convention over configuration using annotations instead of XML files.

1.3 Advantages of Using Spring Boot

- ✅ **Rapid Application Development**
- ✅ **Auto-Configuration**
- ✅ **Embedded Web Servers**
  - Supports Tomcat, Jetty, Undertow
  - Run applications using: `java -jar app.jar`
- ✅ **Microservices-Friendly**
- ✅ **Production-Ready Features**
  - Health checks, metrics, externalized config via Actuator
- ✅ **Reduced Boilerplate Code**
- ✅ **Easy Dependency Management**
- ✅ **Seamless Integration with Spring Ecosystem**
  - Compatible with Spring Data JPA, Spring Security, Spring WebFlux, Spring Batch
- ✅ **Flexible Configuration**
  - Supports `application.properties` and `application.yml`
- ✅ **Community and Ecosystem Support**

1.4 Use Cases

Spring Boot is used in a wide variety of domains:

- RESTful API development
- Microservices architecture
- Rapid prototyping
- Enterprise web applications
- Cloud-native applications

Real Life Examples:

- 🔹 E-Commerce Platforms
- 🔹 Banking & Financial Services
- 🔹 Healthcare Systems
- 🔹 Travel and Booking Platforms
- 🔹 Learning Management Systems (LMS)
- 🔹 Logistics & Supply Chain Systems
- 🔹 Content Management Systems (CMS)
- 🔹 HR & Payroll Systems
- 🔹 IoT Backend Services
- 🔹 Microservices in Large Enterprises

Language Support:

- ✅ Java (Primary Language)
- ✅ Kotlin
- ✅ Groovy
- ⚠️ Scala (Limited Support)

1.5 Spring Boot vs Spring Framework

Key Differences

Feature / Aspect	Spring Framework	Spring Boot
Setup & Configuration	Manual XML/Java-based configuration	Auto-configuration, zero XML
Application Startup	Requires external servlet container	Comes with embedded servers (Tomcat, Jetty, Undertow)
Dependency Management	Developer-managed dependencies	Pre-configured starter dependencies
Boilerplate Code	More boilerplate and configuration	Minimal configuration and boilerplate
Project Structure	Developer decides from scratch	Convention over configuration
Production Readiness	Requires manual setup of monitoring tools	Built-in Actuator endpoints for health, metrics, etc.
Build Output	WAR (typically)	Executable JAR by default
Learning Curve	Steeper for beginners	Easier and quicker to get started
CLI Support	No	Yes, via Spring Boot CLI
Microservices Development	Needs custom setup	Tailored for microservices architecture

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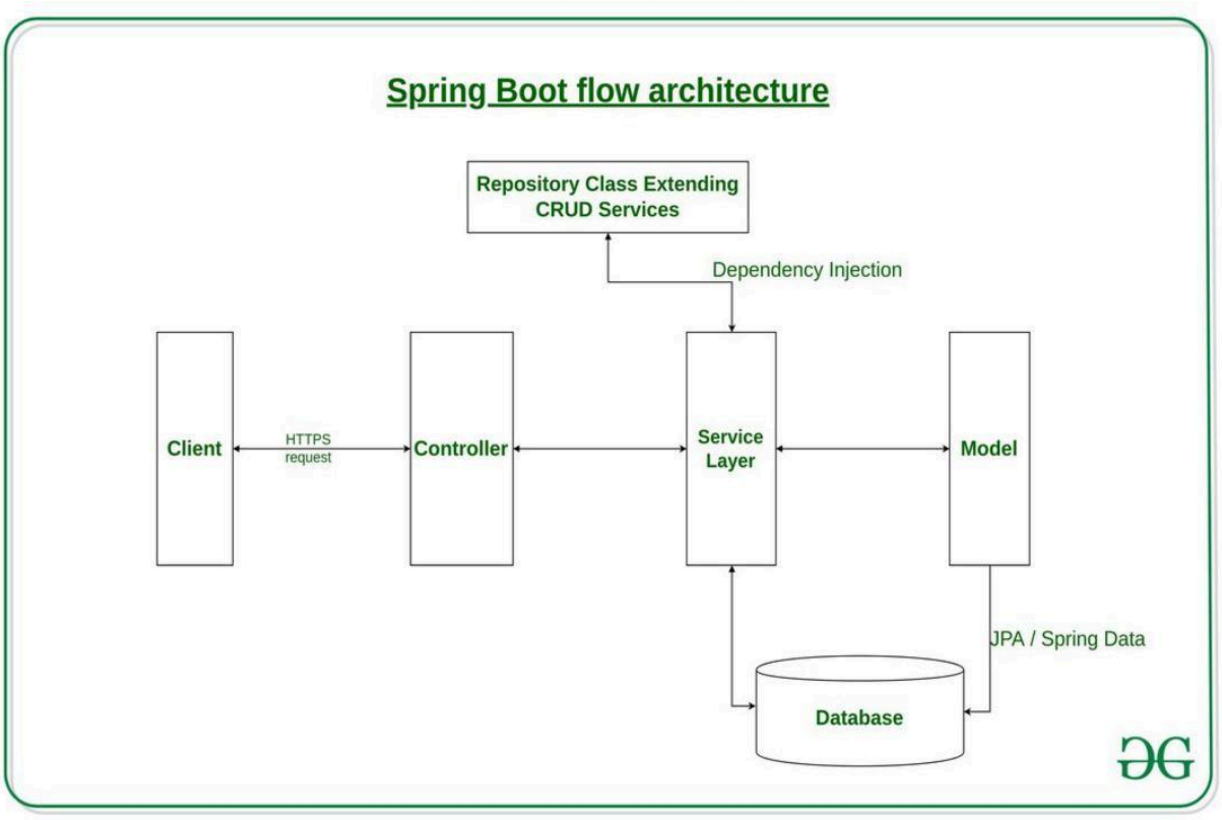
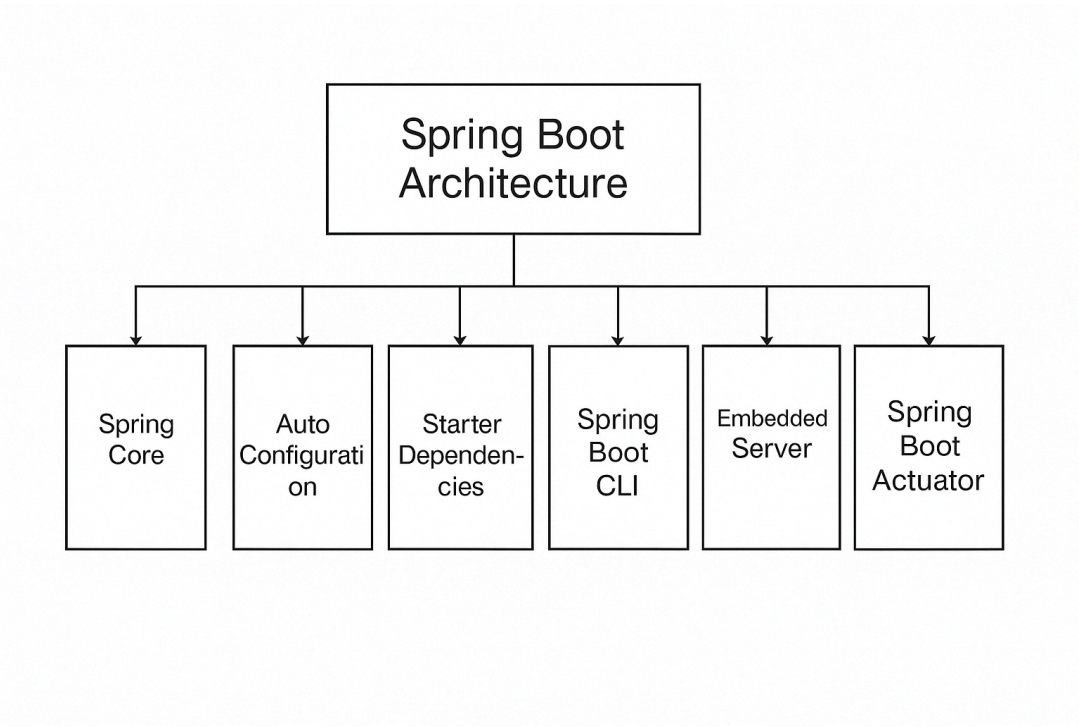
1.5 Spring Boot Architecture



Spring Boot architecture is based on:

- **Spring Core**: Base dependency injection and AOP framework
- **Auto Configuration**: Automatically configures beans based on classpath
- **Starter Dependencies**: Predefined sets of dependencies for various features (web, data, etc.)
- **Spring Boot CLI**: Command-line tool to run and test applications
- **Embedded Server**: Tomcat, Jetty, or Undertow
- **Spring Boot Actuator**: Provides operational endpoints for monitoring and management



Topics Summary:

- **1. Introduction**
  - **1.1. What is Spring Boot?**
  - **1.2. Features of Spring Boot**
  - **1.3. Advantages and Use cases of using Spring Boot**
  - **1.4. Spring Boot vs Spring Framework**
  - **1.5. Spring Boot Architecture**

- **2. Getting Started**
  - **2.1. Setting up Spring Boot Project (Spring Initializr, Maven, Gradle)**
  - **2.2. Project Structure Overview**
  - **2.3. Application Entry Point (`@SpringBootApplication`)**
  - **2.4. Running the Application**

- **3. Core Concepts**
  - **3.1. Spring Boot Annotations**
    1. **`@SpringBootApplication`**
    2. **`@Component`, `@Service`, `@Repository`, `@Controller`, `@RestController`**
    3. **`@Autowired`, `@Qualifier`**

4. `@Configuration`, `@Bean`

3.2. Dependency Injection (DI)

3.3. Inversion of Control (IoC)

➢ **4. Configuration**

4.1. `application.properties` vs `application.yml`

4.2. External Configuration (env vars, CLI args)

4.3. Profiles (`@Profile`)

4.4. Property Injection: `@Value`, `@ConfigurationProperties`

➢ **5. Spring Boot Starters**

5.1. What are Starters?

5.2. Common Starters

1. `spring-boot-starter-web`
2. `spring-boot-starter-data-jpa`
3. `spring-boot-starter-security`
4. `spring-boot-starter-test`, etc.

➢ **6. Web Development (Spring MVC)**

6.1. Creating REST APIs (`@RestController`)

6.2. Handling Request Parameters
`@PathVariable`, `@RequestParam`, `@RequestBody`

6.3. ResponseEntity and Status Codes

6.4. Exception Handling
`@ControllerAdvice`, `@ExceptionHandler`

6.5. Content Negotiation

➢ **7. Data Access**

7.1. Spring Data JPA

1. Entity Classes (`@Entity`)
2. Repositories (`JpaRepository`, `CrudRepository`)
3. Custom Queries (`@Query`)
4. Pagination and Sorting

7.2. JDBC with Spring Boot

7.3. MongoDB / NoSQL

7.4. Transactions (`@Transactional`)

➢ **8. Database Configuration**

8.1. H2 In-Memory Database

8.2. MySQL/PostgreSQL setup

8.3. Connection Pooling (HikariCP)

- 8.4. Schema Initialization (`schema.sql`, `data.sql`)

- **9. Validation**
  - 9.1. Bean Validation (`javax.validation`)
  - 9.2. Using `@Valid`, `@Validated`
  - 9.3. Custom Validators

- **10. Security**
  - 10.1. Spring Security Basics
  - 10.2. Authentication and Authorization
  - 10.3. Password Encoding
  - 10.4. JWT Token-based Security
  - 10.5. Role-Based Access Control

- **11. Testing**
  - 11.1. Unit Testing with JUnit
  - 11.2. Mocking with Mockito
  - 11.3. Integration Testing
  - 11.4. Web Layer Testing (`@WebMvcTest`)
  - 11.5. Data Layer Testing (`@DataJpaTest`)

- **12. Logging**
  - 12.1. SLF4J and Logback
  - 12.2. Configuring Log Levels
  - 12.3. External Log Configuration

- **13. Actuator & Monitoring**
  - 13.1. Spring Boot Actuator Overview
  - 13.2. Common Actuator Endpoints
  - 13.3. Custom Metrics
  - 13.4. Prometheus/Grafana Integration

- **14. Error Handling**
  - 14.1. Default Error Handling
  - 14.2. Custom Error Pages
  - 14.3. Global Exception Handling

- **15. Developer Tools**
  - 15.1. Spring Boot DevTools
  - 15.2. Auto Restart
  - 15.3. Live Reload

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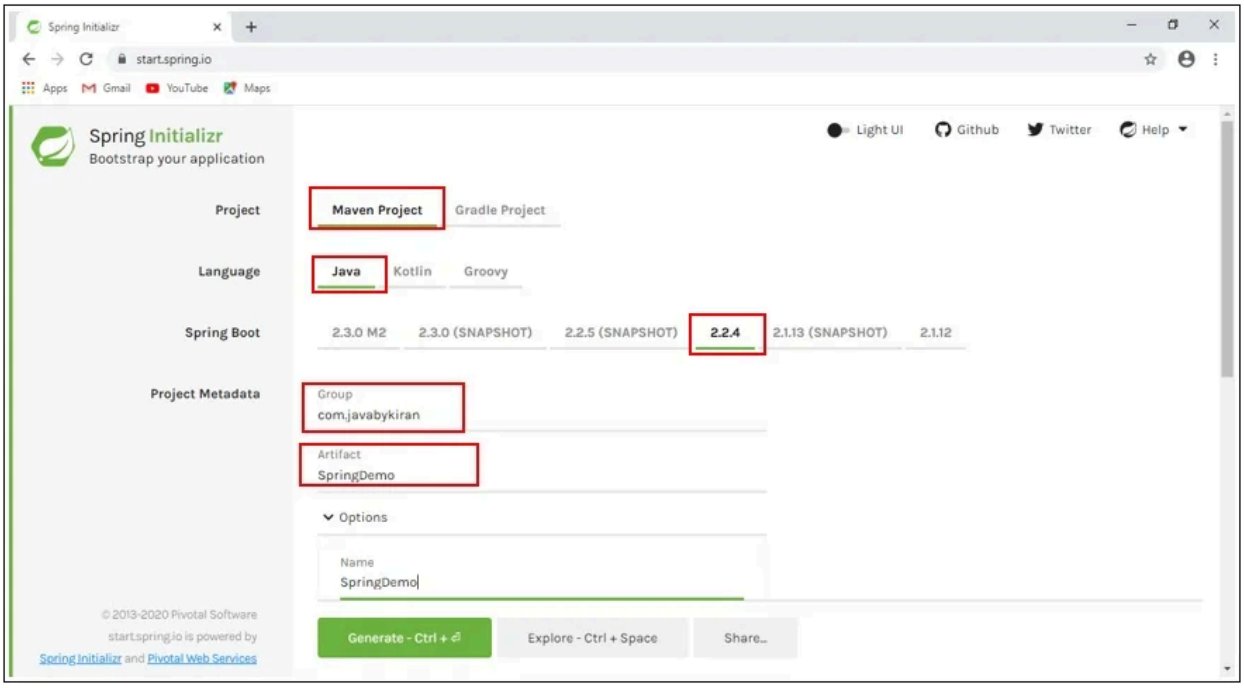
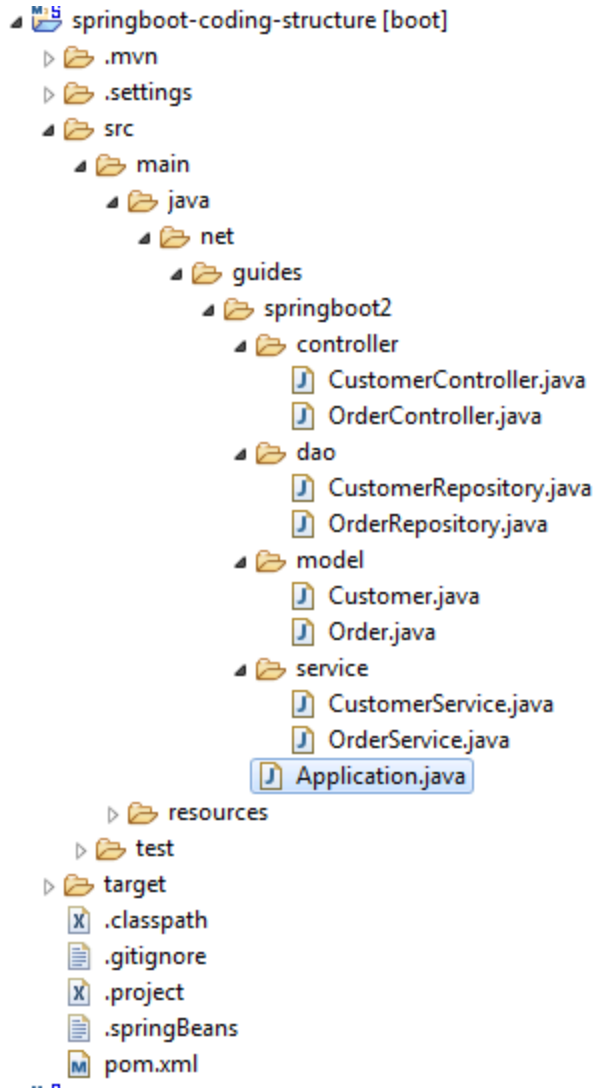
2. Getting Started

2.1. Setting up Spring Boot Project (Spring Initializr, Maven, Gradle)

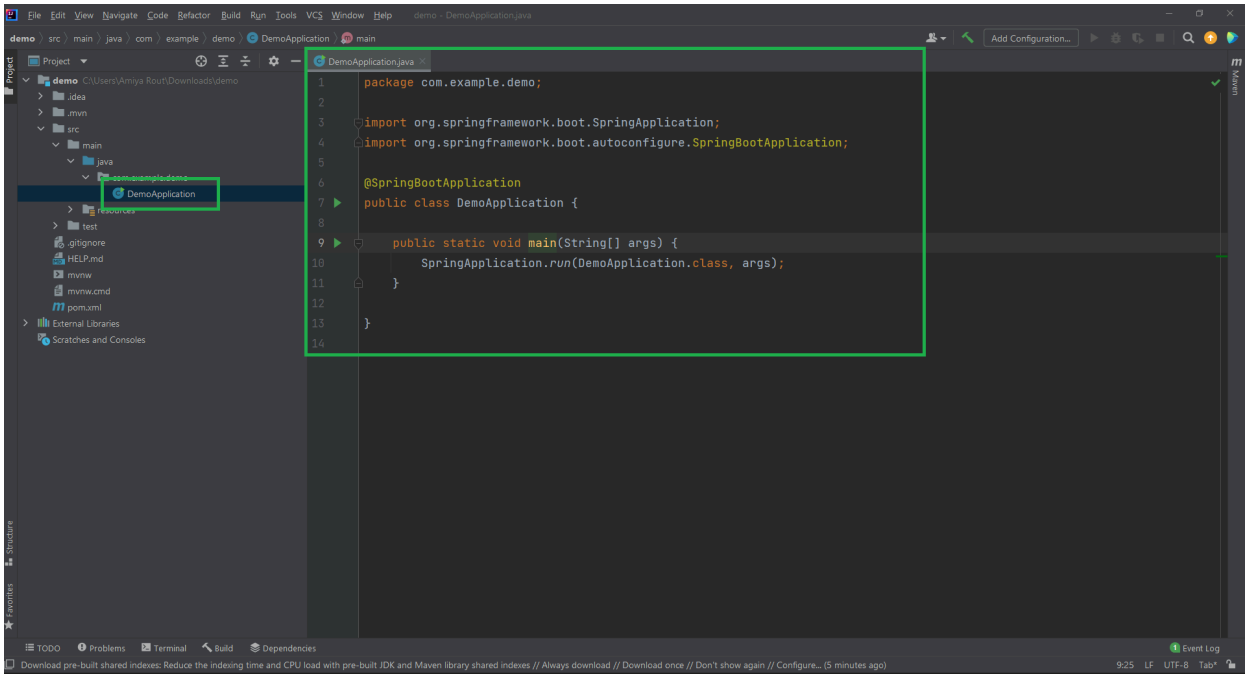
https://start.spring.io/



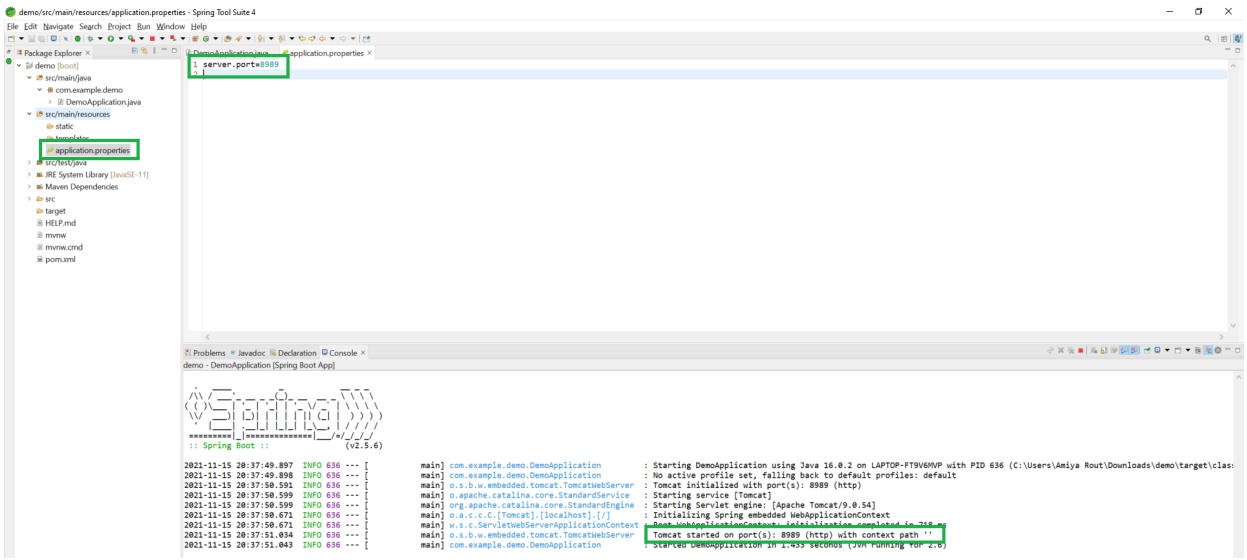
2.2. Project Structure Overview



2.3. Application Entry Point (`@SpringBootApplication`)



2.4. Running the Application



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3. Core Concepts

3.1. Spring Boot Annotations

1. `@SpringBootApplication`

The **`@SpringBootApplication`** annotation is the primary entry point of any Spring Boot application. It is a convenience annotation that combines three commonly used annotations in Spring:

`@SpringBootApplication = @Configuration + @EnableAutoConfiguration + @ComponentScan`

Declaration

```
@SpringBootApplication
public class MyApplication {
	public static void main(String[] args) {
	SpringApplication.run(MyApplication.class, args);
	}
}
```

2.`@Component`, `@Service`, `@Repository`, `@Controller`, `@RestController`

1. `@Component`

Definition

`@Component` is a generic stereotype annotation that marks a class as a Spring-managed component.

```
@Component
public class MyComponent {
    // Business logic
}
```

Use Case

Used when the class doesn't clearly fall into service, repository, or controller layers.

2. `@Service`

Definition

`@Service` is a specialization of `@Component` used to annotate **service layer** classes that contain business logic.

```
@Service
public class OrderService {
    public void processOrder() {
    // Business logic
    }
}
```

Use Case

- Encapsulates business logic
- Makes the code more readable and structured
- Can integrate with AOP (for transaction, logging, etc.)

3. `@Repository`

Definition

`@Repository` is a specialization of `@Component` used for **DAO (Data Access Object)** classes. It also provides exception translation for database errors.

```
@Repository
public class ProductRepository {
        public void save(Product product) {
        // Save to DB
        }
}
```

Use Case

- Used for data persistence
- Automatically translates exceptions to Spring's `DataAccessException`

4. `@Controller`

Definition

`@Controller` is used to define **web layer classes** in Spring MVC. It is used for rendering **views (HTML)** with model data.

```
@Controller
public class HomeController {
        @GetMapping("/")
        public String index(Model model) {
        model.addAttribute("message", "Welcome");
        return "index"; // returns view name
        }
}
```

Use Case

Used when working with traditional web applications (Thymeleaf, JSP, etc.)

5. `@RestController`

Definition

`@RestController` = `@Controller` + `@ResponseBody`
Used to define **RESTful web services**. The return values are serialized as JSON or XML and sent directly to the client.

```
@RestController

public class UserController {

        @GetMapping("/users")

        public List<User> getAllUsers() {

        return userService.getAll();

        }

}
```

Use Case

- Used in REST APIs
- Automatically serializes Java objects to JSON

Summary Table

Annotation	Layer	Inherits From	Purpose	Returns Response Body
`@Component`	Generic	-	General-purpose component	No
`@Service`	Service Layer	`@Component`	Business logic and services	No
`@Repository`	Data Layer	`@Component`	DAO & exception translation	No

`@Controller`	Web (MVC)	`@Component`	Handles web requests & returns views	No (uses View Resolver)
`@RestController`	Web (REST API)	`@Controller`	Returns JSON/XML directly to the client	Yes

3. `@Autowired`, `@Qualifier`

`@Autowired` is used to automatically wire dependencies.

`@Qualifier` is used to resolve conflicts when multiple beans of the same type are available.

1. `@Autowired`

Definition

`@Autowired` is used to automatically inject a bean from the Spring container into another bean by **type**.

```
@Component

public class CarService {


    @Autowired

    private Engine engine;


    // engine will be injected automatically

}
```

Where It Can Be Used

- On fields

- On constructors
- On setter methods

Example (Constructor Injection)

```
@Service
public class OrderService {

	private final PaymentService paymentService;

	@Autowired
	public OrderService(PaymentService paymentService) {
	this.paymentService = paymentService;
	}
}
```

2. @Qualifier

Definition

`@Qualifier` is used with `@Autowired` to **specify which bean to inject** when multiple candidates of the same type are available.

```
@Component("dieselEngine")
public class DieselEngine implements Engine { }

@Component("petrolEngine")
```

```
public class PetrolEngine implements Engine { }


@Service

public class CarService {


      @Autowired

      @Qualifier("dieselEngine")

      private Engine engine;

}
```

Use Case

- Disambiguating among multiple beans of the same type.
- Explicitly specifying the bean to be injected.

4. @Configuration, @Bean

1. @Configuration

Definition

@Configuration is a class-level annotation that indicates the class contains **bean definitions** for the Spring IoC container. It serves as a **replacement for XML-based configuration**.

```
@Configuration

public class AppConfig {

      // Bean definitions go here
```

```
}
@Configuration
public class AppConfig {
     // Bean definitions go here
}
```

2. @Bean

Definition

@Bean is a method-level annotation used inside a @Configuration-annotated class to define a **bean explicitly**.

```
@Bean
public DataSource dataSource() {
     return new HikariDataSource();
}


@Configuration
public class AppConfig {

     @Bean
     public UserService userService() {
     return new UserServiceImpl(userRepository());
     }
```

```
    @Bean
    public UserRepository userRepository() {
    return new InMemoryUserRepository();
    }
}
```

3.2. Dependency Injection (DI)

Dependency Injection is a programming technique where an object receives its dependencies from an external source rather than creating them internally.

Why Use Dependency Injection?

- Promotes **loose coupling** between classes
- Improves **testability** and **maintainability**
- Encourages **modular** and **reusable** code
- Follows **SOLID principles** (especially the "D" — Dependency Inversion Principle)

Types of Dependency Injection in Spring

Type	Description	Syntax Example
Constructor Injection	Dependencies are passed through a constructor.	Preferred for mandatory dependencies

Setter Injection	Dependencies are set via setter methods.	Suitable for optional dependencies
Field Injection	Dependencies are injected directly into fields using `@Autowired`.	Quick but less recommended for testing

Example: Constructor Injection

```
@Service

public class OrderService {

    private final PaymentService paymentService;

    @Autowired

    public OrderService(PaymentService paymentService) {

    this.paymentService = paymentService;

    }

    public void placeOrder() {

    paymentService.processPayment();

    }

}
```

Here:

- `OrderService` **depends on** `PaymentService`**.**
- **The Spring container injects** `PaymentService` **at runtime.**

Dependency Injection vs. Manual Instantiation

Manual Instantiation	With Spring DI
`PaymentService ps = new PaymentService();`	`@Autowired PaymentService paymentService;`
Tightly coupled code	Loosely coupled, easily testable

Spring Annotations for DI

Annotation	Purpose
`@Autowired`	Marks a dependency to be injected by Spring
`@Qualifier`	Resolves ambiguity when multiple beans of same type
`@Inject` (JSR-330)	Java standard equivalent of `@Autowired`
`@Value`	Injects values from properties or expressions

Benefits of Using DI in Spring Boot

- ✅ Loose Coupling: Classes are not tightly bound to specific implementations.
- ✅ Testability: Easier to write unit tests by injecting mock dependencies.

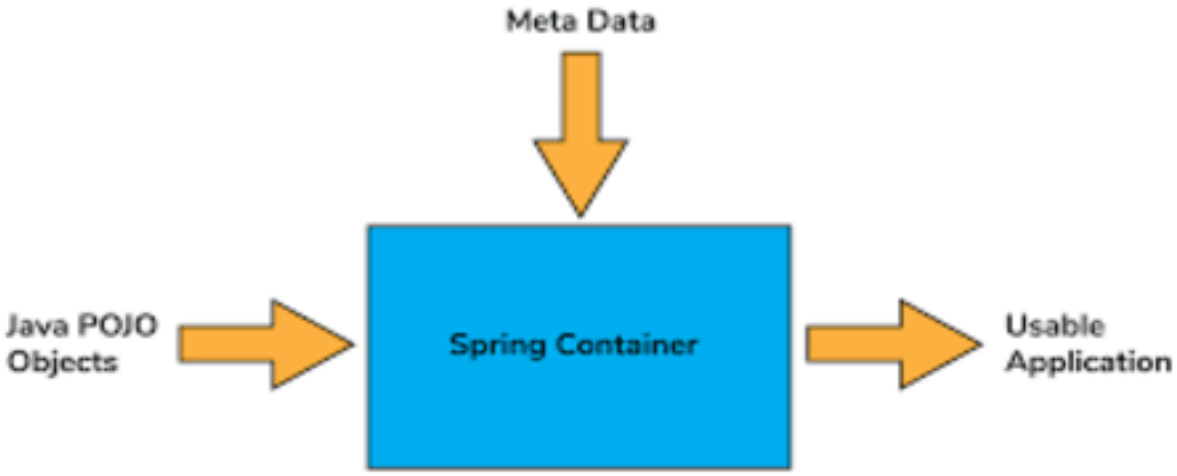
- ✅ **Readability: Clearly defines class dependencies.**
- ✅ **Maintainability: Changes to one class do not affect dependent classes directly.**

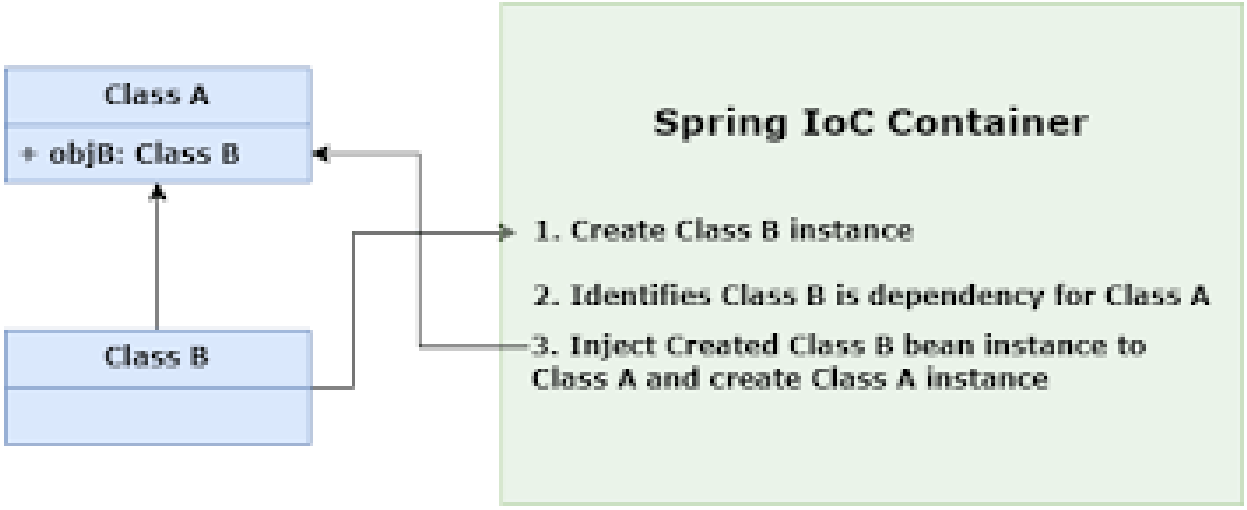
3.3. Inversion of Control (IoC)

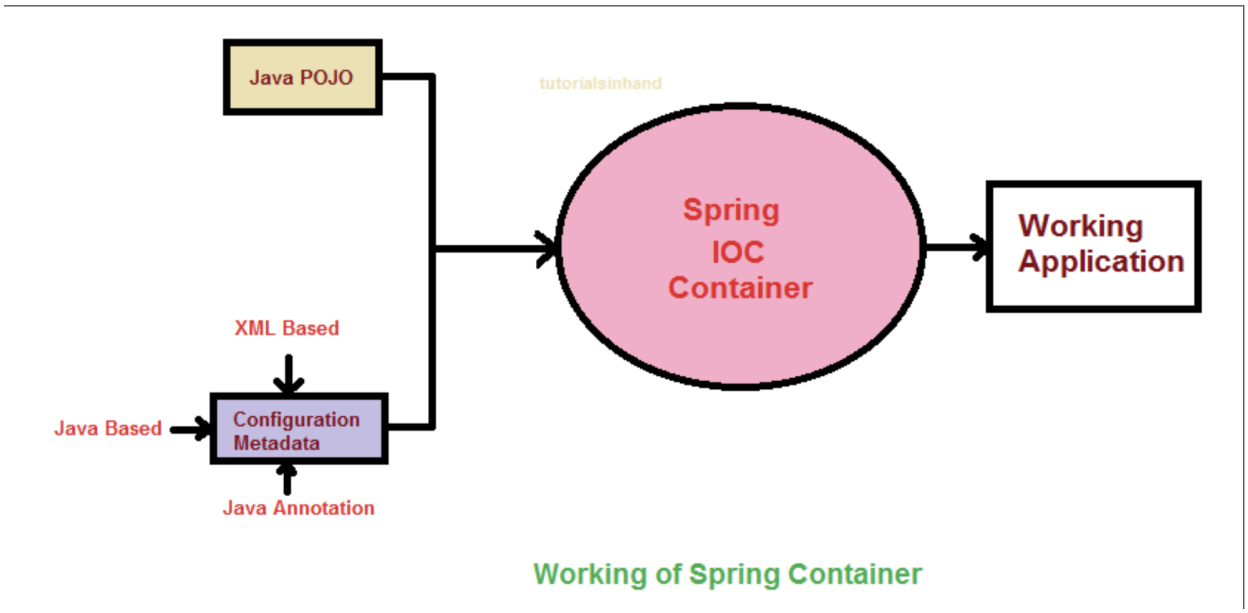
Inversion of Control (IoC) is a design principle in which the control of object creation and dependency resolution is transferred from the program (developer) to a framework or container.

How IoC Works in Spring

1. The developer defines application components (beans) using annotations or configuration.
2. Spring's IoC container:
    - Scans the classpath.
    - Detects annotated components.
    - Creates and wires dependencies automatically.
3. The container manages the entire lifecycle of those objects.


Meta Data
Java POJO Objects
Spring Container
Usable Application


Class A
+ objB: Class B
Class B
Spring IoC Container
1. Create Class B instance
2. Identifies Class B is dependency for Class A
3. Inject Created Class B bean instance to Class A and create Class A instance


Java POJO
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Spring IOC Container
Working Application
XML Based
Java Based
Configuration Metadata
Java Annotation
Working of Spring Container

4. Configuration

Overview

Configuration is a core aspect of Spring Boot that enables you to customize application behavior without changing the source code. Spring Boot provides multiple ways to configure applications, including property files, YAML files, environment variables, command-line arguments, and more.

This section explores key configuration concepts:

- application.properties vs application.yml
- External configuration sources
- Profiles for environment-specific settings
- Property injection using @Value and @ConfigurationProperties

4.1 application.properties vs application.yml

Spring Boot supports two main configuration file formats:

Feature	application.properties	application.yml

Format	Key-value pairs	Hierarchical, indentation-based
Readability for complex configs	Less readable for nested values	More readable for nested/grouped configs
Syntax	key=value	YAML syntax using indentation

Example: application.properties

```
server.port=8081

spring.datasource.url=jdbc:mysql://localhost:3306/db

spring.datasource.username=root

spring.datasource.password=pass
```

Example: application.yml

```
server:

  port: 8081

spring:

  datasource:

      url: jdbc:mysql://localhost:3306/db

      username: root

      password: pass
```

4.2 External Configuration

Spring Boot allows external configuration via:

Source	Priority (High → Low)
Command-line arguments	✅ Highest priority
Environment variables	✅ OS/environment-specific configs
application.properties/yml	✅ Default file-based config
Profile-specific files	✅ Based on environment

Example: Using Environment Variables

export SPRING_DATASOURCE_URL=jdbc:mysql://localhost:3306/db

Spring automatically maps it to `spring.datasource.url`.

Example: Using Command-line Arguments

java -jar myapp.jar --server.port=9090 --logging.level.root=DEBUG

These override values from config files.

4.3 Profiles (`@Profile`)

Spring Profiles allow you to define **environment-specific configurations** (e.g., dev, test, prod).

How to Use Profiles

- Create profile-specific property files:
    - `application-dev.properties`
    - `application-prod.yml`
- Activate profile using:
    - `Application.properties`:

spring.profiles.active=dev

    - Or via CLI:

      java -jar app.jar --spring.profiles.active=prod

Example: Conditional Bean with `@Profile`

```
@Configuration
@Profile("dev")
public class DevConfig {
      @Bean
      public String dataSource() {
      return "H2 In-Memory DB for Dev";
      }
}
```

```
@Configuration

@Profile("prod")

public class ProdConfig {

      @Bean

      public String dataSource() {

      return "MySQL DB for Production";

      }

}
```

4.4 Property Injection: @Value vs @ConfigurationProperties

Spring provides two ways to inject properties into Java classes.

1. @Value Annotation

- Injects individual values from properties or YAML files.
- Lightweight and direct.

```
@Component

public class AppSettings {


      @Value("${server.port}")

      private int port;
```

```
    @Value("${custom.message:Default Message}")
    private String message; // Fallback value if not defined
}
```

2. `@ConfigurationProperties` Annotation

- Maps a **group of related properties** into a POJO.
- Cleaner for structured configs.

YAML Example

```
app:
  name: MyApp
  version: 1.0
```

```
@Component
@ConfigurationProperties(prefix = "app")
public class AppProperties {
    private String name;
    private String version;

    // Getters and Setters
}
```

Enable Binding (if not using `@SpringBootApplication`)

@EnableConfigurationProperties(AppProperties.class)

Comparison Table

Feature	`@Value`	`@ConfigurationProperties`
Purpose	**Inject individual values**	**Bind multiple related properties**
Use Case	**Simple property access**	**Structured/grouped configuration**
Validation Support	**Limited**	**Strong (with JSR-303 annotations)**
Default Value Support	**Yes (`@Value("${key:default}")`)**	**No (use validation instead)**

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5. Spring Boot Starters

5.1 What are Starters?

> A **Starter** is a **pre-defined set of dependencies** bundled under a single starter module, designed to support specific application needs (e.g., web, JPA, security).

Key Benefits

- Simplifies Maven/Gradle configuration
- Reduces boilerplate dependency management

- Ensures compatible versions for Spring Boot

Example pom.xml

<!-- Instead of specifying multiple web libraries manually -->

<dependency>

  <groupId>org.springframework.boot</groupId>

  <artifactId>spring-boot-starter-web</artifactId>

</dependency>

5.2 Common Starters

Below are the most frequently used Spring Boot starters:

5.2.1 `spring-boot-starter-web`

Used to build **web applications and RESTful services** using Spring MVC.

Includes:

- Spring MVC
- Jackson (for JSON binding)
- Embedded Tomcat (by default)

Example Use Case:

@RestController

public class HelloController {

    @GetMapping("/hello")

    public String greet() {

```
    return "Hello, World!";
    }
}
```

5.2.2 `spring-boot-starter-data-jpa`

Used to enable **Spring Data JPA** for data access with relational databases.

Includes:

- Spring Data JPA
- Hibernate
- Spring ORM

Example Use Case:

```
@Entity
public class User {
    @Id @GeneratedValue
    private Long id;
    private String name;
}

public interface UserRepository extends JpaRepository<User, Long> {}
```

5.2.3 `spring-boot-starter-security`

Used to add **authentication and authorization** to your application.

Includes:

- Spring Security

Example Use Case:

Secures all endpoints by default. You can configure custom login:

```
@Configuration
public class SecurityConfig extends WebSecurityConfigurerAdapter {
        @Override
        protected void configure(HttpSecurity http) throws Exception {
        http.authorizeRequests()
        .anyRequest().authenticated()
        .and().formLogin();
        }
}
```

5.2.4 `spring-boot-starter-test`

Used to write **unit and integration tests**.

Includes:

- JUnit 5
- Mockito
- Spring Test
- AssertJ

Example Use Case:

```
@SpringBootTest
public class MyServiceTest {

        @Autowired
```

```
    private MyService myService;


    @Test
    void testLogic() {
    assertEquals("expected", myService.doSomething());
    }
}
```

Other Useful Starters

Starter	Purpose
`spring-boot-starter-thymeleaf`	HTML template rendering
`spring-boot-starter-mail`	Sending emails
`spring-boot-starter-actuator`	Monitoring and managing applications
`spring-boot-starter-validation`	Bean validation using Hibernate Validator

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6. Web Development with Spring Boot (Spring MVC)

Overview

Spring Boot supports full-stack **web development** using **Spring MVC**, allowing you to build RESTful APIs and web applications easily. This section covers core web development concepts such as REST controllers, request handling, exception management, and content negotiation.

6.1 Creating REST APIs (`@RestController`)

`@RestController` combines `@Controller` and `@ResponseBody`, enabling RESTful endpoints.

Example

```
@RestController
@RequestMapping("/api/users")
public class UserController {

        @GetMapping("/{id}")
        public User getUser(@PathVariable Long id) {
        return new User(id, "John Doe");
        }
}
```

6.2 Handling Request Parameters

6.2.1 `@PathVariable`, `@RequestParam`, `@RequestBody`

Annotation	Description	Example Usage
`@PathVariable`	Binds a URL segment to a method parameter	`/users/{id}` → `@PathVariable Long id`
`@RequestParam`	Extracts query parameters from the URL	`/users?role=admin` → `@RequestParam String role`
`@RequestBody`	Binds request JSON/XML body to an object	JSON POST → `@RequestBody User user`

```
@PostMapping("/create")
public ResponseEntity<String> createUser(@RequestBody User user) {
        return ResponseEntity.ok("User created: " + user.getName());
}

@GetMapping("/find")
public String findUser(@RequestParam String role) {
        return "Finding user with role: " + role;
}
```

6.3 ResponseEntity and Status Codes

`ResponseEntity` allows customizing the response body, headers, and HTTP status.

Example

```
@GetMapping("/{id}")
public ResponseEntity<User> getUser(@PathVariable Long id) {
        User user = userService.findById(id);
        if (user == null) {
        return ResponseEntity.status(HttpStatus.NOT_FOUND).build();
        }
        return ResponseEntity.ok(user);
}
```

6.4 Exception Handling

6.4.1 `@ControllerAdvice` and `@ExceptionHandler`

Global exception handling using `@ControllerAdvice` and specific error response logic using `@ExceptionHandler`.

Example

```
@ControllerAdvice
public class GlobalExceptionHandler {

	@ExceptionHandler(UserNotFoundException.class)
	public ResponseEntity<String> handleUserNotFound(UserNotFoundException ex) {
	return ResponseEntity.status(HttpStatus.NOT_FOUND).body(ex.getMessage());
	}
}
```

6.5 Content Negotiation

Spring automatically supports **content negotiation**, allowing responses in different formats (e.g., JSON, XML) based on `Accept` headers.

Example

```
@GetMapping(value = "/info", produces = { MediaType.APPLICATION_JSON_VALUE,
MediaType.APPLICATION_XML_VALUE })
public User getInfo() {
	return new User(1L, "Alice");
}
```

- Request `Accept: application/json` → JSON
- Request `Accept: application/xml` → XML

---

7. Data Access in Spring Boot

Overview

Spring Boot simplifies data access by providing integration with various data sources like relational databases (via JPA and JDBC) and NoSQL databases (e.g., MongoDB). It also supports robust transaction management.

7.1 Spring Data JPA

Spring Data JPA abstracts data access layers by providing ready-to-use repositories and powerful query capabilities.

---

1 Entity Classes (`@Entity`)

`@Entity` marks a Java class as a table in the database.

Example

```
@Entity
public class User {
    @Id @GeneratedValue
    private Long id;
    private String name;
}
```

2 Repositories (`JpaRepository`, `CrudRepository`)

Spring Data provides interfaces for CRUD operations without boilerplate code.

Example

```
public interface UserRepository extends JpaRepository<User, Long> {
    List<User> findByName(String name);
}
```

3 Custom Queries (`@Query`)

Define complex queries using JPQL or native SQL.

Example

@Query("SELECT u FROM User u WHERE u.name LIKE %:name%")

List<User> searchByName(@Param("name") String name);

4 Pagination and Sorting

Built-in support via `Pageable` and `Sort`.

Example

Page<User> page = userRepository.findAll(PageRequest.of(0, 10, Sort.by("name")));

7.2 JDBC with Spring Boot

Use `JdbcTemplate` for fine-grained SQL operations.

Example

@Repository

public class UserDao {

    @Autowired

    private JdbcTemplate jdbcTemplate;

    public List<User> getUsers() {

    return jdbcTemplate.query("SELECT * FROM users",

    (rs, rowNum) -> new User(rs.getLong("id"), rs.getString("name")));

```
    }
}
```

7.3 MongoDB / NoSQL

Spring Boot provides `spring-boot-starter-data-mongodb` for integrating MongoDB.

Example

```
@Document
public class Product {
    @Id
    private String id;
    private String name;
}

public interface ProductRepository extends MongoRepository<Product, String> {
    List<Product> findByName(String name);
}

<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-data-mongodb</artifactId>
</dependency>
```

7.4 Transactions (`@Transactional`)

Ensures atomicity for multiple database operations.

Example

```
@Service
public class UserService {

    @Autowired
    private UserRepository userRepository;

    @Transactional
    public void registerUser(User user) {
    userRepository.save(user);
    // Additional DB operations
    }
}
```

You can also use `@Transactional(readOnly = true)` for read operations.

---

8. Database Configuration in Spring Boot

Overview

Spring Boot offers seamless integration with relational databases such as **H2, MySQL, PostgreSQL**, and supports configuration for **connection pooling** and **schema initialization** through simple properties or SQL files.

8.1 H2 In-Memory Database

The **H2 database** is an in-memory relational database ideal for development and testing. It runs in memory and is destroyed when the application stops.

Add Dependency

<dependency>

  <groupId>com.h2database</groupId>

  <artifactId>h2</artifactId>

  <scope>runtime</scope>

</dependency>

Configure (application.properties)

spring.datasource.url=jdbc:h2:mem:testdb

spring.datasource.driver-class-name=org.h2.Driver

spring.datasource.username=sa

spring.datasource.password=

spring.h2.console.enabled=true

H2 Console

Access the console at: `http://localhost:8080/h2-console`
Driver Class: `org.h2.Driver`
JDBC URL: `jdbc:h2:mem:testdb`

8.2 MySQL / PostgreSQL Setup

MySQL Example Configuration

<!-- Add MySQL dependency -->

<dependency>

<groupId>mysql</groupId>

<artifactId>mysql-connector-j</artifactId>

<scope>runtime</scope>

</dependency>

 # application.properties

spring.datasource.url=jdbc:mysql://localhost:3306/mydb

spring.datasource.username=root

spring.datasource.password=your_password

spring.jpa.hibernate.ddl-auto=update

spring.jpa.show-sql=true

PostgreSQL Configuration

<dependency>

<groupId>org.postgresql</groupId>

<artifactId>postgresql</artifactId>

<scope>runtime</scope>

</dependency>

spring.datasource.url=jdbc:postgresql://localhost:5432/mydb

spring.datasource.username=postgres

spring.datasource.password=your_password

8.3 Connection Pooling (HikariCP)

Spring Boot uses HikariCP as the default connection pool for better performance.

Default Settings (optional to override)

spring.datasource.hikari.maximum-pool-size=10

spring.datasource.hikari.minimum-idle=5

spring.datasource.hikari.idle-timeout=30000

spring.datasource.hikari.pool-name=SpringBootHikariCP

8.4 Schema Initialization (schema.sql, data.sql)

Spring Boot executes these SQL files automatically on startup to initialize the database.

Usage

Place these files in `src/main/resources/`:

- `schema.sql` → **For creating tables**
- `data.sql` → **For inserting initial data**

Example: schema.sql

```
CREATE TABLE users (
        id BIGINT PRIMARY KEY AUTO_INCREMENT,
        name VARCHAR(100)
);
```

Example: data.sql

INSERT INTO users (name) VALUES ('John Doe'), ('Alice');

---

9. Validation in Spring Boot

Overview

Spring Boot supports **bean validation** using **JSR-380 (Jakarta Bean Validation / `javax.validation`)**. It allows automatic input validation for REST APIs and form data using annotations like `@NotNull`, `@Email`, and more. Validation can be enhanced using `@Valid`, `@Validated`, and custom validators.

9.1 Bean Validation (`javax.validation`)

Spring Boot auto-configures bean validation when `spring-boot-starter-validation` is on the classpath.

Add Dependency (if needed)

<dependency>

<groupId>org.springframework.boot</groupId>

<artifactId>spring-boot-starter-validation</artifactId>

</dependency>

Common Validation Annotations

Annotation	Description
`@NotNull`	Field must not be null

`@NotBlank`	Field must not be null or empty
`@Email`	Must be a valid email address
`@Size(min, max)`	String/collection size constraints
`@Min`, `@Max`	Numeric value limits

Example

```
public class User {

    @NotBlank
    private String name;

    @Email
    private String email;

    @Min(18)
    private int age;

    // Getters & Setters
}
```

9.2 Using `@Valid` and `@Validated`

`@Valid`

Used to trigger validation on a method parameter (commonly in controllers).

```
@RestController
@RequestMapping("/users")
public class UserController {

    @PostMapping
    public ResponseEntity<String> addUser(@Valid @RequestBody User user) {
    return ResponseEntity.ok("User is valid");
    }
}
```

Spring will automatically return a 400 Bad Request if validation fails, along with error messages.

`@Validated`

Used on a class to validate method-level constraints or with groups for conditional validation.

```
@Validated
@Service
public class PaymentService {

    public void process(@Min(100) int amount) {
    // Only processes if amount >= 100
```

```
    }
}
```

9.3 Custom Validators

You can create custom constraints using `@Constraint`.

Steps to Create a Custom Validator

1. **Define the annotation:**

```
@Constraint(validatedBy = UsernameValidator.class)
@Target({ FIELD })
@Retention(RUNTIME)
public @interface ValidUsername {
    String message() default "Invalid username";
    Class<?>[] groups() default {};
    Class<? extends Payload>[] payload() default {};
}
```

2. Create the validator class:

```
public class UsernameValidator implements ConstraintValidator<ValidUsername, String>
{

    @Override
    public boolean isValid(String value, ConstraintValidatorContext context) {
    return value != null && value.matches("^[a-zA-Z0-9_]{5,20}$");
```

```
    }
}
```

3. Use the annotation:

```
public class User {
    @ValidUsername
    private String username;
}
```

---

10. Security in Spring Boot

Overview

Spring Boot integrates **Spring Security**, a powerful and customizable authentication and access-control framework. It provides robust security for web applications, REST APIs, and microservices.

10.1 Spring Security Basics

To enable security in Spring Boot, include the **starter dependency**:

Dependency

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-security</artifactId>
</dependency>
```

By default, Spring Security:

- Secures all endpoints
- Provides a default login form
- Uses an auto-generated password (logged at startup)

10.2 Authentication and Authorization

Authentication identifies **who** the user is.
Authorization defines **what** the user is allowed to do.

Basic Configuration Example

```
@Configuration

@EnableWebSecurity

public class SecurityConfig {


    @Bean

    public SecurityFilterChain securityFilterChain(HttpSecurity http) throws Exception {

    http

    .authorizeHttpRequests(auth -> auth

            .requestMatchers("/admin/**").hasRole("ADMIN")

            .requestMatchers("/user/**").hasAnyRole("USER", "ADMIN")

            .anyRequest().authenticated()

    )

    .httpBasic(); // For simple authentication

    return http.build();
```

```
    }

    @Bean
    public InMemoryUserDetailsManager userDetailsService() {
    UserDetails user =
User.withUsername("user").password("{noop}1234").roles("USER").build();
    UserDetails admin =
User.withUsername("admin").password("{noop}admin123").roles("ADMIN").build();
    return new InMemoryUserDetailsManager(user, admin);
    }
}
```

10.3 Password Encoding

Use **PasswordEncoder** to store hashed passwords securely.

Example using BCrypt

```
@Bean
public PasswordEncoder passwordEncoder() {
    return new BCryptPasswordEncoder();
}

String encoded = passwordEncoder.encode("mypassword");
```

Always use encoded passwords (e.g., in DB) instead of plain text.

10.4 JWT Token-based Security

JWT (JSON Web Tokens) are widely used for securing REST APIs in stateless systems.

JWT Flow

1. User sends credentials → gets a **JWT**
2. Client sends JWT with requests
3. Server validates the JWT

Example Controller to Issue JWT

```
@RestController
public class AuthController {

    @PostMapping("/login")
    public String login(@RequestBody AuthRequest request) {
    // Authenticate and generate JWT
    return jwtService.generateToken(request.getUsername());
    }
}
```

JWT Filter (Simplified)

```
public class JwtFilter extends OncePerRequestFilter {
    protected void doFilterInternal(HttpServletRequest request, HttpServletResponse response, FilterChain chain) {
    String token = request.getHeader("Authorization");
    // validate token and set authentication
```

```
        chain.doFilter(request, response);
        }
}
```

You must register the filter in the security chain.

10.5 Role-Based Access Control (RBAC)

Spring Security allows controlling access to resources by roles or authorities.

Example

```
@GetMapping("/admin/dashboard")
@PreAuthorize("hasRole('ADMIN')")
public String adminDashboard() {
        return "Admin area";
}
```

Enable Method-Level Security

```
@EnableMethodSecurity
public class MethodSecurityConfig {
}
```

---

11. Testing in Spring Boot

Overview

Spring Boot provides first-class support for testing through **JUnit**, **Mockito**, and **Spring TestContext Framework**. It enables testing of individual components (unit tests), interactions (mocking), and full application context (integration testing).

11.1 Unit Testing with JUnit

JUnit is the standard framework for writing unit tests in Java.

Dependency

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-test</artifactId>
  <scope>test</scope>
</dependency>
```

Example

```
class CalculatorService {
        int add(int a, int b) {
        return a + b;
        }
}

class CalculatorServiceTest {

        @Test
        void testAdd() {
        CalculatorService calc = new CalculatorService();
```

```
    assertEquals(5, calc.add(2, 3));
    }
}
```

11.2 Mocking with Mockito

Mockito is used to **mock dependencies** for isolated unit tests.

Example

```
@Service
class OrderService {
    @Autowired private PaymentService paymentService;

    public boolean placeOrder() {
    return paymentService.pay();
    }
}

class OrderServiceTest {

    @Mock PaymentService paymentService;

    @InjectMocks OrderService orderService;

    @BeforeEach
```

```
    void init() {
    MockitoAnnotations.openMocks(this);
    }

    @Test
    void testPlaceOrder() {
    when(paymentService.pay()).thenReturn(true);
    assertTrue(orderService.placeOrder());
    }
}
```

11.3 Integration Testing

Integration tests load the full application context to test real behavior of beans.

Example

```
@SpringBootTest
class UserServiceIntegrationTest {

    @Autowired UserService userService;

    @Test
    void testFindUser() {
    User user = userService.findById(1L);
    assertNotNull(user);
```

```
    }
}
```

11.4 Web Layer Testing (`@WebMvcTest`)

Used to test only the **web layer** (controllers) without loading the full context.

Example

```
@WebMvcTest(UserController.class)
class UserControllerTest {

    @Autowired private MockMvc mockMvc;

    @Test
    void testGetUser() throws Exception {
    mockMvc.perform(get("/users/1"))
    .andExpect(status().isOk());
    }
}
```

> It auto-configures Spring MVC infrastructure and can mock service beans using `@MockBean`.

11.5 Data Layer Testing (`@DataJpaTest`)

Used to test **repository layer** with in-memory database and only JPA components.

Example

```
@DataJpaTest

class UserRepositoryTest {


        @Autowired private UserRepository userRepository;


        @Test

        void testSaveUser() {

        User user = new User("John");

        User saved = userRepository.save(user);

        assertNotNull(saved.getId());

        }

}
```

Uses H2 in-memory database by default and rolls back transactions after each test.

---

12. Logging in Spring Boot

Overview

Spring Boot uses **SLF4J** (Simple Logging Facade for Java) as a logging API and **Logback** as the default logging implementation. Logging helps monitor application behavior, track errors, and audit key events.

12.1 SLF4J and Logback

SLF4J

- A facade that allows switching between logging frameworks like Logback, Log4j, etc.
- Spring Boot includes SLF4J and Logback by default.

Basic Usage

```
import org.slf4j.Logger;

import org.slf4j.LoggerFactory;


@RestController

public class DemoController {

	private static final Logger logger = LoggerFactory.getLogger(DemoController.class);


	@GetMapping("/test")

	public String test() {

	logger.info("INFO log - test endpoint called");

	logger.warn("WARN log");

	logger.error("ERROR log");

	return "Check logs";

	}

}
```

12.2 Configuring Log Levels

Spring Boot allows configuring log levels in `application.properties` or `application.yml`.

Example: application.properties

logging.level.root=INFO

logging.level.com.example.demo=DEBUG

logging.file.name=app.log

Log Levels

- `TRACE` – Finest level (e.g., for debugging)
- `DEBUG` – Development details
- `INFO` – General application events
- `WARN` – Potential issues
- `ERROR` – Serious issu

12.3 External Log Configuration

You can use an external `logback-spring.xml` for advanced logging configurations.

Steps:

1. Place `logback-spring.xml` in `src/main/resources`
2. Use Spring profile-specific logging, log rotation, custom patterns, etc.

Example: logback-spring.xml

```
<configuration>

  <property name="LOG_FILE" value="myapp.log"/>

  <appender name="FILE" class="ch.qos.logback.core.rolling.RollingFileAppender">
        <file>${LOG_FILE}</file>
        <rollingPolicy class="ch.qos.logback.core.rolling.TimeBasedRollingPolicy">
        <fileNamePattern>${LOG_FILE}.%d{yyyy-MM-dd}.gz</fileNamePattern>
        </rollingPolicy>
        <encoder>
        <pattern>%d{HH:mm:ss.SSS} [%thread] %-5level %logger{36} - %msg%n</pattern>
        </encoder>
  </appender>

  <root level="INFO">
        <appender-ref ref="FILE"/>
  </root>

</configuration>
```

You can also use environment variables and Spring profiles for flexible logging configurations.

---

13. Actuator & Monitoring in Spring Boot

Overview

Spring Boot Actuator provides built-in **monitoring and management endpoints** to inspect application health, metrics, and environment details. It is essential for observing applications in production environments.

13.1 Spring Boot Actuator Overview

Dependency

<dependency>

<groupId>org.springframework.boot</groupId>

<artifactId>spring-boot-starter-actuator</artifactId>

</dependency>

Enable Actuator Endpoints

management.endpoints.web.exposure.include=*

By default, only limited endpoints like `/health` and `/info` are exposed.

13.2 Common Actuator Endpoints

Endpoint	Description
`/actuator/health`	**Shows application health status**

`/actuator/info`	Displays custom application info
`/actuator/metrics`	Shows system and custom metrics
`/actuator/env`	Lists environment properties
`/actuator/beans`	Lists all Spring beans
`/actuator/mappings`	Shows all request mappings

Example: Custom Info

management.endpoints.web.exposure.include=info

info.app.name=MyApp

info.app.version=1.0

13.3 Custom Metrics

You can create and register custom metrics using `MeterRegistry`.

Example: Custom Counter

@Component

public class VisitCounter {

```
    private final Counter counter;

    public VisitCounter(MeterRegistry registry) {
    this.counter = registry.counter("custom.visit.counter");
    }

    public void increment() {
    counter.increment();
    }
}
```

Access at: `/actuator/metrics/custom.visit.counter`

13.4 Prometheus/Grafana Integration

Actuator integrates with Micrometer, which supports exporting metrics to Prometheus, Datadog, New Relic, etc.

Prometheus Setup

Add dependency:

```
<dependency>
  <groupId>io.micrometer</groupId>
  <artifactId>micrometer-registry-prometheus</artifactId>
</dependency>
```

application.properties:

```
management.endpoints.web.exposure.include=prometheus

management.metrics.export.prometheus.enabled=true
```

Access Prometheus endpoint:

```
/actuator/prometheus
```

Grafana Integration

1. **Add Prometheus as a data source in Grafana.**
2. **Use `actuator` metrics in custom dashboards.**
3. **Monitor CPU, memory, GC, and custom metrics visually.**

---

14. Error Handling in Spring Boot

Overview

Spring Boot provides a default error handling mechanism and allows full customization via exception handlers, error pages, and controller advice. Proper error handling ensures a better user experience and easier debugging.

14.1 Default Error Handling

By default, Spring Boot handles exceptions and returns a **JSON error response** for REST APIs or a **whitelabel error page** for web applications.

Example: Default Error Response

{

"timestamp": "2025-06-14T12:30:00.000+00:00",

"status": 404,

"error": "Not Found",

"path": "/api/users/100"

}

14.2 Custom Error Pages

You can provide custom HTML error pages by adding files in `/resources/public` or `/resources/static` directories with the following names:

Examples:

- `/resources/public/error/404.html` → Custom page for 404 errors
- `/resources/public/error/500.html` → Custom page for 500 errors

These are served automatically for browser-based requests.

14.3 Global Exception Handling

Use `@ControllerAdvice` and `@ExceptionHandler` to define centralized exception handling for all controllers.

Example:

@ControllerAdvice

public class GlobalExceptionHandler {

```
    @ExceptionHandler(ResourceNotFoundException.class)

    public ResponseEntity<String> handleNotFound(ResourceNotFoundException ex) {

    return new ResponseEntity<>("Resource not found: " + ex.getMessage(),
HttpStatus.NOT_FOUND);

    }


    @ExceptionHandler(Exception.class)

    public ResponseEntity<String> handleGeneral(Exception ex) {

    return new ResponseEntity<>("Internal error: " + ex.getMessage(),
HttpStatus.INTERNAL_SERVER_ERROR);

    }

}
```

This ensures consistent and customizable error responses across the application.

Best Practices

- Use `@ResponseStatus` to bind HTTP status codes to exceptions.
- Log exceptions for debugging.
- Return **meaningful messages** to users, hide sensitive stack traces in production.
- Customize **error attributes** using `ErrorAttributes` bean if needed.

---

15. Developer Tools in Spring Boot

Overview

Spring Boot Developer Tools (**DevTools**) enhance the development experience by enabling **automatic restarts**, **live reload**, and additional features like **runtime property override** and **template caching disablement**.

15.1 Spring Boot DevTools

`spring-boot-devtools` is a module that provides development-time features to increase productivity.

Dependency

Add this dependency to your `pom.xml` (it's automatically disabled in production):

<dependency>

<groupId>org.springframework.boot</groupId>

<artifactId>spring-boot-devtools</artifactId>

<optional>true</optional>

</dependency>

In Gradle:
`developmentOnly("org.springframework.boot:spring-boot-devtools")`

15.2 Auto Restart

Spring Boot DevTools monitors classpath files. When a change is detected (like a Java class file update), the application is automatically restarted.

Benefits:

- Eliminates the need to manually stop and start the app.

- Improves feedback loop during development.

Example

- Modify a controller method in your IDE.
- Save → Spring Boot automatically restarts the context.
- Changes are reflected immediately.

You can exclude directories from being monitored using:

```
spring.devtools.restart.exclude=static/**,public/**
```

15.3 Live Reload

Spring Boot DevTools integrates with **LiveReload** to refresh the browser automatically when static resources (HTML, CSS, JS) change.

Steps to Enable:

1. Add DevTools dependency.
2. Install LiveReload browser extension.
3. Make a change in an HTML or template file.
4. The browser reloads automatically.

Configuration (optional)

```
spring.devtools.livereload.enabled=true
```

Other Features

- **Disable Caching** for `Thymeleaf`, `Freemarker`, etc.
- **Remote Debugging Support** for deploying DevTools to remote environments (optional and secured).
- **Automatic Property Overrides** for dev-time config.

---

16. Caching in Spring Boot

Overview

Caching improves performance by storing frequently accessed data in memory or external caches. Spring Boot supports transparent caching using annotations and multiple providers like Ehcache, Caffeine, and Redis.

16.1 Using `@Cacheable` and `@CacheEvict`

Spring provides simple annotations to manage caching behavior.

✅ `@EnableCaching`

Enable caching in your main class:

@SpringBootApplication

@EnableCaching

public class MyApp { ... }

✅ `@Cacheable`

Marks a method's return value to be cached. The result is stored the first time and reused for subsequent calls with the same parameters.

```
@Cacheable("products")
public Product getProductById(Long id) {
        simulateSlowService(); // e.g., DB call
        return productRepository.findById(id).orElse(null);
}
```

`products` is the cache name.

On first call, the method executes and result is cached.

On subsequent calls with same `id`, value is fetched from the cache.

✅ `@CacheEvict`

Removes an entry from the cache.

```
@CacheEvict(value = "products", key = "#id")
public void deleteProduct(Long id) {
        productRepository.deleteById(id);
}
```

- **Ensures cache is cleared when the data changes.**

16.2 Cache Providers

Spring Boot supports pluggable caching providers. Some popular ones:

Ehcache (In-memory, Java-based)

➢ Add dependency:

```
<dependency>
  <groupId>org.ehcache</groupId>
  <artifactId>ehcache</artifactId>
</dependency>
```

➢ Configuration example (`ehcache.xml` or Java config)

```
<config>
  <cache alias="products">
        <heap>1000</heap>
  </cache>
</config>
```

Caffeine (Fast Java-based cache)

➢ Add dependency:

```
<dependency>
  <groupId>com.github.ben-manes.caffeine</groupId>
  <artifactId>caffeine</artifactId>
</dependency>
```

➢ Configuration (`application.properties`):

```
spring.cache.type=caffeine
spring.cache.caffeine.spec=maximumSize=1000,expireAfterAccess=5m
```

Redis (Distributed cache)

➤ Add dependencies:

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-data-redis</artifactId>
</dependency>
```

➤ Configuration:

```
spring.cache.type=redis
spring.redis.host=localhost
spring.redis.port=6379
```

Ideal for microservices and distributed environments.

---

17. Scheduling & Asynchronous Execution in Spring Boot

Overview

Spring Boot simplifies the execution of background and periodic tasks through annotations like `@Scheduled` and `@Async`. These features enable automation, performance optimization, and non-blocking operations.

17.1 Scheduling Tasks (`@Scheduled`)

`@Scheduled` allows you to run methods at fixed intervals or specific times.

✅ Enable Scheduling

@SpringBootApplication

@EnableScheduling

public class MyApp { }

✅ Using `@Scheduled`

```
@Component
public class ScheduledTasks {

	@Scheduled(fixedRate = 5000) // every 5 seconds
	public void reportStatus() {
	System.out.println("Status Check: " + LocalDateTime.now());
	}

	@Scheduled(cron = "0 0 9 * * ?") // every day at 9 AM
	public void dailyTask() {
	System.out.println("Running daily task");
	}
}
```

fixedRate: Runs task at regular intervals.

fixedDelay: Runs with a delay after the previous execution.

cron: Offers flexible scheduling using cron expressions.

17.2 Asynchronous Execution (@Async)

@Async enables methods to run in a separate thread, allowing non-blocking execution.

✅ Enable Async Execution

```
@SpringBootApplication

@EnableAsync

public class MyApp { }
```

✅ Using @Async

```
@Service

public class EmailService {


      @Async

      public void sendEmail(String to) {

      // Simulate delay

      try {

            Thread.sleep(3000);
```

```
        } catch (InterruptedException ignored) {}
        System.out.println("Email sent to: " + to);
        }
}
```

✅ Calling the Async Method

```
@RestController
public class NotificationController {

    @Autowired
    private EmailService emailService;

    @GetMapping("/notify")
    public String notifyUser() {
    emailService.sendEmail("user@example.com");
    return "Notification started";
    }
}
```

- The method returns immediately.
- Actual email sending happens in a background thread.

⚠️ Async methods must be called from another bean, not the same class.

---

18. Messaging in Spring Boot

Overview

Spring Boot offers powerful support for **message-driven architecture** using brokers like **RabbitMQ**, **Apache Kafka**, and **JMS (Java Message Service)**. Messaging enables **asynchronous communication**, **event-driven processing**, and **microservice decoupling**.

18.1 RabbitMQ

RabbitMQ is a message broker that supports **AMQP** for reliable, asynchronous message delivery.

✅ Add Dependency

<dependency>

<groupId>org.springframework.boot</groupId>

<artifactId>spring-boot-starter-amqp</artifactId>

</dependency>

✅ Configuration (`application.properties`)

spring.rabbitmq.host=localhost

spring.rabbitmq.port=5672

spring.rabbitmq.username=guest

spring.rabbitmq.password=guest

✅ Producer Example

```
@Service
public class MessageProducer {
        @Autowired
        private RabbitTemplate rabbitTemplate;

        public void send(String message) {
        rabbitTemplate.convertAndSend("myQueue", message);
        }
}
```

✅ Consumer Example

```
@Component
public class MessageConsumer {
        @RabbitListener(queues = "myQueue")
        public void receive(String message) {
        System.out.println("Received: " + message);
        }
}
```

18.2 Apache Kafka

Kafka is a distributed event streaming platform used for high-throughput and fault-tolerant messaging.

✅ Add Dependency

```
<dependency>
```

```
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-kafka</artifactId>
</dependency>
```

✅ Configuration (`application.properties`)

```
spring.kafka.bootstrap-servers=localhost:9092
spring.kafka.consumer.group-id=my-group
spring.kafka.consumer.auto-offset-reset=earliest
```

✅ Producer Example

```
@Service
public class KafkaProducer {
        @Autowired
        private KafkaTemplate<String, String> kafkaTemplate;

        public void send(String message) {
        kafkaTemplate.send("myTopic", message);
        }
}
```

✅ Consumer Example

```
@Component
public class KafkaConsumer {
        @KafkaListener(topics = "myTopic", groupId = "my-group")
```

```
    public void listen(String message) {
    System.out.println("Received from Kafka: " + message);
    }
}
```

18.3 JMS Integration

JMS (Java Message Service) is a Java API for messaging, often used with **ActiveMQ**.

✅ Add Dependency

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-artemis</artifactId>
</dependency>
```

✅ Configuration

```
spring.artemis.broker-url=tcp://localhost:61616
spring.artemis.user=admin
spring.artemis.password=admin
```

✅ Producer Example

```
@Service
public class JmsProducer {
    @Autowired
    private JmsTemplate jmsTemplate;
```

```
        public void send(String msg) {
        jmsTemplate.convertAndSend("queue.sample", msg);
        }
}
```

✅ Consumer Example

```
@Component
public class JmsConsumer {
        @JmsListener(destination = "queue.sample")
        public void receive(String msg) {
        System.out.println("Received from JMS: " + msg);
        }
}
```

---

19. File Upload & Download in Spring Boot

Overview

Spring Boot provides built-in support for handling **file uploads** using `MultipartFile`, and allows **secure file storage and download** through REST APIs. These features are essential for applications like user portals, document systems, and image uploads.

19.1 Multipart File Upload

✅ Controller for File Upload

```
@RestController

@RequestMapping("/files")

public class FileUploadController {



    @PostMapping("/upload")

    public ResponseEntity<String> handleFileUpload(@RequestParam("file") MultipartFile file) throws IOException {

    String uploadDir = "uploads/";

    Path path = Paths.get(uploadDir + file.getOriginalFilename());

    Files.createDirectories(path.getParent());

    Files.write(path, file.getBytes());



    return ResponseEntity.ok("File uploaded successfully: " + file.getOriginalFilename());

    }

}
```

✅ Frontend / Postman Test

- Set `POST` method to `/files/upload`
- Use `form-data` with key `file` and select a file

19.2 File Storage and Download Handling

✅ Download File Endpoint

```
@GetMapping("/download/{filename}")
```

```
public ResponseEntity<Resource> downloadFile(@PathVariable String filename) throws
IOException {

        Path path = Paths.get("uploads/" + filename);

        Resource resource = new UrlResource(path.toUri());



        if (!resource.exists()) {

        return ResponseEntity.notFound().build();

        }



        return ResponseEntity.ok()

        .contentType(MediaType.APPLICATION_OCTET_STREAM)

        .header(HttpHeaders.CONTENT_DISPOSITION, "attachment; filename=\"" + filename +
"\"")

        .body(resource);

}
```

- Files are stored in a local `uploads/` directory.
- Files are downloaded with correct headers for browser compatibility.

✅ Security Tip

Always validate:

- File type (e.g., `.jpg`, `.pdf`)
- File size limits
- Filename/path sanitization to avoid directory traversal

spring.servlet.multipart.max-file-size=5MB

spring.servlet.multipart.max-request-size=10MB

---

20. Frontend Integration in Spring Boot

Overview

Spring Boot simplifies frontend integration by allowing you to serve static content, use server-side templating engines like **Thymeleaf**, and enable **CORS** for cross-origin requests from frontend frameworks like Angular, React, or Vue.

20.1 Serving Static Files

Spring Boot automatically serves static content (HTML, CSS, JS, images) placed in specific directories:

✅ Default Static Locations

Place your files in:

src/main/resources/static/

src/main/resources/public/

src/main/resources/resources/

✅ Example

`src/main/resources/static/index.html`
Accessible via: `http://localhost:8080/index.html`

Add JS/CSS/images in the same folder:

/static/js/app.js

/static/css/style.css

20.2 Using Thymeleaf

Thymeleaf is a server-side Java template engine for rendering dynamic HTML.

✅ Add Dependency

<dependency>

<groupId>org.springframework.boot</groupId>

<artifactId>spring-boot-starter-thymeleaf</artifactId>

</dependency>

✅ Controller

```
@Controller
public class HomeController {
        @GetMapping("/home")
        public String home(Model model) {
        model.addAttribute("message", "Welcome to Spring Boot + Thymeleaf!");
        return "home";
        }
}
```

✅ Template: `src/main/resources/templates/home.html`

```
<!DOCTYPE html>
<html xmlns:th="http://www.thymeleaf.org">
```

```
<head><title>Home</title></head>
<body>
    <h1 th:text="${message}"></h1>
</body>
</html>
```

Access via: http://localhost:8080/home

20.3 Enabling CORS

CORS (Cross-Origin Resource Sharing) allows frontend apps (like React or Angular) to call Spring Boot APIs hosted on another domain or port.

✅ Enable CORS Globally

```
@Configuration
public class WebConfig implements WebMvcConfigurer {
    @Override
    public void addCorsMappings(CorsRegistry registry) {
    registry.addMapping("/api/**")
            .allowedOrigins("http://localhost:4200")
            .allowedMethods("GET", "POST", "PUT", "DELETE");
    }
}
```

✅ **Enable CORS at Controller Level**

```
@CrossOrigin(origins = "http://localhost:4200")

@RestController

@RequestMapping("/api")

public class ProductController {

      @GetMapping("/products")

      public List<String> getProducts() {

      return List.of("Pen", "Notebook", "Pencil");

      }

}
```

---

21. Build & Deployment in Spring Boot

Overview

Spring Boot simplifies application deployment with flexible options such as **executable JARs/WARs**, **Docker containers**, **cloud deployment**, and **CI/CD integration** for automated delivery.

21.1 Building JAR/WAR

✅ JAR Packaging (Default)

Add to `pom.xml`:

<packaging>jar</packaging>

Build the JAR:

mvn clean package

Run the JAR:

java -jar target/myapp-0.0.1-SNAPSHOT.jar

✅ **WAR Packaging (Optional)**

<packaging>war</packaging>

Extend `SpringBootServletInitializer`

```
@SpringBootApplication
public class MyApp extends SpringBootServletInitializer {
	@Override
	protected SpringApplicationBuilder
configure(SpringApplicationBuilder builder) {
	return builder.sources(MyApp.class);
	}
}
```

Deploy to external servers (Tomcat, JBoss, etc.)

21.2 Dockerizing Spring Boot Application

✅ Create `Dockerfile`

```
FROM openjdk:21
```

```
COPY target/myapp.jar app.jar

ENTRYPOINT ["java", "-jar", "/app.jar"]
```

✅ **Build Docker Image**

```
docker build -t myapp .
```

✅ **Run Container**

```
docker run -p 8080:8080 myapp
```

21.3 Deploying to Cloud

Spring Boot can be deployed on AWS, Azure, GCP, and others.

✅ AWS (Elastic Beanstalk)

- **Package as JAR/WAR**
- **Use AWS CLI or Management Console**
- **Example:**

```
eb init

eb create my-spring-env

eb deploy
```

✅ Azure App Service

- **Create app using Azure CLI or portal**
- **Deploy using:**

```
az webapp up --name myapp --resource-group mygroup
```

✅ GCP App Engine

- **Create `app.yaml`:**

```
runtime: java

env: standard
```

Deploy:

```
gcloud app deploy
```

21.4 CI/CD Integration

Automate builds, tests, and deployments using CI/CD tools.

✅ GitHub Actions (Sample Workflow)

```
name: Build Spring Boot App

on: [push]

jobs:

  build:

      runs-on: ubuntu-latest

      steps:
```

```
- uses: actions/checkout@v3

- name: Set up JDK

uses: actions/setup-java@v3

with:

     java-version: '21'

- name: Build

run: mvn clean package
```

✅ Other CI/CD Options

- **Jenkins – Create pipelines to build and deploy automatically.**
- **GitLab CI – `.gitlab-ci.yml` for stages.**
- **CircleCI, Bitbucket Pipelines, Azure DevOps – Full cloud-based CI/CD support.**

---

22. Advanced Topics in Spring Boot

Overview

Advanced Spring Boot features enable the development of **resilient**, **scalable**, and **modular** applications using **microservices**, **event-driven architecture**, and **custom starters**.

22.1 Microservices with Spring Boot

Spring Boot combined with **Spring Cloud** offers comprehensive tools for building distributed systems.

22.1.1 Spring Cloud

A set of tools to support microservice patterns: configuration, discovery, routing, load balancing, and resilience.

<dependency>

<groupId>org.springframework.cloud</groupId>

<artifactId>spring-cloud-dependencies</artifactId>

<version>2023.0.0</version>

<type>pom</type>

<scope>import</scope>

</dependency>

22.1.2 Eureka (Service Discovery)

- **Eureka Server**:

@EnableEurekaServer

@SpringBootApplication

public class EurekaServerApp { ... }

Eureka Client:

@EnableEurekaClient

@SpringBootApplication

public class ProductServiceApp { ... }

Add dependency:

<dependency>

```
  <groupId>org.springframework.cloud</groupId>
  <artifactId>spring-cloud-starter-netflix-eureka-server</artifactId>
</dependency>
```

22.1.3 Spring Cloud Gateway / Zuul

- **Spring Cloud Gateway** is the modern replacement for Zuul.

```
@SpringBootApplication
public class GatewayApp { ... }
```

Config in `application.yml`:

```
spring:
  cloud:
        gateway:
        routes:
        - id: product_route
        uri: http://localhost:8081
        predicates:
        - Path=/products/**
```

22.1.4 Circuit Breaker (Resilience4j, Hystrix)

- Use **Resilience4j** for fault tolerance.

```
<dependency>
  <groupId>io.github.resilience4j</groupId>
  <artifactId>resilience4j-spring-boot3</artifactId>
</dependency>

@CircuitBreaker(name = "productService", fallbackMethod = "fallback")
public String getProduct() {
  return restTemplate.getForObject("http://product-service/api", String.class);
}

public String fallback(Throwable t) {
  return "Fallback response";
```

}

22.1.5 Config Server

- Centralized external configuration management for microservices.

Config Server:

```
@EnableConfigServer
@SpringBootApplication
public class ConfigServerApp { ... }
```

application.yml:

```
spring:
  cloud:
        config:
        server:
        git:
        uri: https://github.com/my-org/config-repo
```

Client:

```
spring:
  config:
        import: optional:configserver:http://localhost:8888
```

22.2 ApplicationEventPublisher & Event Listeners

✅ Define Custom Event

```
public class UserCreatedEvent extends ApplicationEvent {
        private String email;
        public UserCreatedEvent(Object source, String email) {
        super(source);
        this.email = email;
        }
}
```

✅ Publish Event

```
@Autowired
private ApplicationEventPublisher publisher;

public void createUser(String email) {
        // Save user logic
        publisher.publishEvent(new UserCreatedEvent(this, email));
}
```

✅ Listen to Event

```
@Component
public class UserEventListener {
        @EventListener
        public void handleUserCreated(UserCreatedEvent event) {
        System.out.println("User created: " + event.getEmail());
        }
}
```

22.3 Creating Custom Starters

Creating your own Spring Boot starter allows packaging reusable logic.

✅ Steps:

1. Create a separate module (e.g., `my-spring-boot-starter`)
2. Include `spring-boot-autoconfigure`
3. Add `META-INF/spring.factories` (or `spring/org.springframework.boot.autoconfigure.AutoConfiguration.imports` for Spring Boot 3)

```
org.springframework.boot.autoconfigure.EnableAutoConfiguration=\
  com.example.autoconfig.MyAutoConfiguration
```

4. Example Auto-Configuration:

```
@Configuration
public class MyAutoConfiguration {
        @Bean
        public MyService myService() {
        return new MyService();
```

```
        }
}
```

Then include your custom starter as a dependency in another project.
