Introducing Aspect Oriented Programming (AOP)

Developing Aspects with Spring AOP

1.18.5

Objectives

After completing this lesson, you should be able to do the following

- Explain the concepts behind AOP and the problems that it solves
- Implement and deploy Advices using Spring AOP
- Use AOP Pointcut Expressions
- Explain different types of Advice and when to use them

Agenda

- **What Problems Does AOP Solve?**
- Core AOP Concepts
- Quick Start
- Defining Pointcuts
- Implementing Advice
- Lab
- Advanced Topics

What Problems Does AOP Solve?

- Aspect-Oriented Programming (AOP) enables modularization of cross-cutting concerns
  - The code for a cross-cutting concern is in a single place, in a module - in Java, a class represents a module

What are Cross-Cutting Concerns?

- Generic functionality that is needed in many places in your application
- Examples of cross-cutting concerns
  - Logging and Tracing
  - Transaction Management
  - Security
  - Caching
  - Error Handling
  - Performance Monitoring
  - Custom Business Rules

An Example Requirement

- Perform a role-based security check before every application method

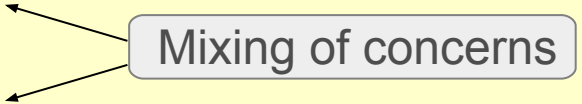
A sign this requirement is a cross-cutting concern

Implementing Cross Cutting Concerns Without Modularization

- Failing to modularize cross-cutting concerns leads to two problems
  - Code tangling
    - Coupling of concerns
  - Code scattering
    - The same concern spread across modules

Symptom #1: Code Tangling

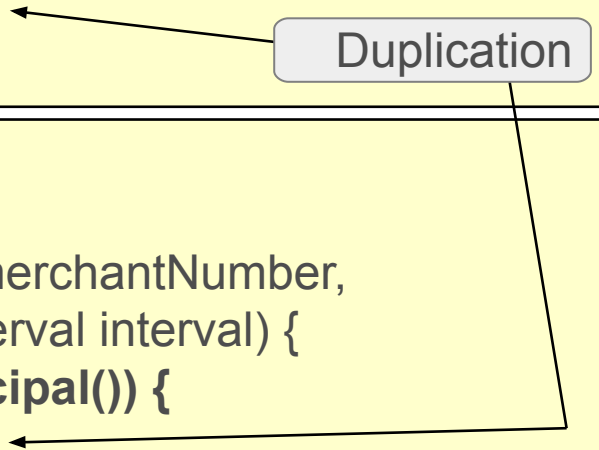
```
public class RewardNetworkImpl implements RewardNetwork {
    public RewardConfirmation rewardAccountFor(Dining dining) {

        // Security-related code
        if (!hasPermission(SecurityContext.getPrincipal()) {
            throw new AccessDeniedException();
        }

        // Application code
        Account a = accountRepository.findByCreditCard(…
        Restaurant r = restaurantRepository.findByMerchantNumber(…
        MonetaryAmount amt = r.calculateBenefitFor(account, dining);
        …
    }
}
```



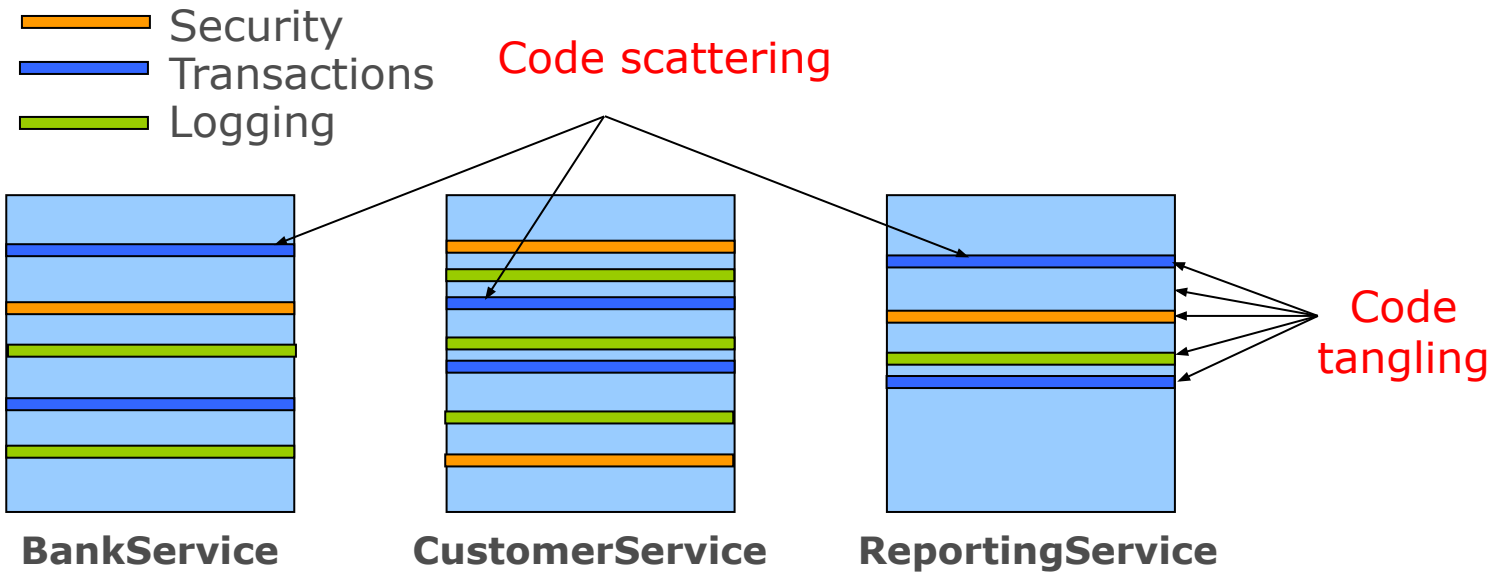
Symptom #2: Code Scattering

```
public class JpaAccountManager implements AccountManager {
    public Account getAccountForEditing(Long id) {
        if (!hasPermission(SecurityContext.getPrincipal()) {
            throw new AccessDeniedException();
        }
        …
```

```
public class JpaMerchantReportingService
        implements MerchantReportingService {
    public List<DiningSummary> findDinings(String merchantNumber,
                                           DateInterval interval) {
        if (!hasPermission(SecurityContext.getPrincipal()) {
            throw new AccessDeniedException();
        }
        …
```



System Evolution Without Modularization



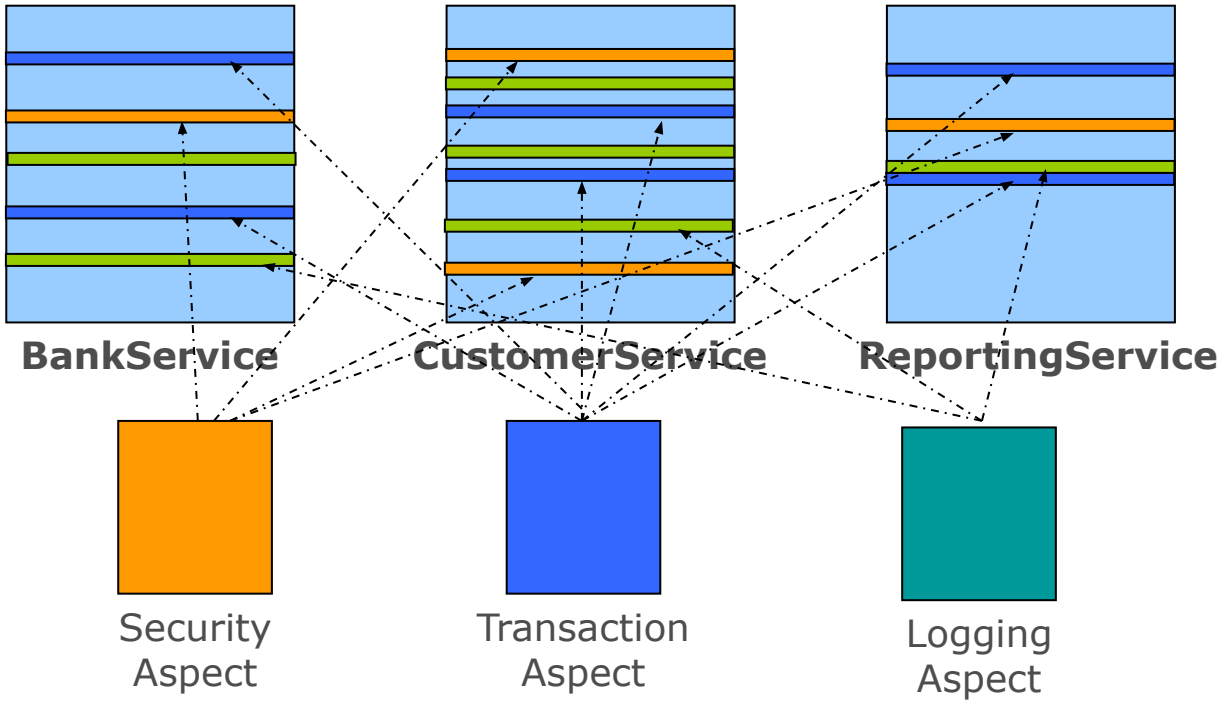
Aspect Oriented Programming (AOP)

- Aspect-Oriented Programming (AOP) enables modularization of cross-cutting concerns
  - To avoid code tangling
  - To eliminate code scattering

How to use AOP in your application

- Implement your mainline application logic
  - Focusing on the core problem
- Write aspects to implement your cross-cutting concerns
  - Spring provides many aspects out-of-the-box
- Weave the aspects into your application
  - Adding the cross-cutting behaviours to the right places

System Evolution: AOP based



Leading AOP Technologies

- AspectJ
  - Original AOP technology (first version in 1995)
  - A full-blown Aspect Oriented Programming language
    - Uses bytecode modification for aspect weaving
- Spring AOP
  - Java-based AOP framework with AspectJ integration
    - Uses dynamic proxies for aspect weaving
  - Focuses on using AOP to solve enterprise problems
  - The focus of this session

Spring Framework Reference – Aspect Oriented Programming
https://docs.spring.io/spring-framework/docs/current/reference/html/core.html#aop

Agenda

- What Problems Does AOP Solve?
- **Core AOP Concepts**
- Quick Start
- Defining Pointcuts
- Implementing Advice
- Lab
- Advanced Topics

Core AOP Concepts

- **Join Point**
  - A point in the execution of a program such as a method call or exception thrown
- **Pointcut**
  - An expression that selects one or more Join Points
- **Advice**
  - Code to be executed at each selected Join Point
- **Aspect**
  - A module that encapsulates pointcuts and advice
- **Weaving**
  - Technique by which aspects are combined with main code

Core AOP Concepts: Proxy

- **Proxy**
  - Someone who stands in place of someone else
    - Such as at an auction or an official meeting

- **AOP Proxy**
  - An “enhanced” class that stands in place of your original
    - With extra behavior (Aspect) added (woven) into it

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AOP Quick Start

- Consider this basic requirement

Log a message every time a property is about to change

- How can you use AOP to meet it?

An Application Object Whose Properties Could Change

```
public interface Cache {
    public void setCacheSize(int size);
    public void setTimeout(int ms);
}
```

```
public class SimpleCache
        implements Cache {
    private int cacheSize,ms;
    private String name;

    public SimpleCache(String beanName) { name = beanName; }

    public void setCacheSize(int size) { cacheSize = size; }
    public void setTimeout(int ms) { ms = ms; }
    …

   public String toString() { return name; }      // For convenience later
}
```

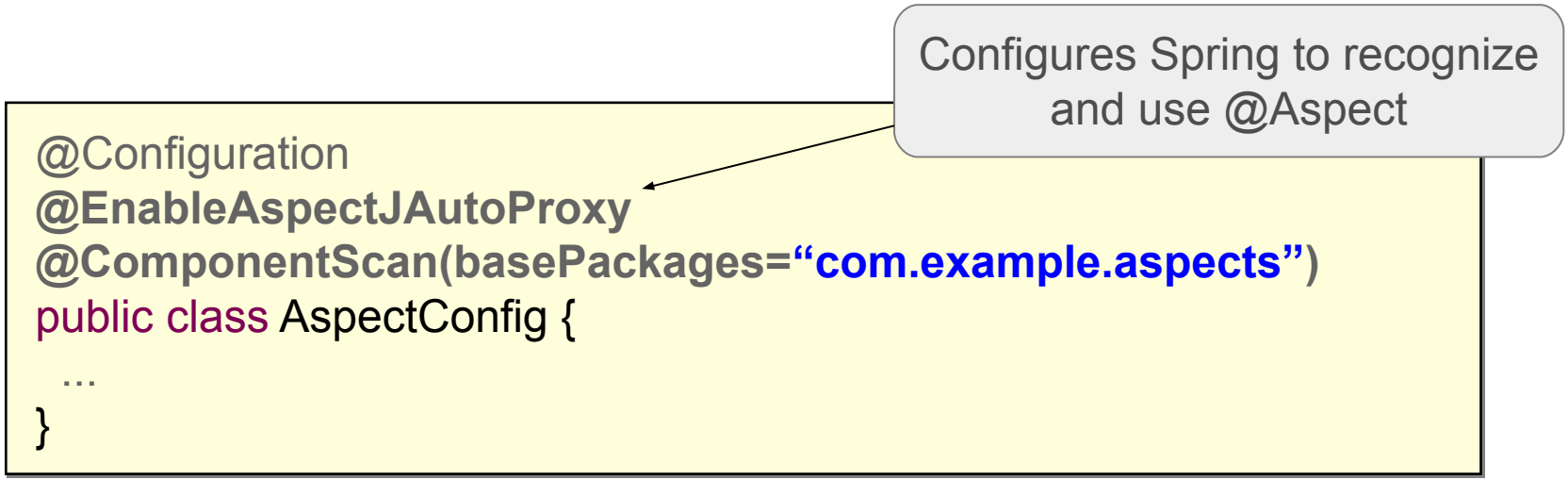
Implement the Aspect

```
@Aspect
@Component
public class PropertyChangeTracker {
    private Logger logger = Logger.getLogger(getClass());

    @Before("execution(void set*(*))")
    public void trackChange() {
        logger.info("Property about to change…");
    }
}
```

Configure Aspect as a Bean

- Must *enable* use of **@Aspect**
  - Spring uses all beans annotated with **@Aspect** as aspects



Include the Aspect Configuration

```
@Configuration
@Import(AspectConfig.class)
public class MainConfig {
    @Bean
    public Cache cacheA() { return new SimpleCache("cacheA"); }

    @Bean
    public Cache cacheB() { return new SimpleCache("cacheB"); }

    @Bean
    public Cache cacheC() { return new SimpleCache("cacheC"); }
}
```

Include aspect configuration

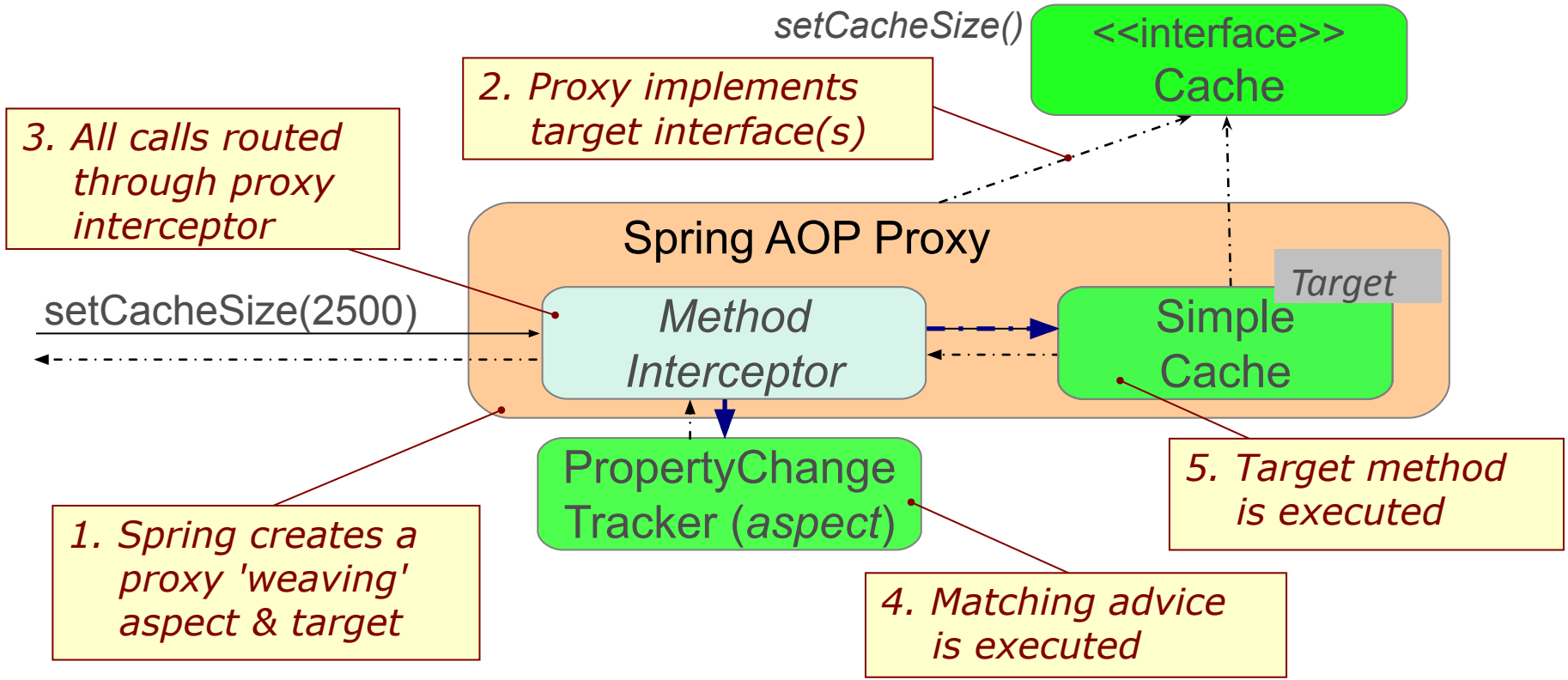
Test the Application

```
ApplicationContext context = SpringApplication.run(MainConfig.class);
```

```
@Autowired
@Qualifier(”cacheA”);
private Cache cache;
…
cache.setCacheSize(2500);
```

```
INFO: Property about to change…
```

How Aspects are Applied



Which Setter is Proxied?

```
public class DatabaseCache implements Cache (

    private int cacheSize, ms;
    private DataSource dataSource;
    private String name;

    public SimpleCache(String beanName) { name = beanName; }

    public void setCacheSize(int size) { cacheSize = size; }
    public void setTimeout(int ms) { ms = ms; }
    public void setDataSource(DataSource ds) { dataSource = ds; }

    …

    public String toString() { return name; }      // For convenience later
}
```

```
public interface Cache {
    public void setCacheSize(int size);
    public void setTimeout(int ms);
}
```

YES – on **`Cache`** interface

NO – *not* on **`Cache`** interface

Tracking Property Changes – With Context

```
@Aspect @Component
public class PropertyChangeTracker {
    private Logger logger = Logger.getLogger(getClass());

    @Before("execution(void set*(*))")
    public void trackChange(JoinPoint point) {
        String methodName = point.getSignature().getName();
        Object newValue = point.getArgs()[0];
        logger.info(methodName + " about to change to " +
                    newValue + " on " +
                    point.getTarget());
    }
}
```

`JoinPoint` parameter provides context about the intercepted point

toString() returns bean-name

INFO: setCacheSize about to change to 2500 on cacheA

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Defining Pointcuts

- Spring AOP uses AspectJ's pointcut expression language
  - For selecting where to apply advice
- Complete expression language reference available at
  - http://www.eclipse.org/aspectj/docs.php
- Spring AOP supports a practical subset

See: Spring Framework Reference – Declaring a Pointcut
https://docs.spring.io/spring-framework/docs/current/reference/html/core.html#aop-pointcuts

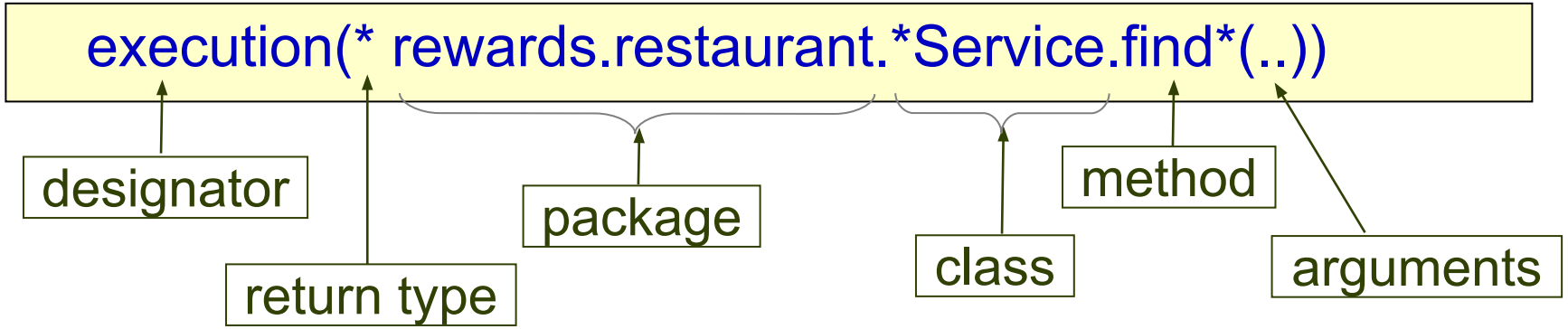
Common Pointcut Designator

- **`execution(<method pattern>)`**
  - The method must match the pattern

- Can chain together to create composite pointcuts
  - && (and), || (or), ! (not)
  - **`execution(<pattern1>) || execution(<pattern2>)`**

- Method Pattern
  - [Modifiers] ReturnType [ClassType]
    MethodName (*Arguments)* [throws ExceptionType]

Example Expression



Wildcards:

- `*` – matches once (return type, package, class, method name, argument)
- `..` – matches zero or more (arguments or packages)

Execution Expression Examples
Any Class or Package

execution(void send*(rewards.Dining))

- Any method starting with send that takes a single Dining parameter and has a void return type
- Note use of *fully-qualified class name*

execution(* send(*))

- Any method named send that takes a single parameter

execution(* send(int, ..))

- Any method named send whose first parameter is an int (the ".." signifies 0 or more parameters may follow)

Execution Expression Examples
Implementations vs Interfaces

- Restrict by *class*

  execution(void example.MessageServiceImpl.*(..))
  - Any void method in the *MessageServiceImpl* class
    - Including any sub-class
  - But will be ignored if a different implementation is used

- Restrict by *interface*

  execution(void example.MessageService.send(*))
  - Any void *send* method taking one argument, in any object implementing *MessageService*
  - More flexible choice – works if implementation changes

Execution Expression Examples
Using Annotations

execution(@javax.annotation.security.RolesAllowed void send*(..))

- Any void method whose name starts with "*send*" that is annotated with the *@RolesAllowed* annotation

```
public interface Mailer {
    @RolesAllowed("USER")
    public void sendMessage(String text);
}
```

- Ideal technique for your own annotations on your own classes
  - Matches if annotation is present

Execution Expression Examples
Working with Packages

execution(* rewards.*.restaurant.*.*(..))

- There is one directory between rewards and restaurant

execution(* rewards..restaurant.*.*(..))

- There may be several directories between rewards and restaurant

execution(* *..restaurant.*.*(..))

- Any sub-package called restaurant

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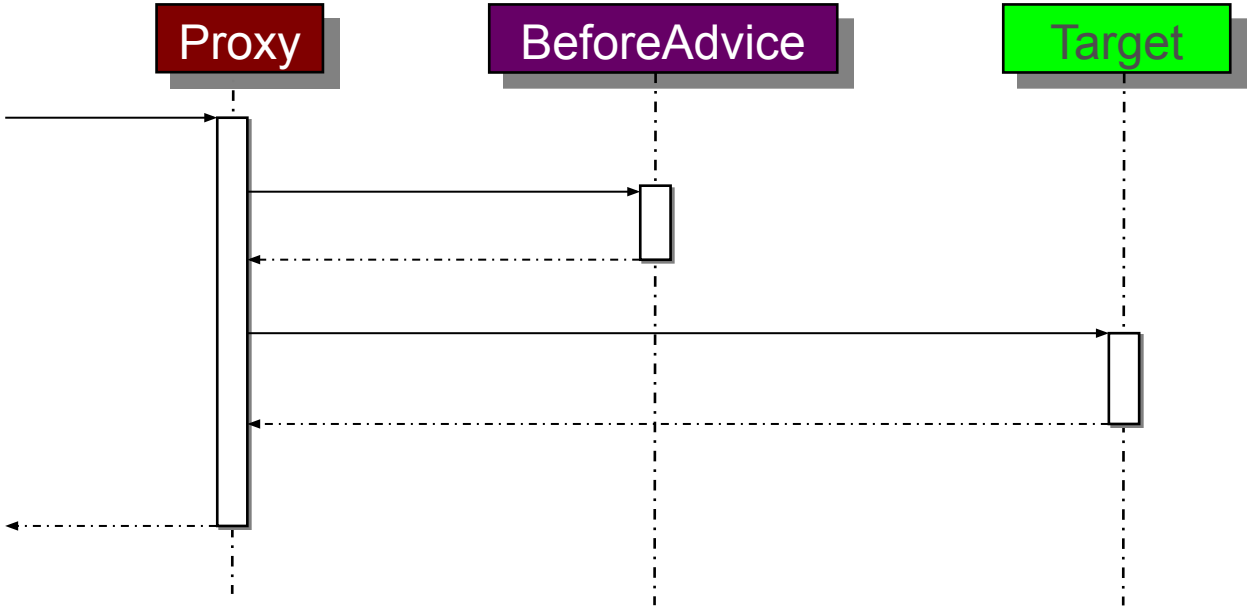
Advice Types: Before



Before Advice Example

- Use *@Before* annotation

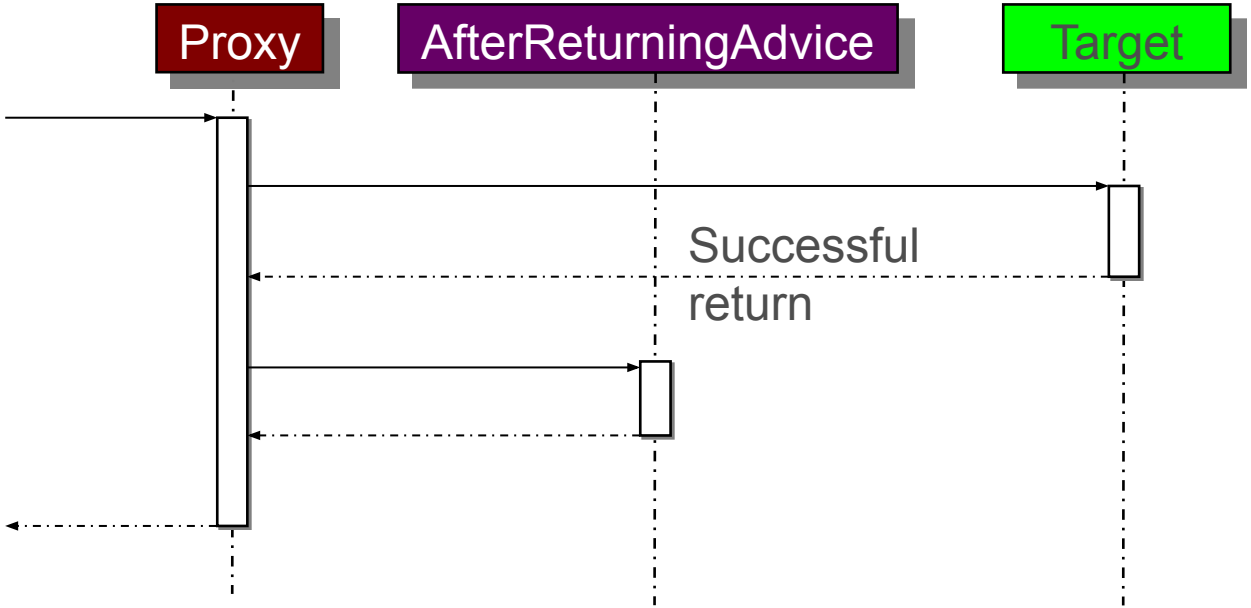
Track calls to all setter methods

```
@Aspect
@Component
public class PropertyChangeTracker {
    private Logger logger = Logger.getLogger(getClass());

    @Before("execution(void set*(*))")
    public void trackChange() {
        logger.info("Property about to change…");
    }
}
```

- **Note:** if the advice throws an exception, target will not be called – this is a valid use of a *Before Advice*

Advice Types: After Returning



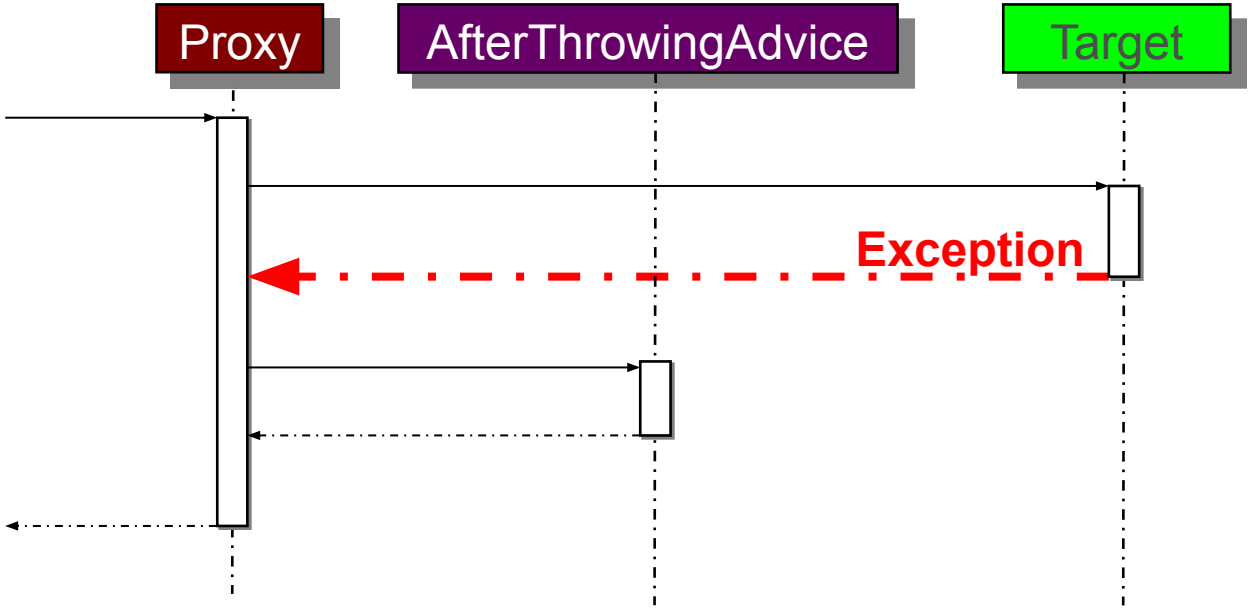
After Returning Advice - Example

- Use *@AfterReturning* annotation with the *returning* attribute

Audit all operations in the *service* package that return a *Reward* object

```
@AfterReturning(value="execution(* service..*.*(..))",
                returning="reward")
public void audit(JoinPoint jp, Reward reward) {
    auditService.logEvent(jp.getSignature() +
        " returns the following reward object :"  + reward.toString() );
}
```

Advice Types: After Throwing



After Throwing Advice - Example

- Use *@AfterThrowing* annotation with the *throwing* attribute
  - Only invokes advice if the right exception type is thrown

Send an email every time a Repository class throws an exception of type DataAccessException

```
@AfterThrowing(value="execution(* *..Repository.*(..))", throwing="e")
public void report(JoinPoint jp, DataAccessException e) {
    mailService.emailFailure("Exception in repository", jp, e);
}
```

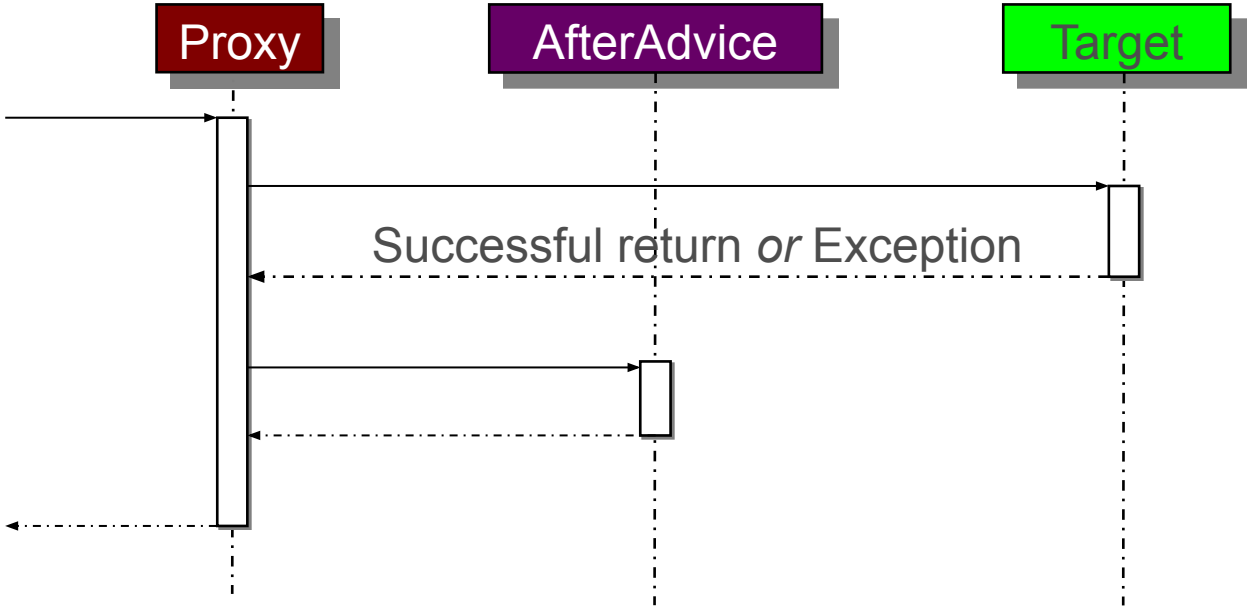
After Throwing Advice - Propagation

- The @AfterThrowing advice will not stop the exception from propagating
  - However it can throw a different type of exception

```
@AfterThrowing(value="execution(* *..Repository.*(..))", throwing="e")
public void report(JoinPoint jp, DataAccessException e) {
   mailService.emailFailure("Exception in repository", jp, e);
   throw new RewardsException(e);
}
```

If you wish to stop the exception from propagating any further, you can use an @Around advice (see later)

Advice Types: After



After Advice Example

- Use *@After* annotation
  - Called regardless of whether an exception has been thrown by the target or not

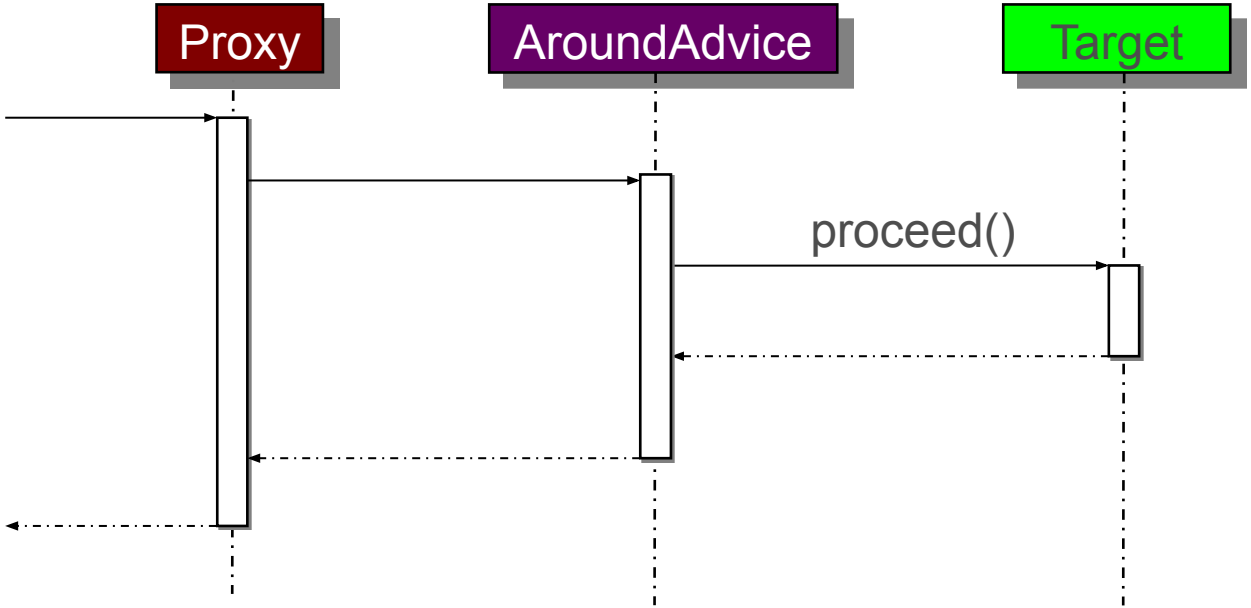
Track calls to all update methods

```
@Aspect
@Component
public class PropertyChangeTracker {
    private Logger logger = Logger.getLogger(getClass());

    @After("execution(void update*(..))")
    public void trackUpdate() {
        logger.info("An update has been attempted …");
    }
}
```

We don't know how the method terminated

Advice Types: Around



Around Advice Example

- Use *@Around* annotation *and* a *ProceedingJoinPoint*
  - Inherits from *JoinPoint* and adds the *proceed()* method

```
@Around("execution(@example.Cacheable * rewards.service..*.*(..))")
public Object cache(ProceedingJoinPoint point)  throws Throwable {
    Object value = cacheStore.get(CacheUtils.toKey(point));

    if (value != null)  return value;

    value = point.proceed();
    cacheStore.put(CacheUtils.toKey(point), value);
    return value;
}
```

Value exists? If so just return it

Proceed *only* if not already cached

Cache values returned by *cacheable* services

Limitations of Spring AOP

- Can only advise *non-private* methods
- Can only apply aspects to *Spring Beans*
- Limitations of weaving with proxies
  - When using proxies, suppose method a() calls method b() on the *same* class/interface
    - advice will *never* be executed for method b()

Summary

- Aspect Oriented Programming (AOP) *modularizes cross-cutting concerns*
- An aspect is a module (Java class) containing the cross-cutting behavior
  - Annotated with *@Aspect*
  - Behavior is implemented as an "*advice*" method
  - Pointcuts select *joinpoints* (methods) where *advice* applies
  - Five advice types
    - Before, AfterThrowing, AfterReturning, After and Around

Lab: Introducing Aspect Oriented Programming

Lab project:
22-aop

Anticipated Lab time:
35 Minutes

Optional Topics: Named pointcuts, context selection, annotations in pointcuts

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- What Problems Does AOP Solve?
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- **Advanced Topics**
  - **Named Pointcuts**
  - Context Selecting Pointcuts
  - Working with Annotations

Named Pointcut Annotation

```
@Aspect
public class PropertyChangeTracker {
    private Logger logger = Logger.getLogger(getClass());

    @Before("serviceMethod() || repositoryMethod()")
    public void monitor() {
        logger.info("A business method has been accessed…");
    }

    @Pointcut("execution(* rewards.service..*Service.*(..))")
    public void serviceMethod() {}

    @Pointcut("execution(* rewards.repository..*Repository.*(..))")
    public void repositoryMethod() {}
}
```

The method *name* becomes the pointcut ID.
The method is *not* executed.

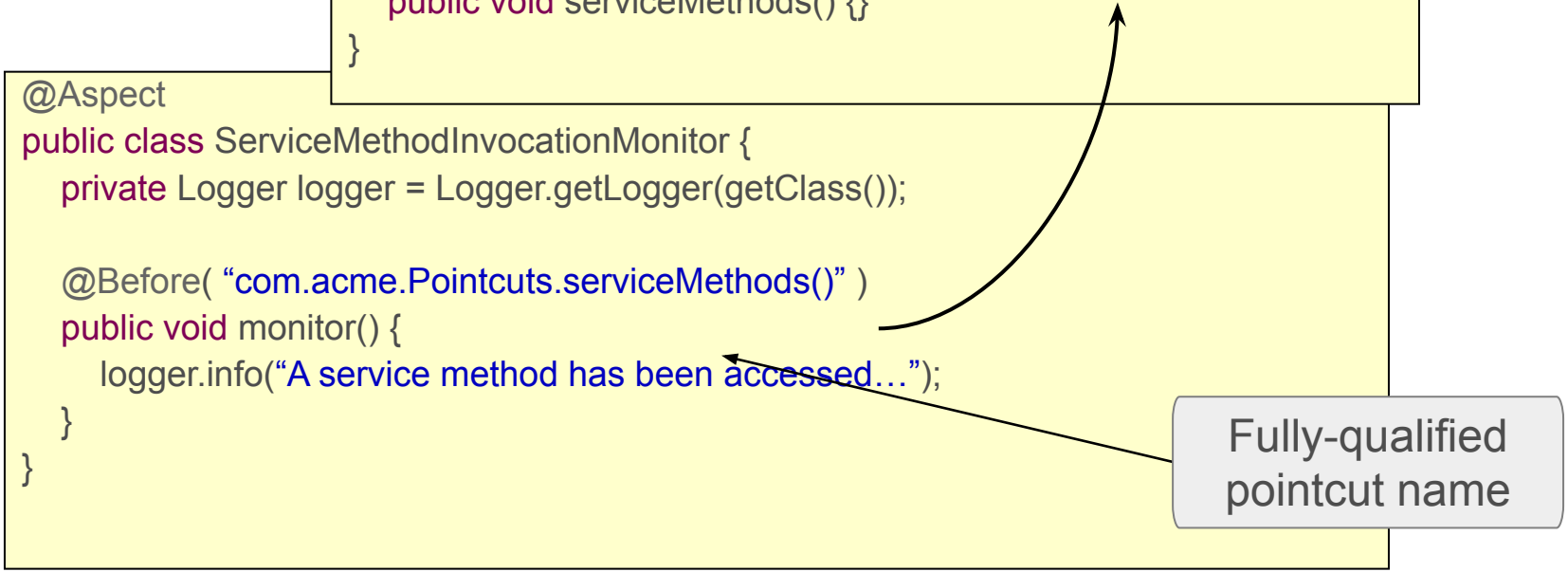
Named Pointcuts

- Expressions can be externalized

```
public class Pointcuts {
    @Pointcut("execution(* rewards.service..*Service.*(..))")
    public void serviceMethods() {}
}
```

```
@Aspect
public class ServiceMethodInvocationMonitor {
    private Logger logger = Logger.getLogger(getClass());

    @Before( "com.acme.Pointcuts.serviceMethods()" )
    public void monitor() {
        logger.info("A service method has been accessed…");
    }
}
```



Named Pointcuts - Summary

- Can break one complicated expression into several sub-expressions
- Allow pointcut expression reusability
- Best practice: consider externalizing expressions into one dedicated class
  - When working with many pointcuts
  - When writing complicated expressions

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Context Selecting Pointcuts

- Pointcuts may also select useful join point context
  - The target object
  - Method arguments
  - Annotations associated with the method, target, or arguments
  - The currently executing object (proxy)
- Allows for simple POJO advice methods
  - Alternative to working with a JoinPoint object directly

Context Selecting Example

- Consider this basic requirement

Log a message every time Server is about to start

```
public interface Server {
    public void start(Map input);
    public void stop();
}
```

In the advice, how do we access Server? Map?

Without Context Selection

- All needed info must be obtained from *JoinPoint* object
  - No type-safety guarantees
  - Write advice *defensively*

```
@Before("execution(void example.Server.start(java.util.Map))")
public void logServerStartup(JoinPoint jp) {
    // A 'safe' implementation would also check target type
    Server server = (Server) jp.getTarget();
    // Don't assume args[0] exists
    Object[] args= jp.getArgs();
    Map map = args.length > 0 ? (Map) args[0] : new HashMap();
    logger.info( server + " starting – params: " + map);
}
```

With Context Selection

- Best practice: use context selection
  - Method attributes are bound automatically
  - Types must match or advice skipped

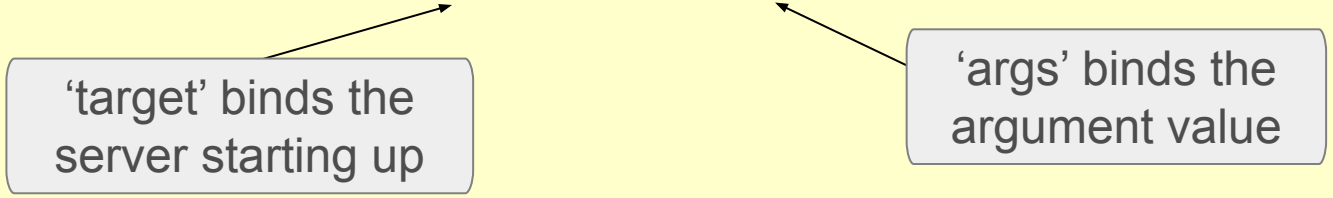
```
@Before("execution(void example.Server.start(java.util.Map))
   && target(server) && args(input)")
public void logServerStartup(Server server, Map input) {
    …
}
```

- target(server) selects the target of the execution (your object)
- this(server) would have selected the proxy

Context Selection - Named Pointcut

```
@Before("serverStartMethod(server, input)")
public void logServerStartup(Server server, Map input) {
    …
}

@Pointcut("execution(void example.Server.start(java.util.Map))
                                && target(server) && args(input)")
public void serverStartMethod (Server server, Map input) {}
```



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AOP and Annotations - Example

- Use of the *annotation()* designator

```
@Around("execution(* *(..)) && @annotation(txn)")
public Object execute(ProceedingJoinPoint jp, Transactional txn) {
    TransactionStatus tx;

    try {
       TransactionDefinition defintion = new DefaultTransactionDefinition();
       definition.setTimout(txn.timeout());
       definition.setReadOnly(txn.readOnly());
       ...
       tx = txnMgr.getTransaction(definition);
       return jp.proceed();
    }
    … // commit or rollback
}
```

No need for @Transactional in *execution* expression – the *@annotation* matches it instead

AOP and Annotations – Named pointcuts

- Same example using a named-pointcut

```
@Around("transactionalMethod(txn)")
public Object execute(ProceedingJoinPoint jp, Transactional txn) {
    ...
}

@Pointcut("execution(* *(..)) && @annotation(txn)")
public void transactionalMethod(Transactional txn) {}
```

Advanced Topics Summary

- Topics covered were:
  - Named Pointcuts
  - Context-Selecting Pointcuts
  - Working with Annotations