Project Jigsaw: Under the Hood

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Java Platform Group, Oracle
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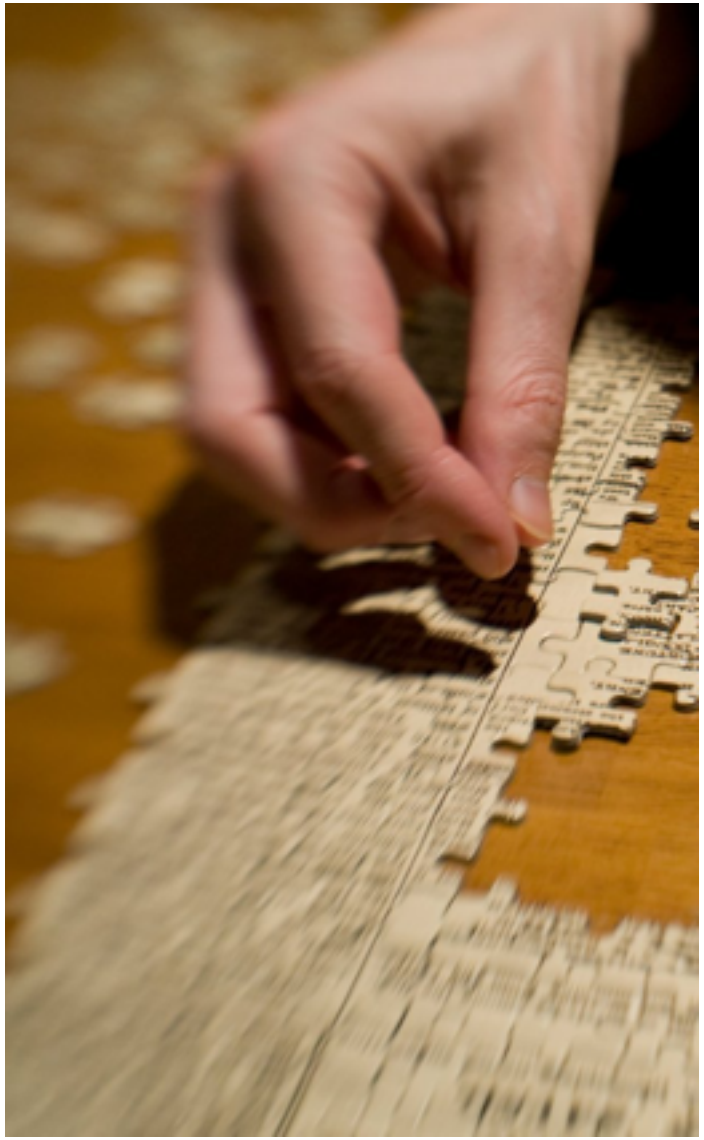
http://openjdk.java.net/projects/jigsaw



Project Jigsaw: Under The Hood

Part I: Accessibility and Readability

Part II: Different Kinds of Modules

Part III: Loaders and Layers

Part I: Accessibility and Readability

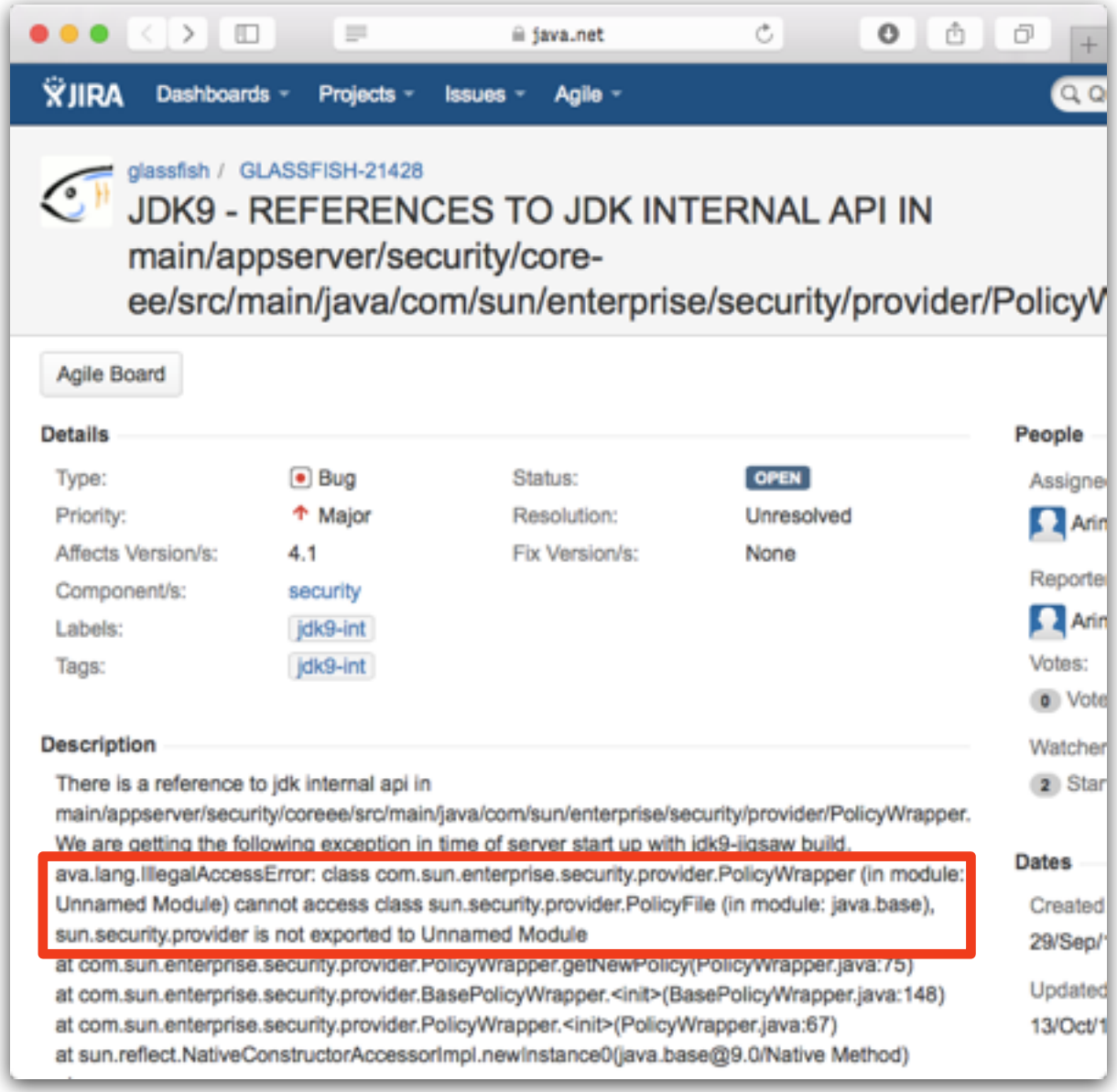
Accessibility 1995–2015

- public
- protected
- <package>
- private

Accessibility 2015–

- *public to everyone*
- *public but only to specific modules*
- *public only within a module*
- protected
- <package>
- private

“public” no longer means “accessible.”

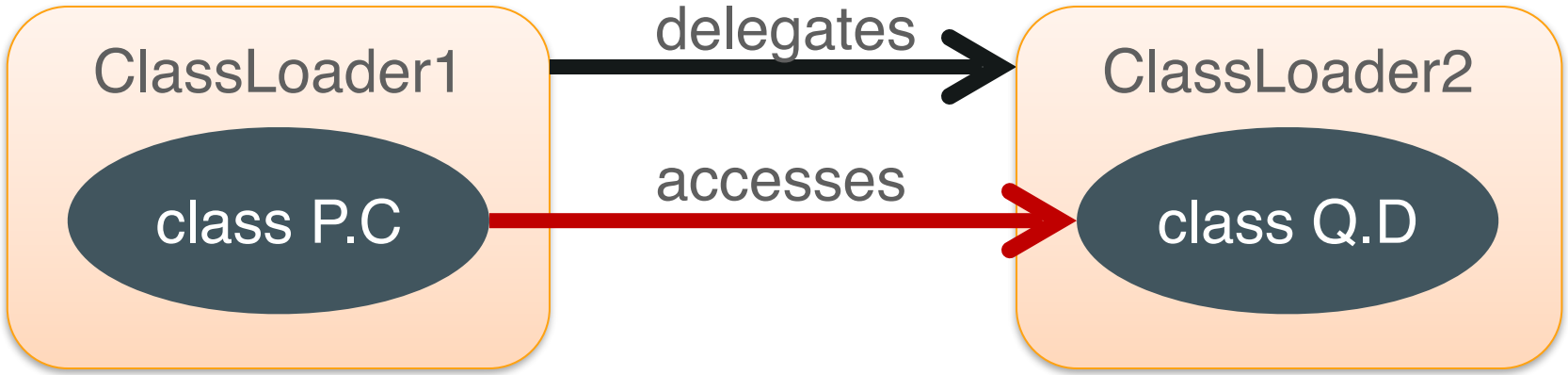


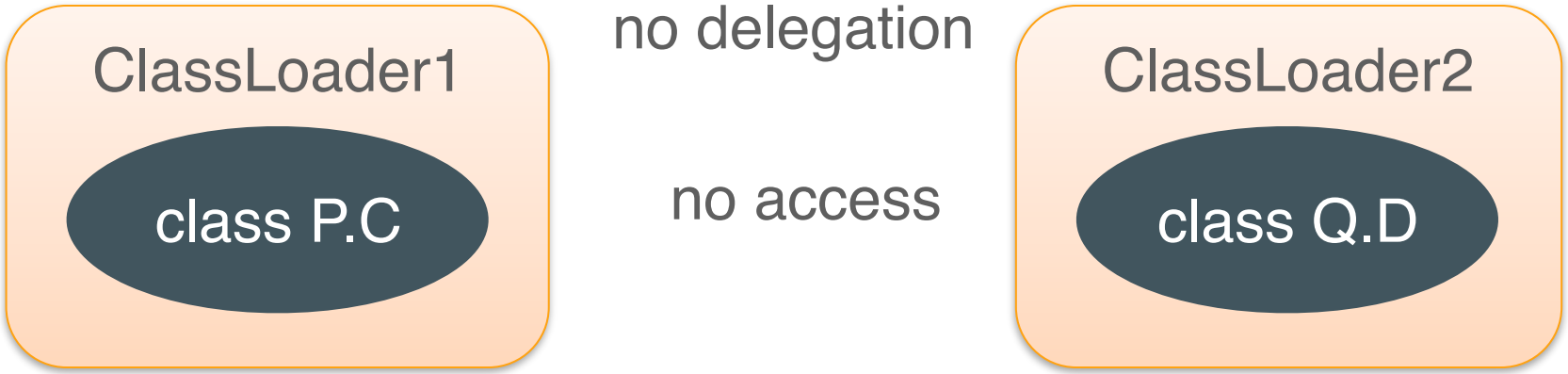
#Jfokus #Jigsaw

Accessibility and Module Declarations

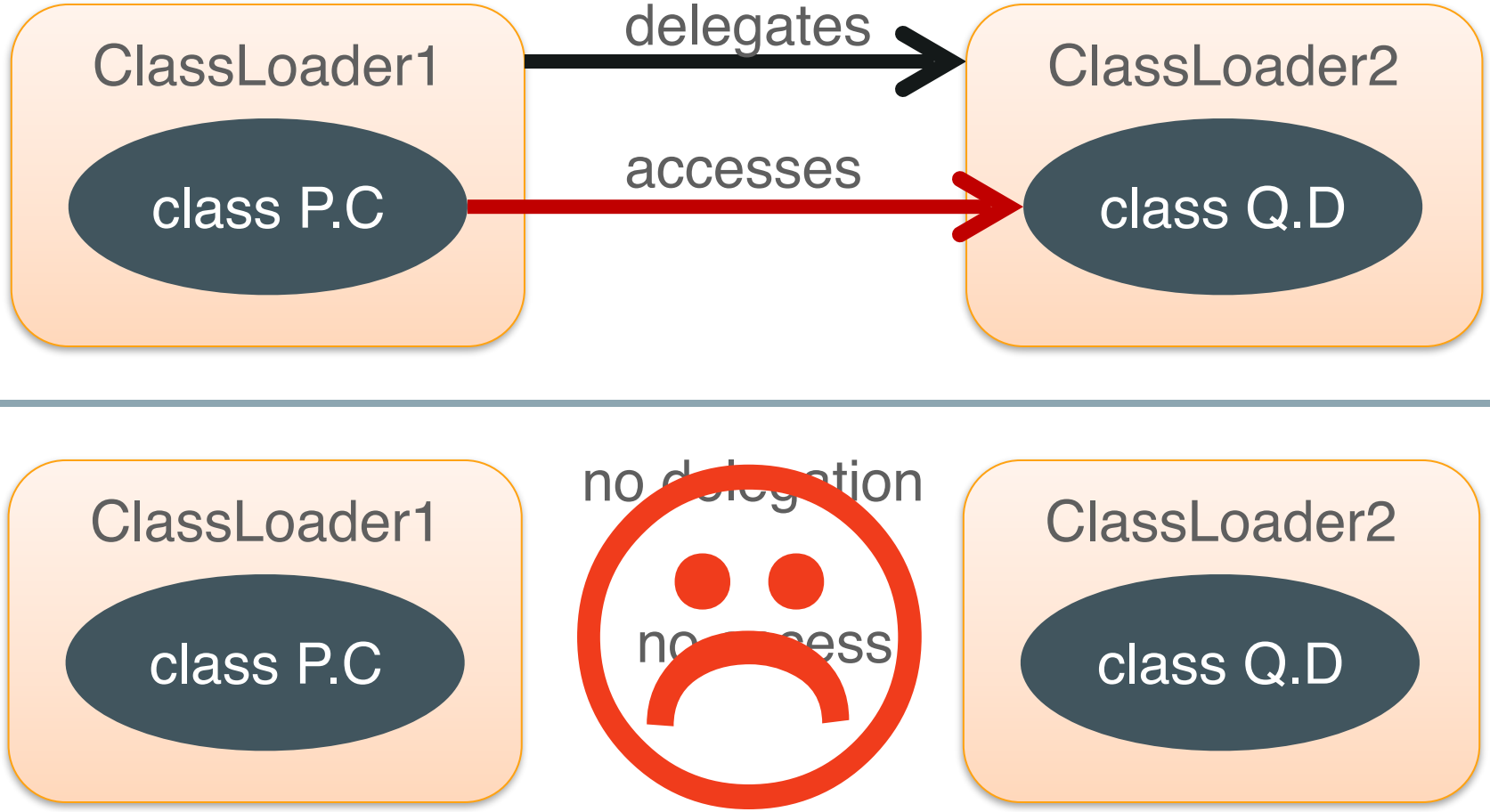
```
// src/java.sql/module-info.java
module java.sql {
  exports java.sql;
  exports javax.sql;
  exports javax.transaction.xa;
}
```

Accessibility and Class Loaders

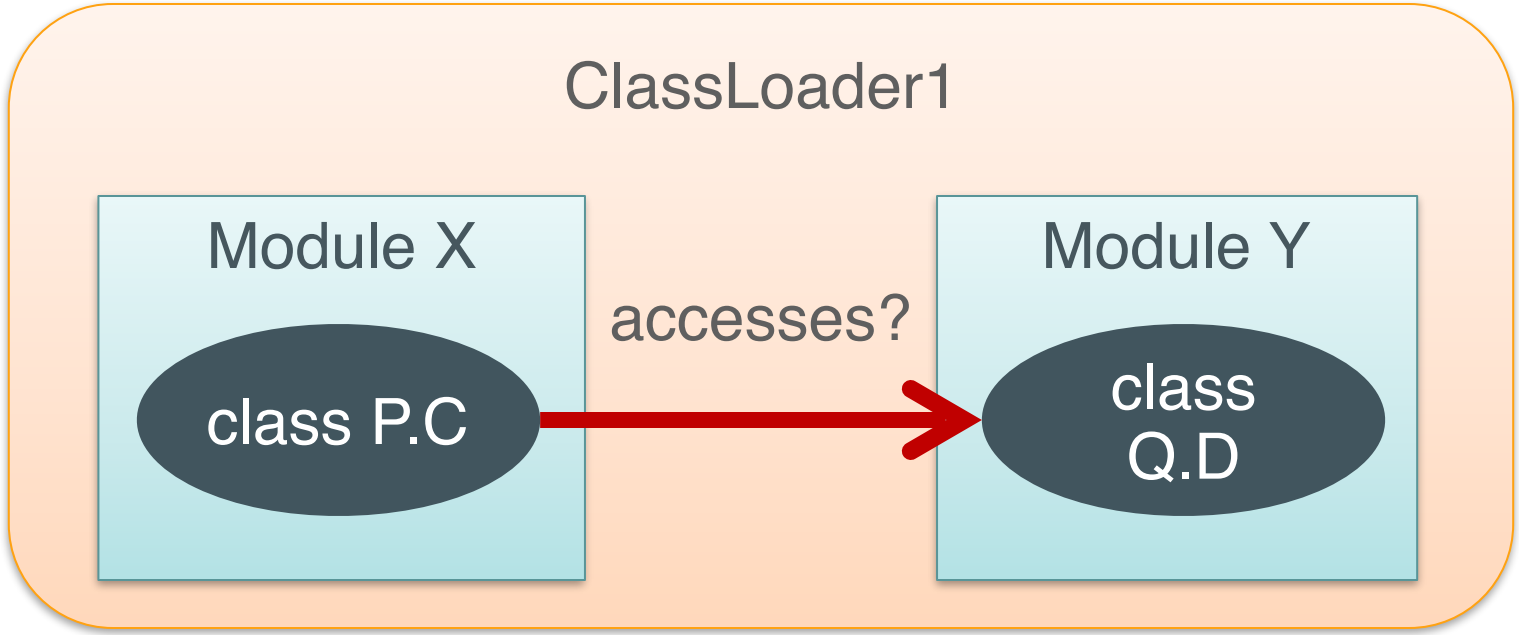




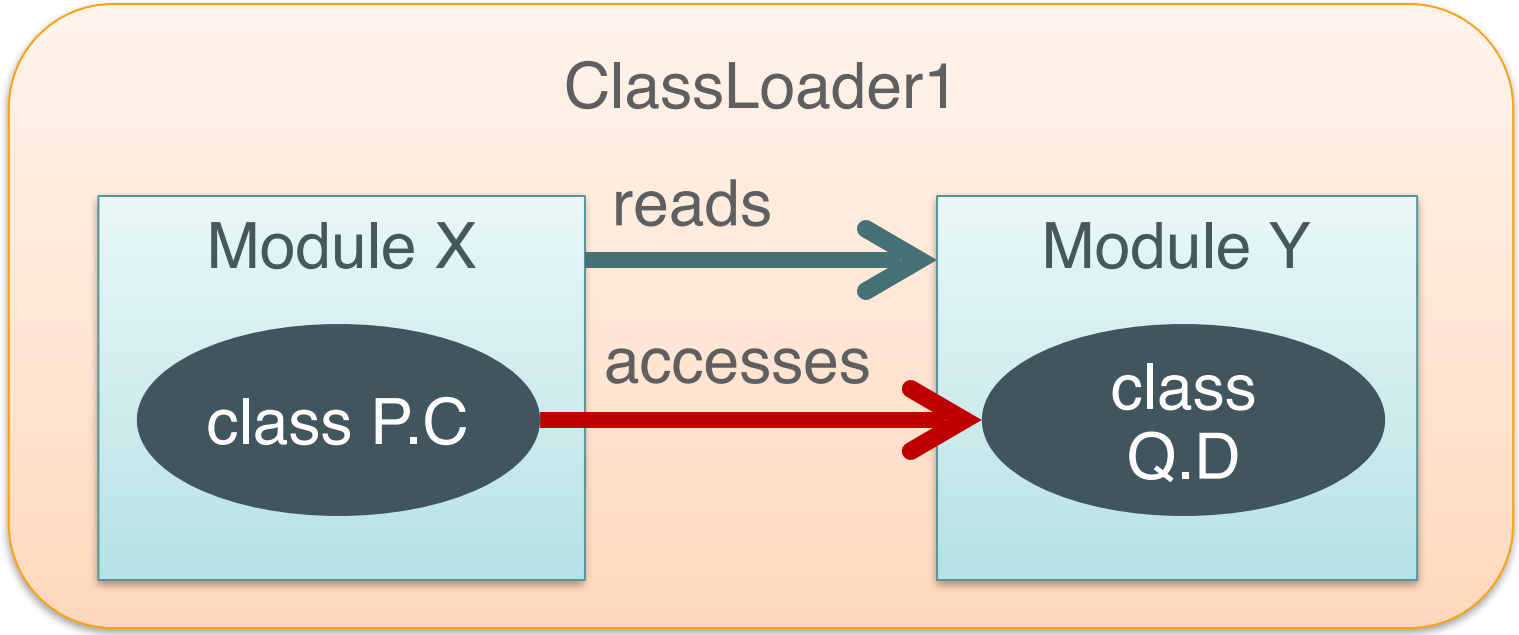
Accessibility and Class Loaders



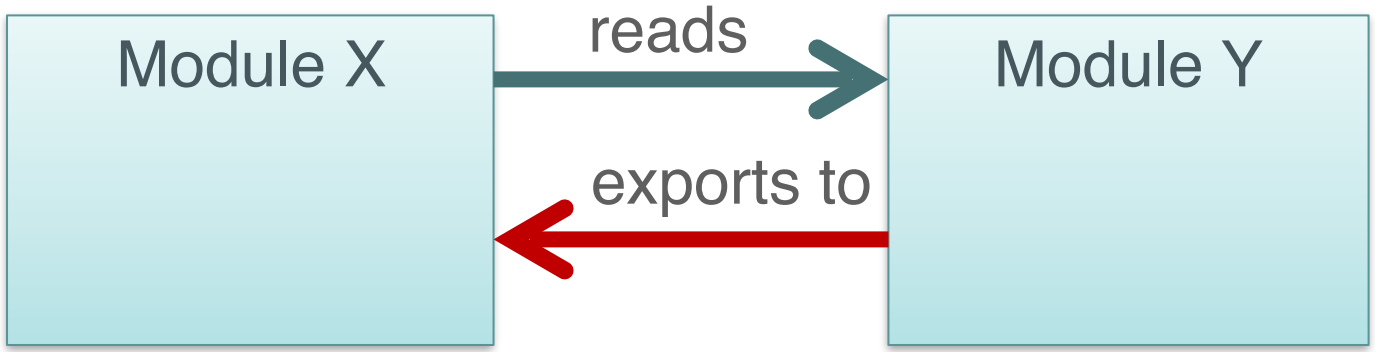
One Class Loader, Many Modules



The Role of Readability



The Role of Readability




```
module X {
  requires Y;
}
```

```
module Y {
  exports Q;
}
```

Readability in the Java SE module graph

```
module java.sql {
  requires java.logging;
  exports java.sql;
}
```

```
module java.logging {
  exports java.util.logging;
}
```

```
package java.sql;
import java.util.logging.Logger;
public class DriverManager {
  new Logger() {..}
}
```

```
package java.util.logging;
public class Logger {
  ...
}
```

Readability in the Java SE module graph

```
module java.sql {
  requires java.logging;
  exports java.sql;
}
```

```
module java.logging {
  exports java.util.logging;
}
```

```
package java.sql;
import java.util.logging.Logger;
public interface Driver {
  Logger getParentLogger();
}
```

```
package java.util.logging;
public class Logger {
  ...
}
```

Readability in the Java SE module graph

```
module myApp {
  requires java.sql;
  requires java.logging;
}
```

```
module java.sql {
  requires java.logging;
  exports java.sql;
}
```

```
module java.logging {
  exports java.util.logging;
}
```

Readability in the Java SE module graph

```
module myApp {
  requires java.sql;
  requires java.logging;
}
```

```
module java.sql {
  requires public java.logging;
  exports java.sql;
}
```

```
module java.logging {
  exports java.util.logging;
}
```

Readability in the Java SE module graph

```
module myApp {
  requires java.sql;
}
```

```
module java.sql {
  requires public java.logging;
  requires public java.sql.time;
}
```

```
module java.logging {
  exports java.util.logging;
}
```

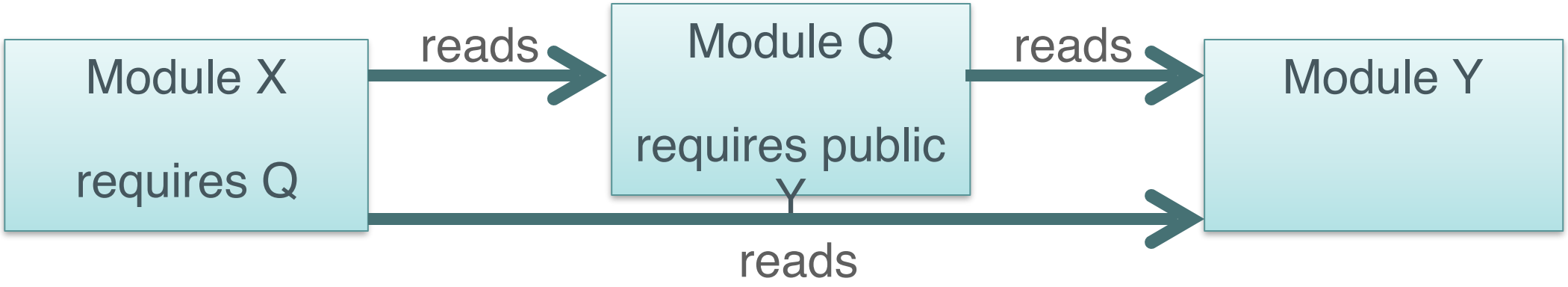
```
module java.sql.time {
  exports java.sql.time;
}
```

Direct and implied readability

- X reads Y if:
  - X requires Y

  or

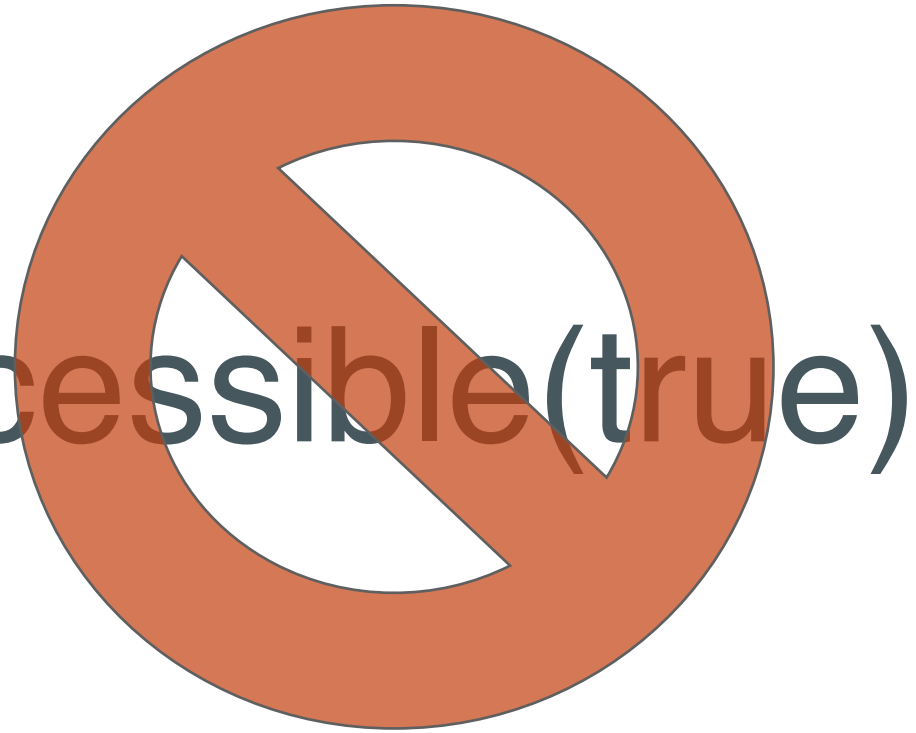
  - X reads Q, and Q requires public Y



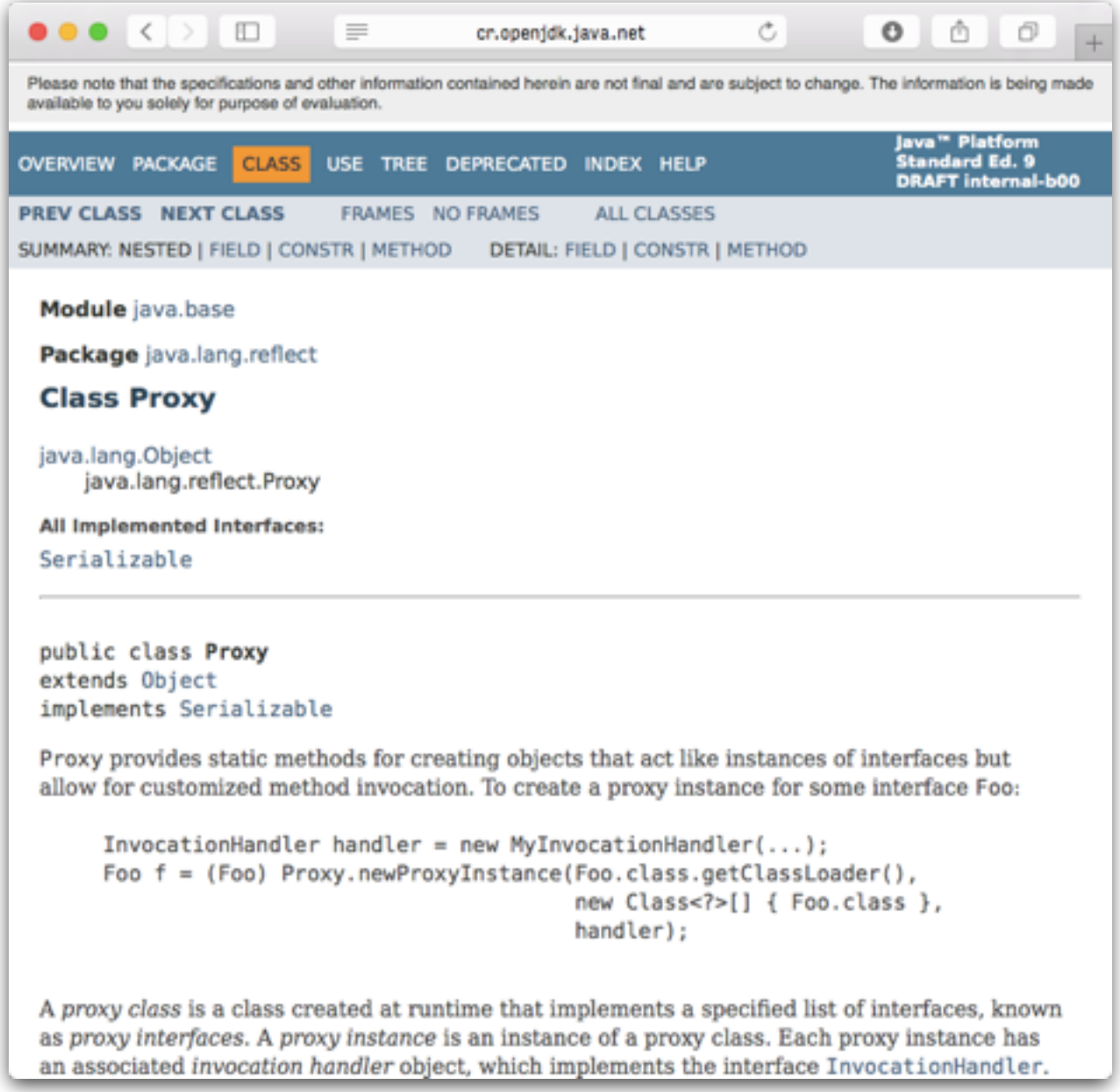
Core Reflection

```
void doSomething(Class<?> c) {
    Method[] ms = c.getDeclaredMethods();
    ms[0].invoke(…);
}
```

Core Reflection



Proxies



cr.openjdk.java.net

Please note that the specifications and other information contained herein are not final and are subject to change. The information is being made available to you solely for purpose of evaluation.

OVERVIEW PACKAGE CLASS USE TREE DEPRECATED INDEX HELP — Java™ Platform Standard Ed. 9 DRAFT internal-b00

PREV CLASS NEXT CLASS FRAMES NO FRAMES ALL CLASSES

SUMMARY: NESTED | FIELD | CONSTR | METHOD DETAIL: FIELD | CONSTR | METHOD

Module java.base

Package java.lang.reflect

Class Proxy

java.lang.Object
    java.lang.reflect.Proxy

All Implemented Interfaces:

Serializable

```
public class Proxy
extends Object
implements Serializable
```

Proxy provides static methods for creating objects that act like instances of interfaces but allow for customized method invocation. To create a proxy instance for some interface Foo:

```
InvocationHandler handler = new MyInvocationHandler(...);
Foo f = (Foo) Proxy.newProxyInstance(Foo.class.getClassLoader(),
                                     new Class<?>[] { Foo.class },
                                     handler);
```

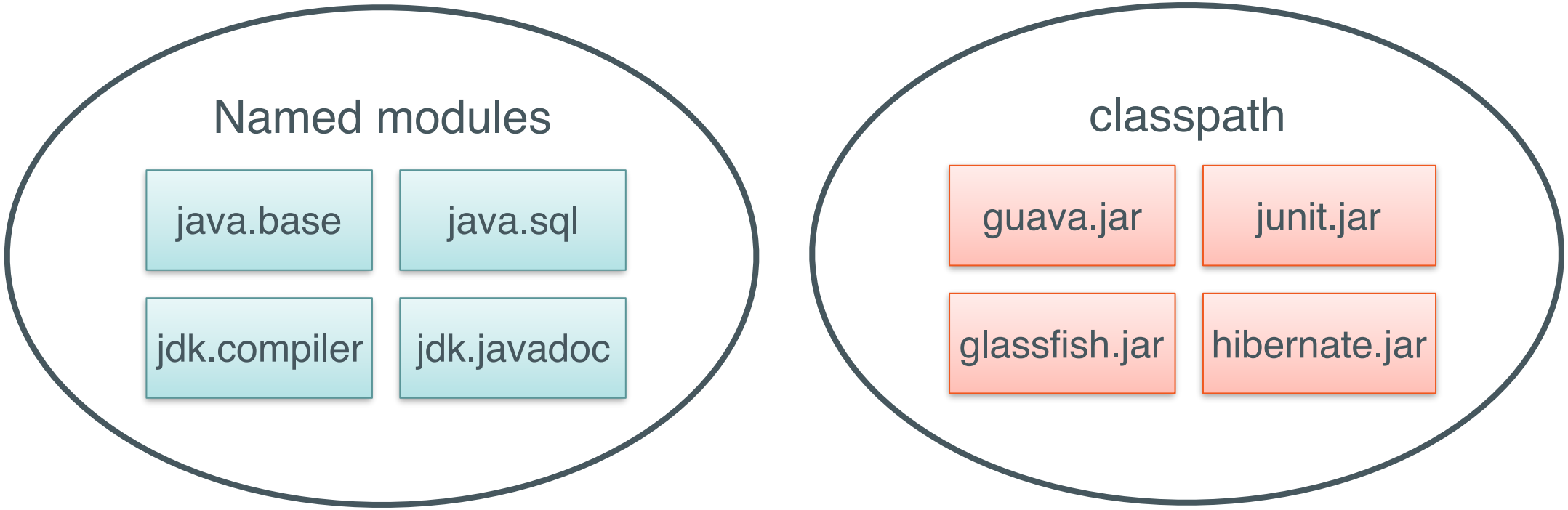
A *proxy class* is a class created at runtime that implements a specified list of interfaces, known as *proxy interfaces*. A *proxy instance* is an instance of a proxy class. Each proxy instance has an associated *invocation handler* object, which implements the interface InvocationHandler.

Summary of Part I: Accessibility and Readability

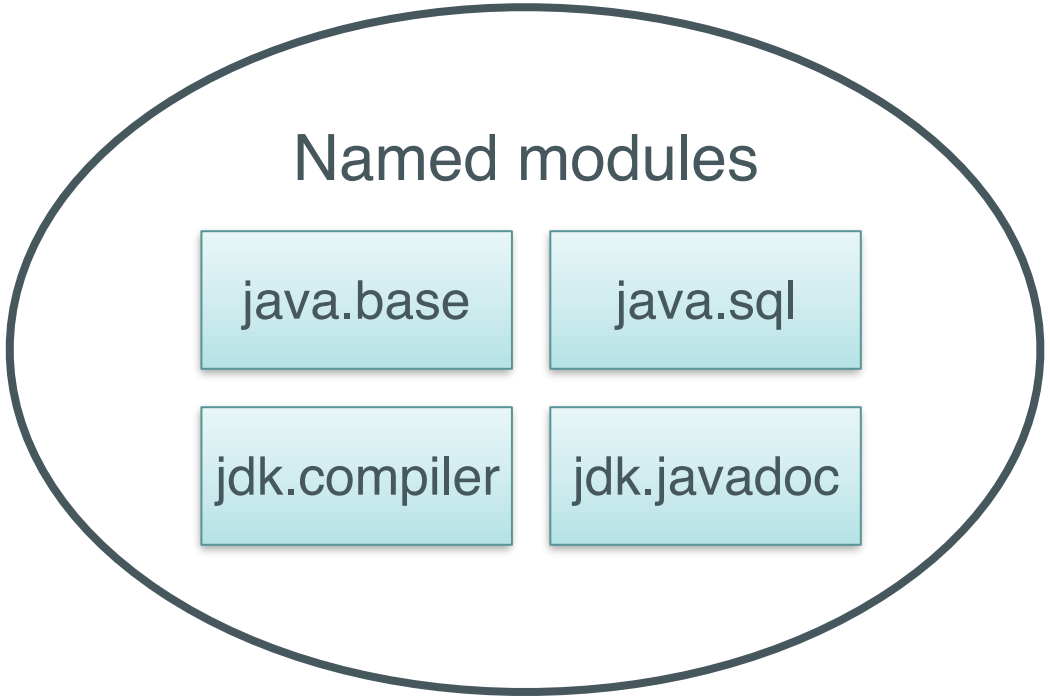
- Accessibility used to be a simple check for ‘public’ or “same package”.
- In Java SE 9, accessibility strongly encapsulates module internals.
- Accessibility relies on readability, which can be direct or implied.
- **Accessibility is enforced by the compiler, VM, and Core Reflection.**

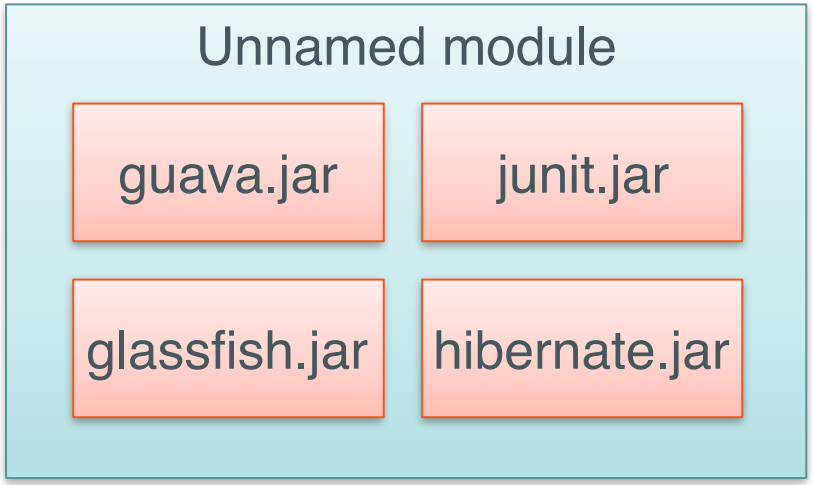
Part II: Different Kinds of Modules

Named Modules

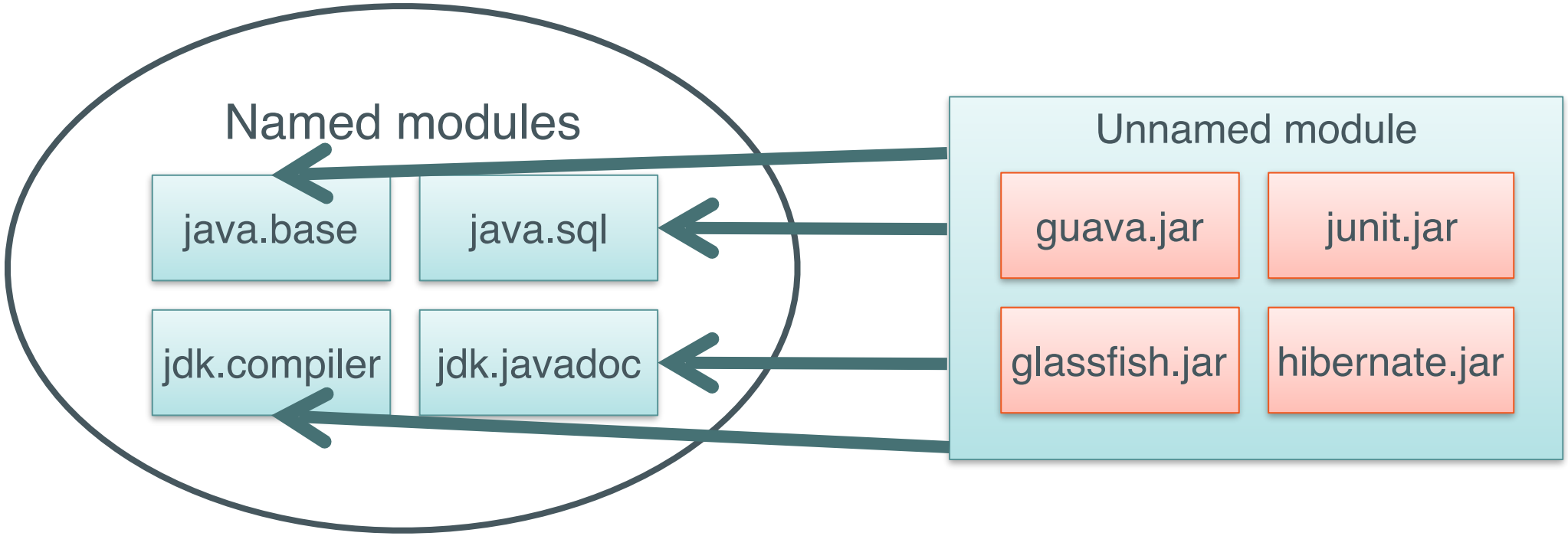


The Unnamed Module

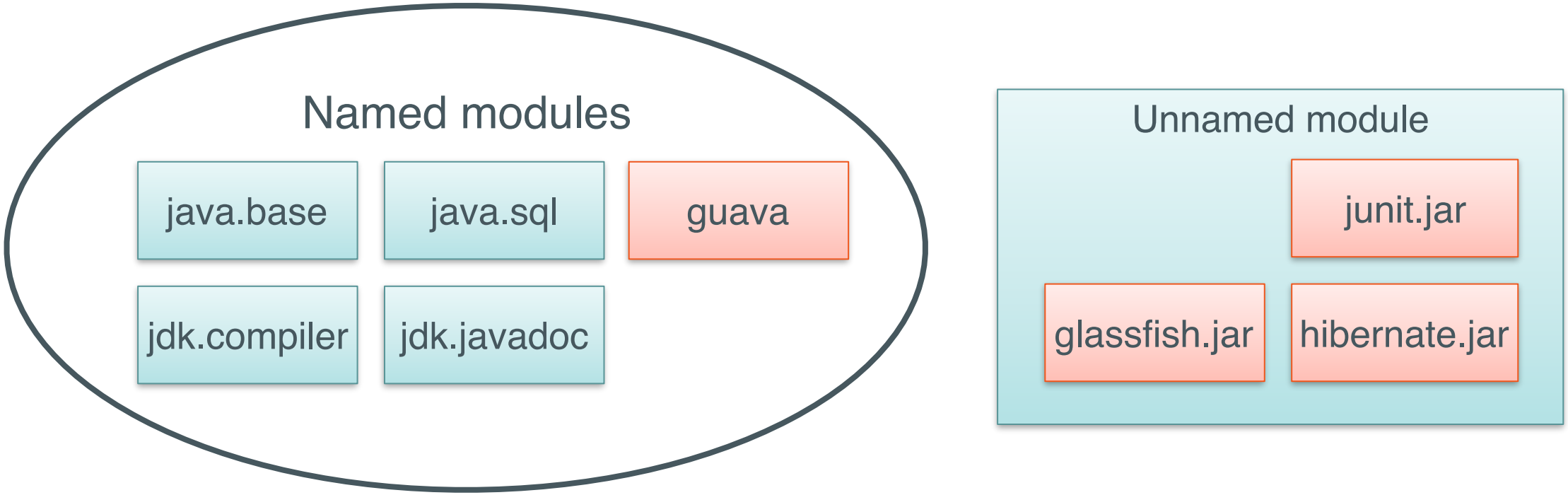




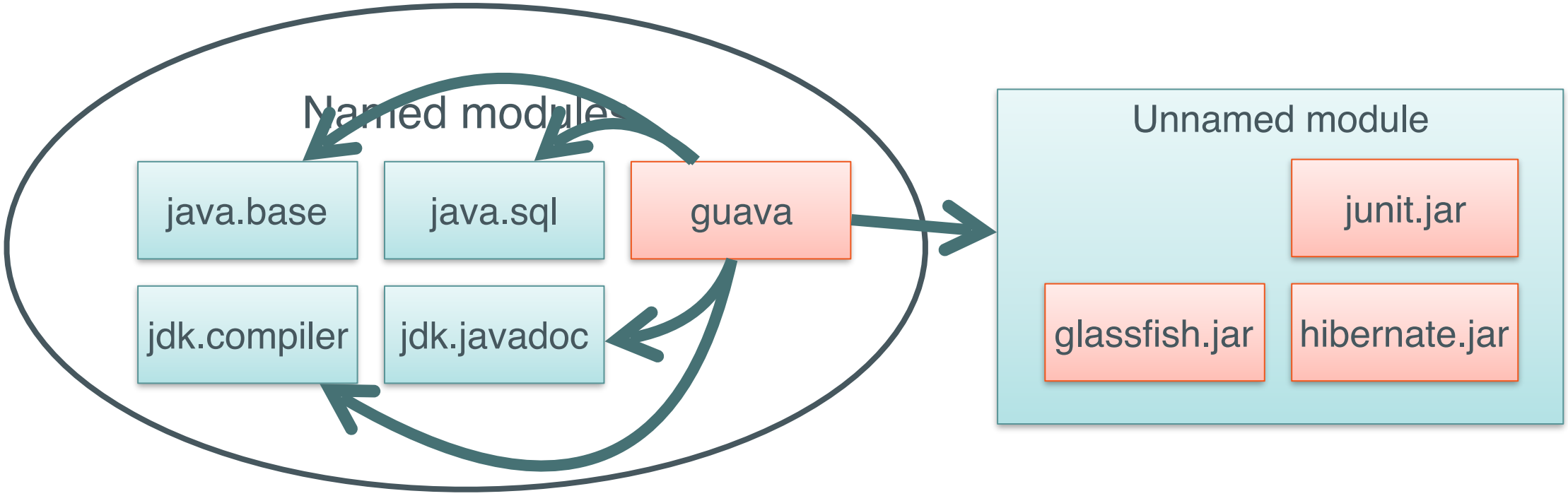
The Unnamed Module



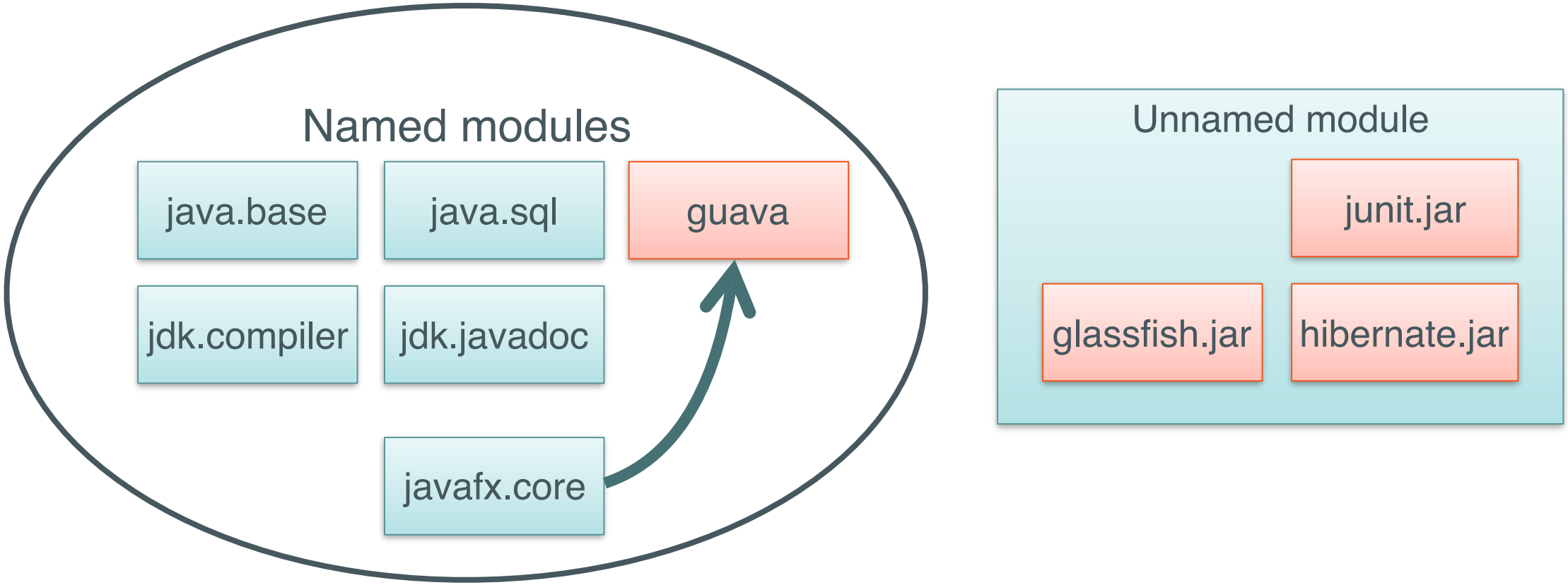
Automatic Modules



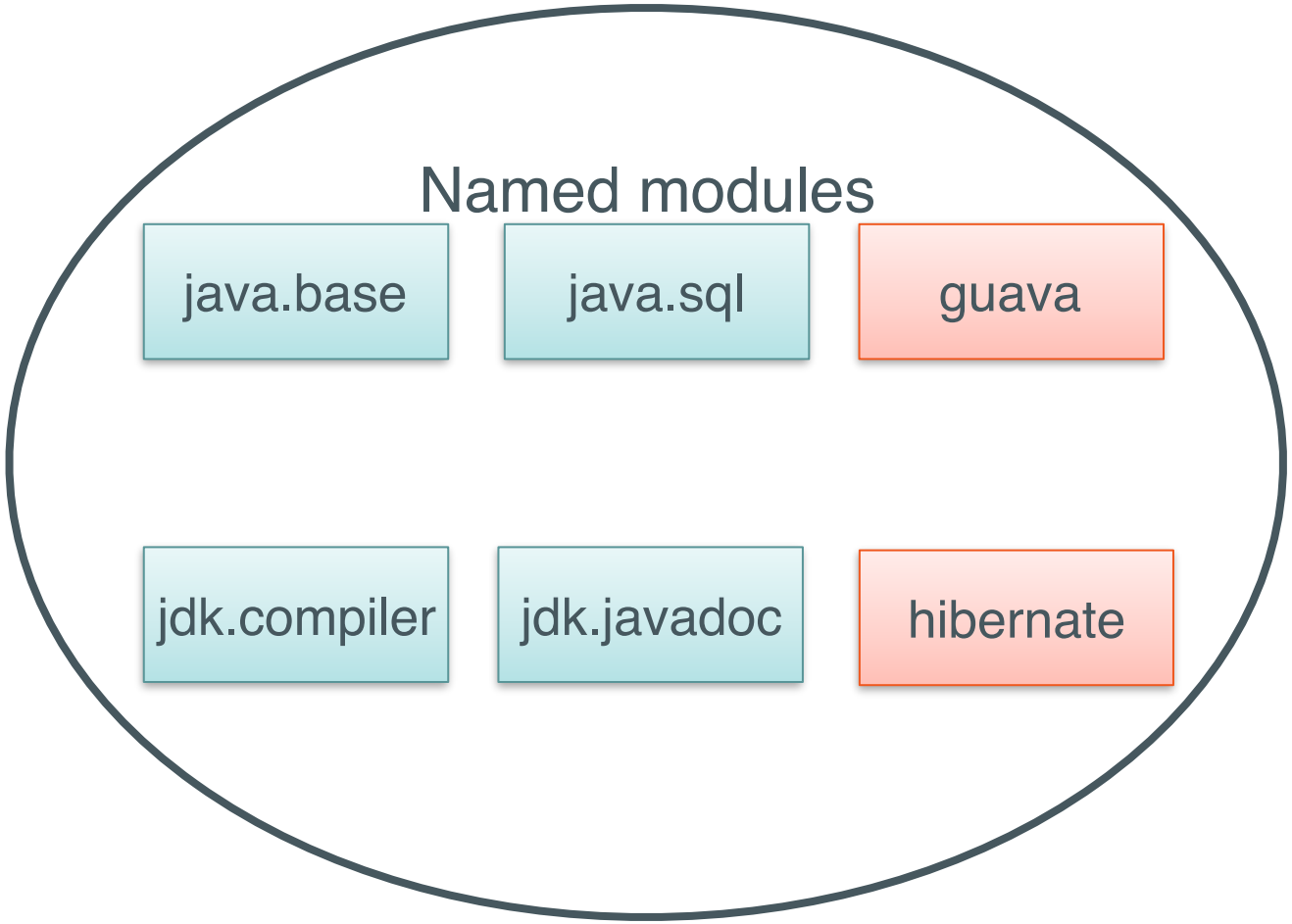
Automatic Modules

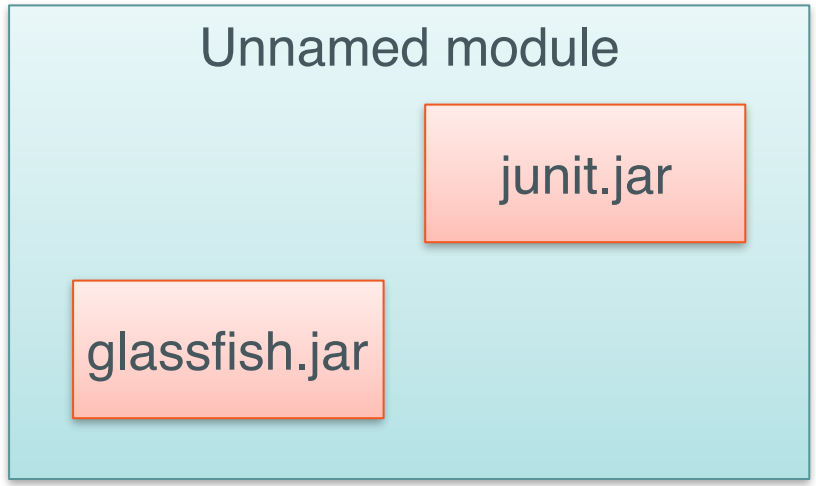


Automatic Modules

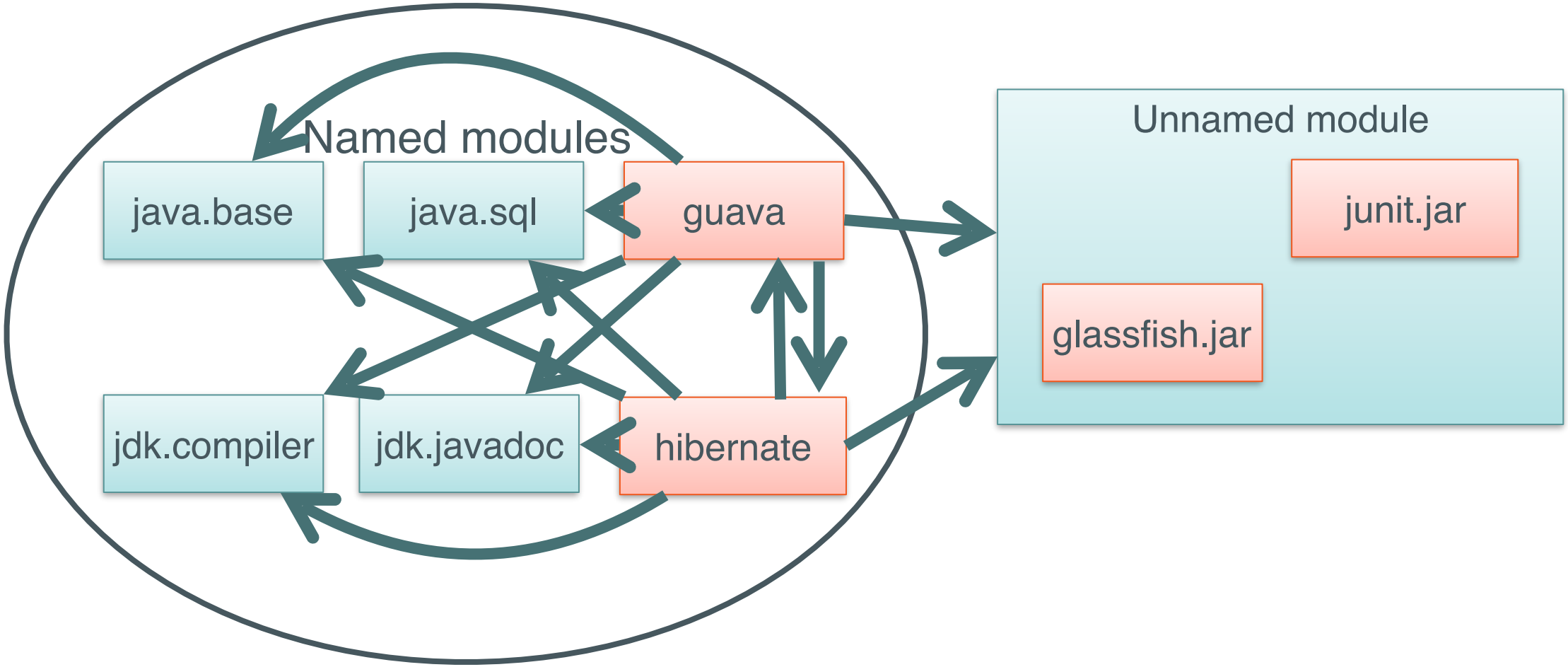


Multiple Automatic Modules





Multiple Automatic Modules



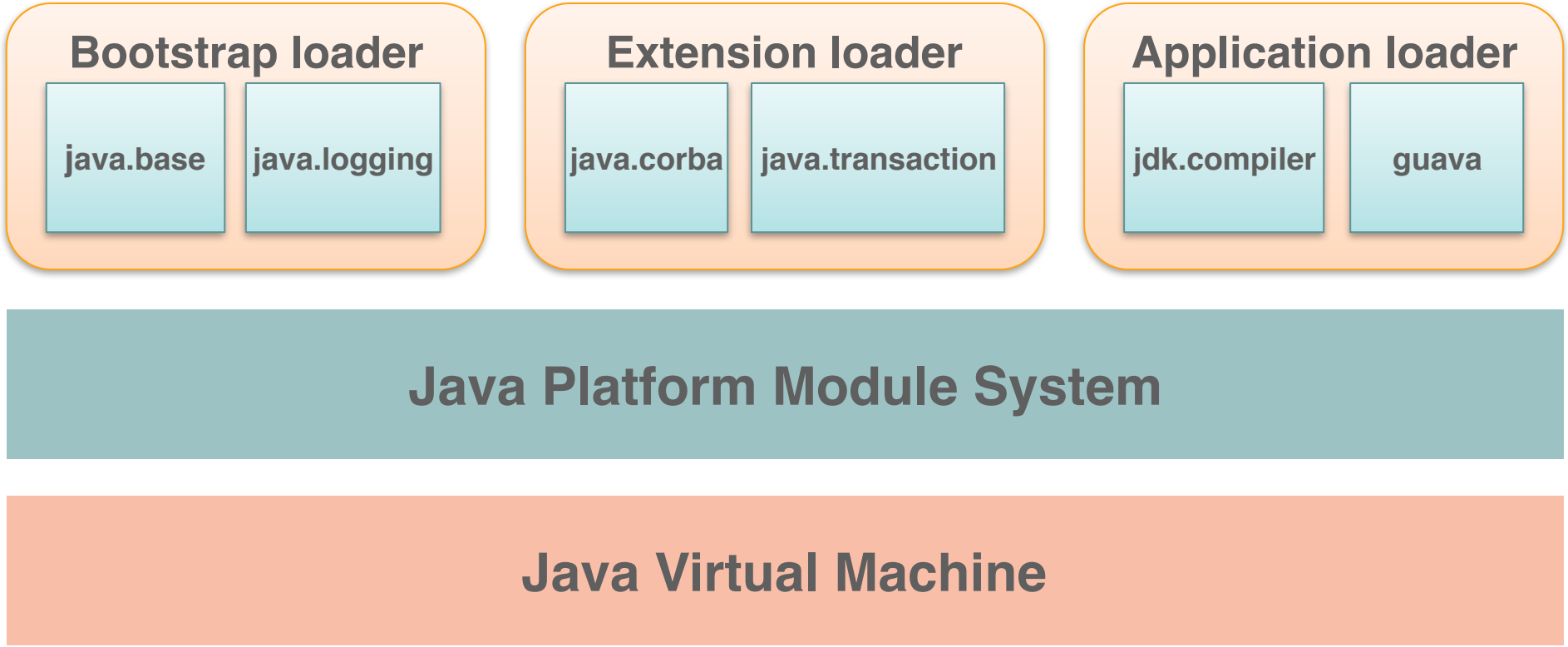
Summary of Part II: Different Kinds of Modules

- Explicit named modules (java.sql)
- Automatic named modules (guava)
- Unnamed module (*a.k.a.* the classpath)
- **Lots of readability "for free" to help with migration.**

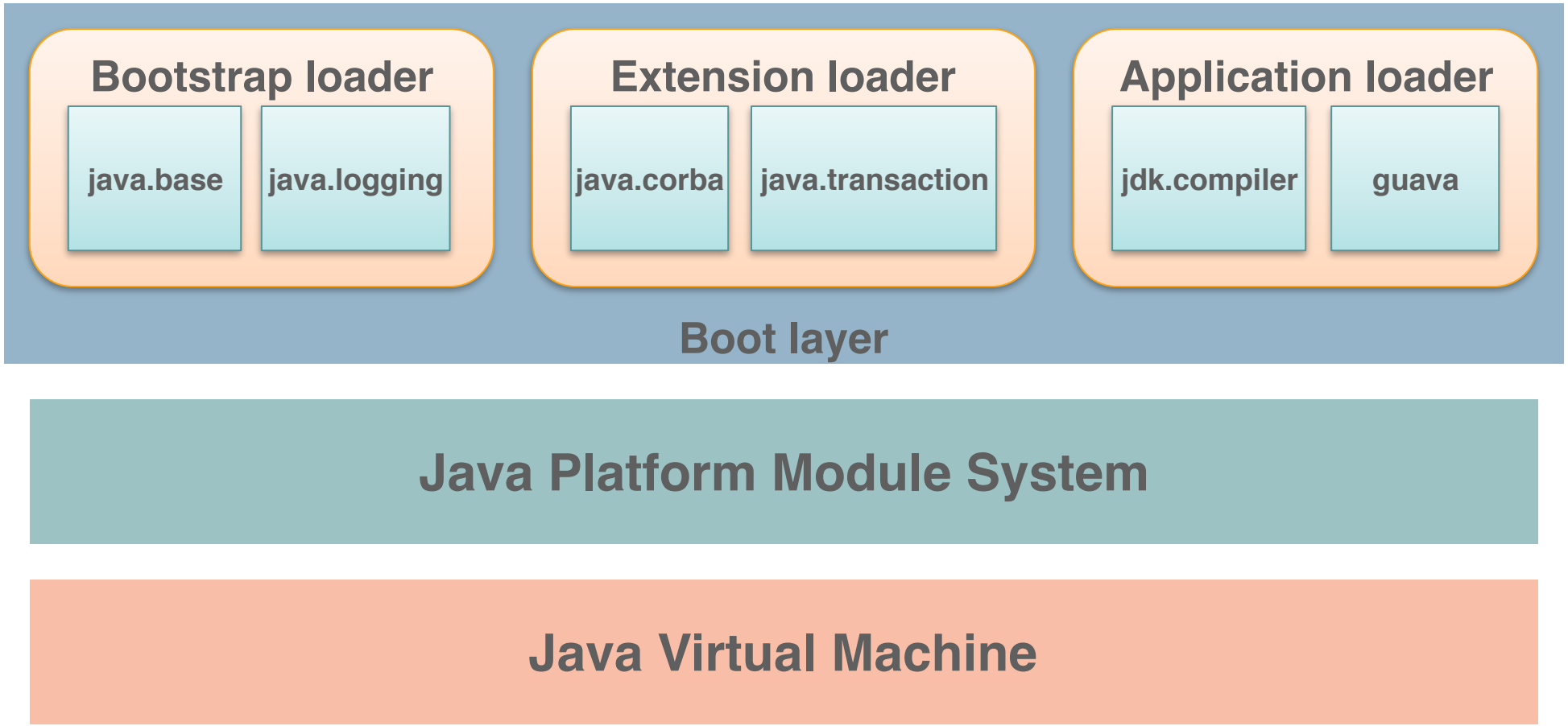
Part III: Loaders and Layers

Class loading does not change.

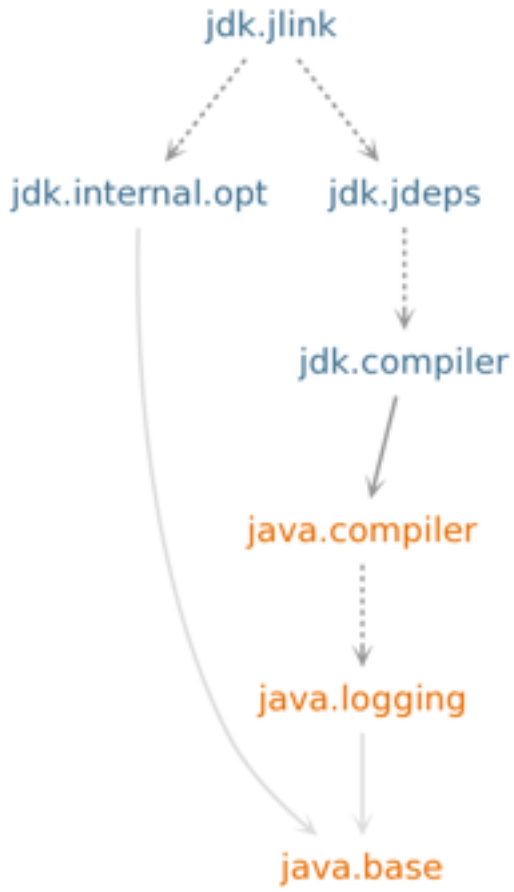
Class Loaders in the JDK



Layers

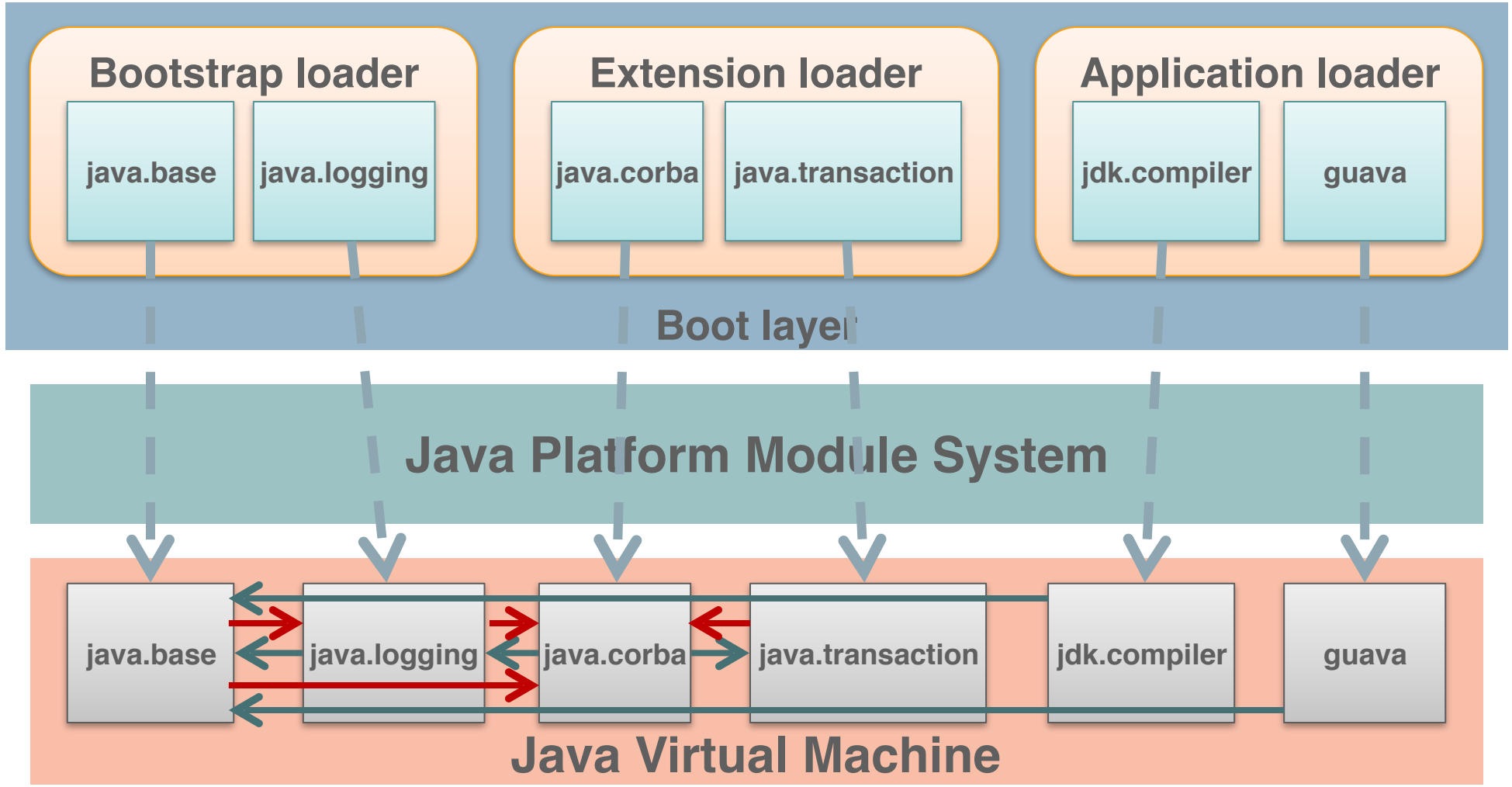


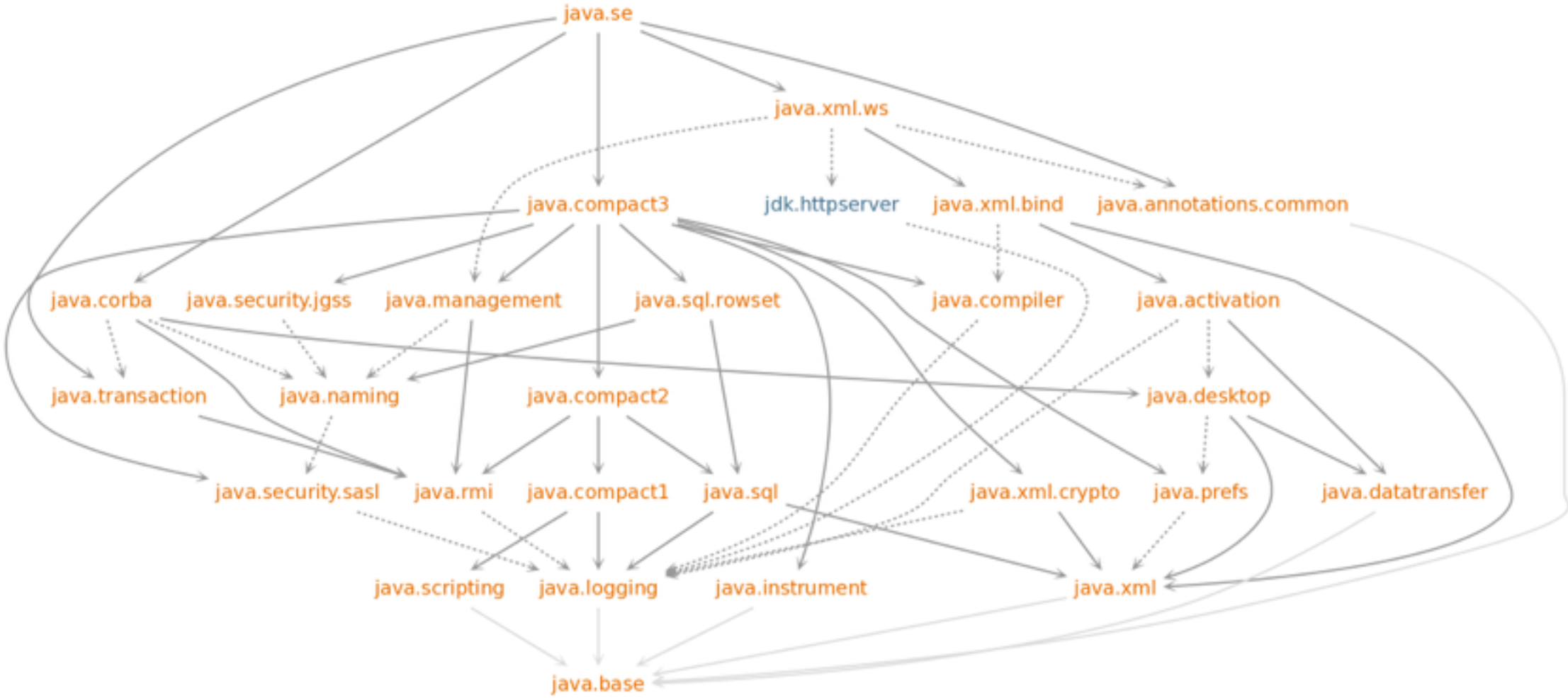
Layer creation




```
String moduleName -> {
    switch (moduleName) {
        case "java.base":
        case "java.logging":
            return BOOTSTRAP_LDR;
        default:
            return APP_LDR;
    }
}
```

Layers and the VM





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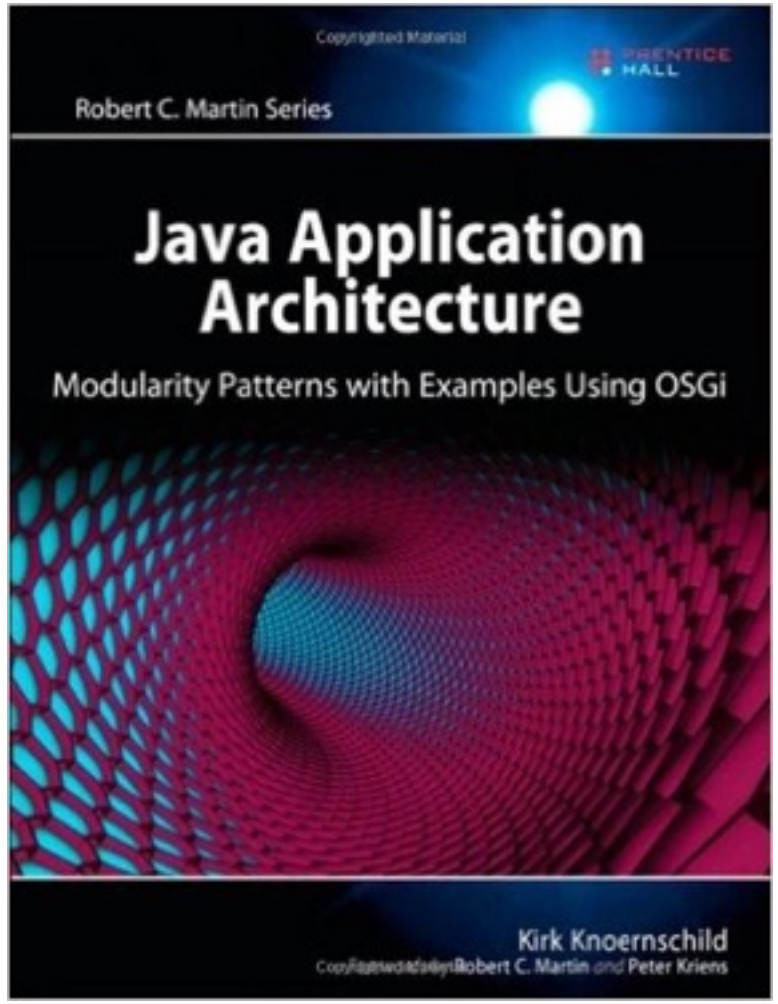
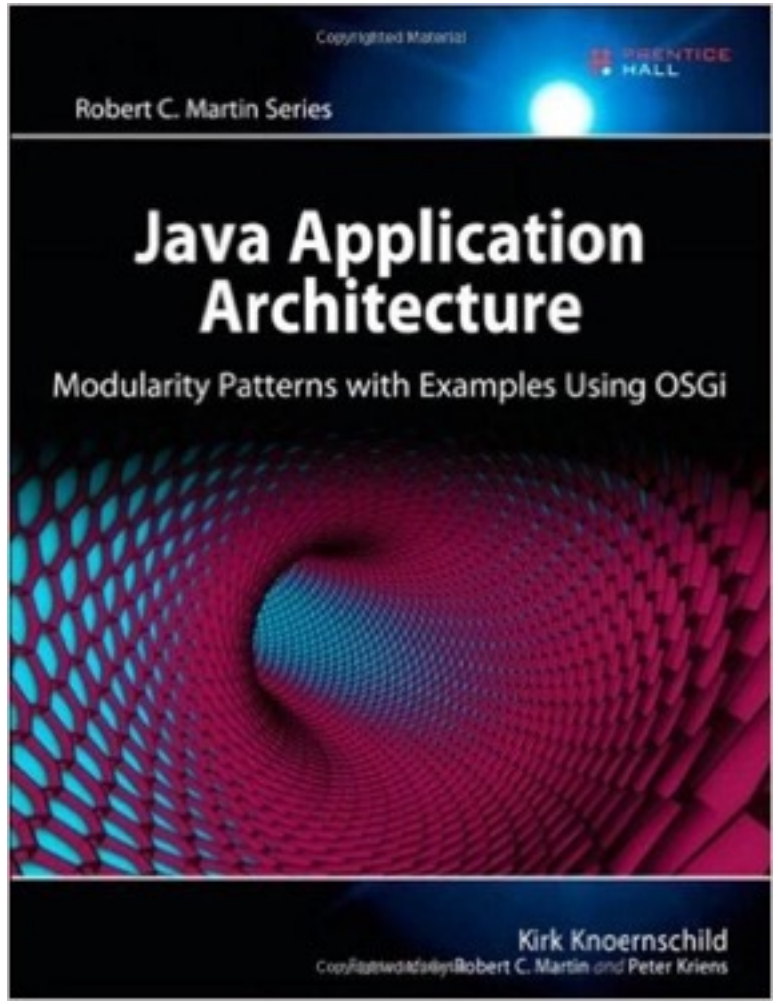
Well-formed graphs

"Excessive dependencies are bad. But, cyclic dependencies are especially bad."



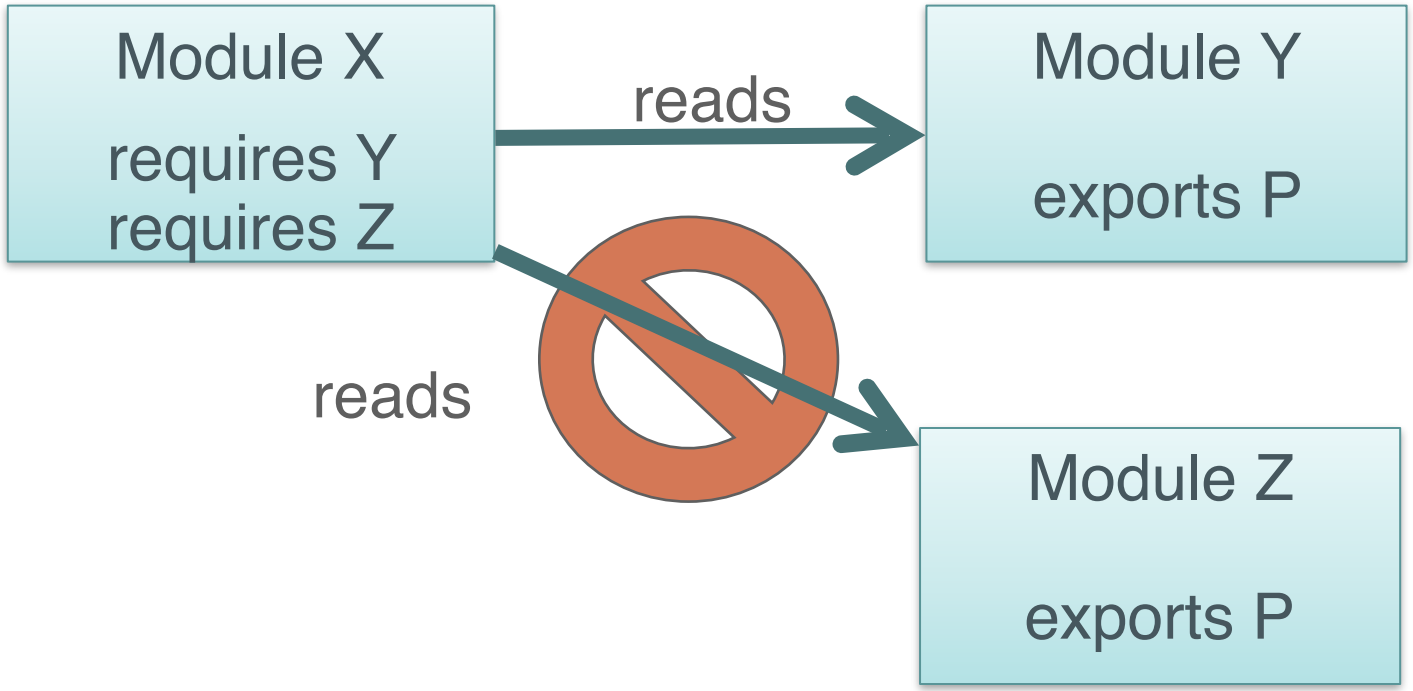
Well-formed graphs

"Generally speaking, cycles are always bad! However, some cycles are worse than others. Cycles among classes are tolerable, assuming they don't cause cycles among the packages or modules containing them. Cycles among packages may also be tolerable, assuming they don't cause cycles among the modules containing them.
Module relationships must never be cyclic."



Well-formed graphs

- A module may read at most one module that exports a package called P.

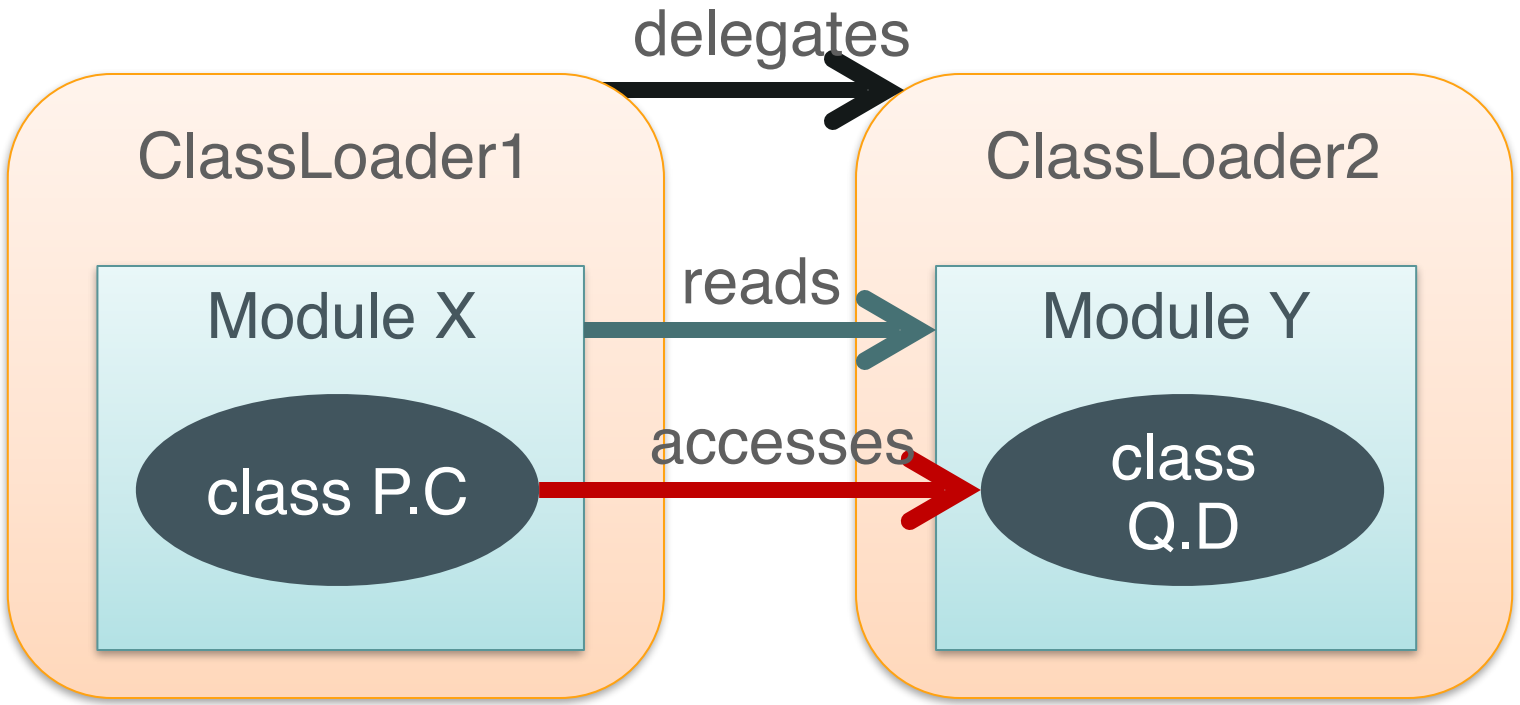


Well-formed maps

```
String moduleName -> {
    switch (moduleName) {
        case "java.base":
        case "java.logging":
            return BOOTSTRAP_LDR;
        default:
            return APP_LDR;
    }
}
```

- Different modules with the same package map to different loaders.
- (Loader delegation respects module readability.)

Loaders and Readability



Example: DOM APIs

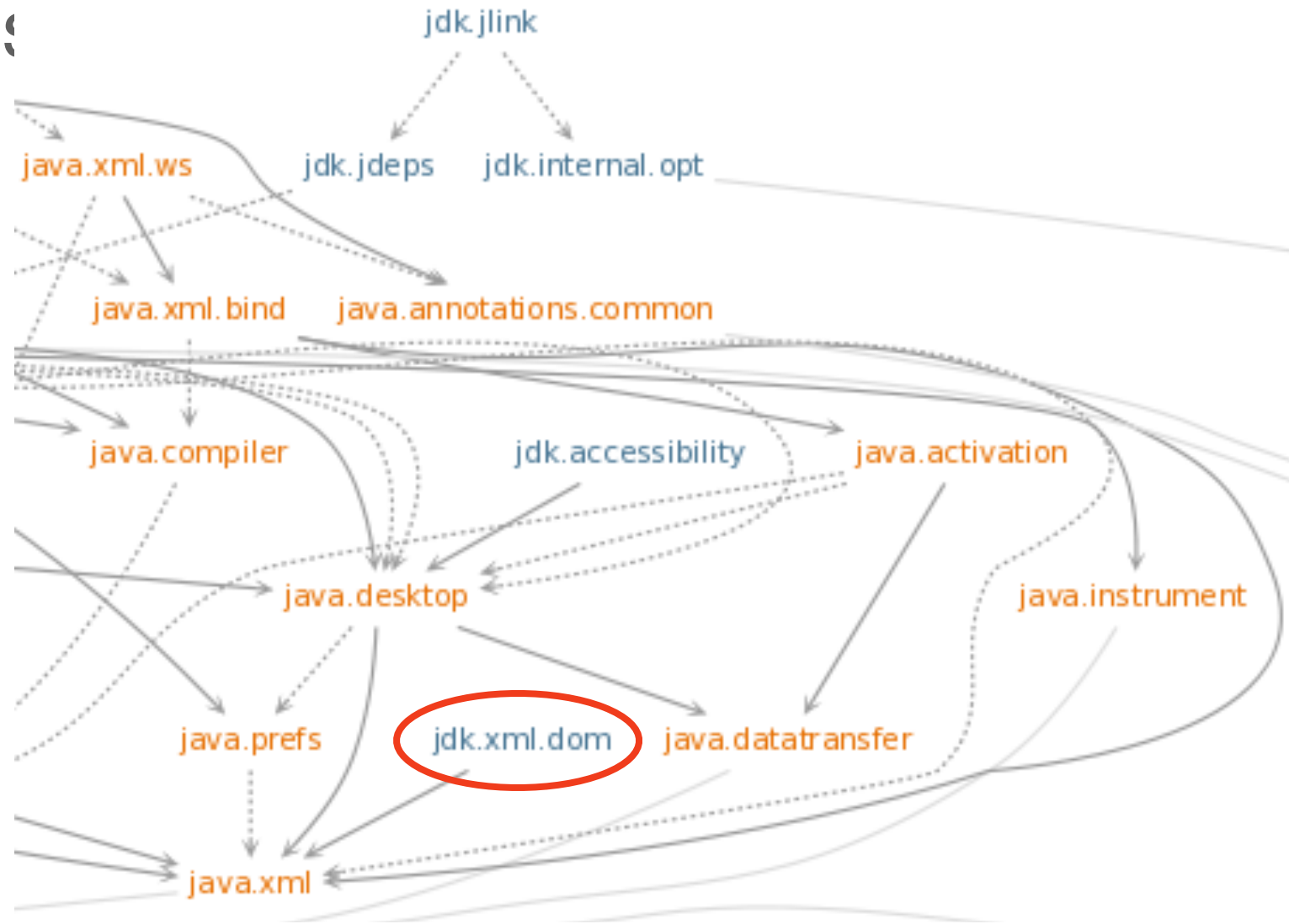
org.w3c.dom.css

org.w3c.dom.html

org.w3c.dom.stylesheets

org.w3c.dom.xpath

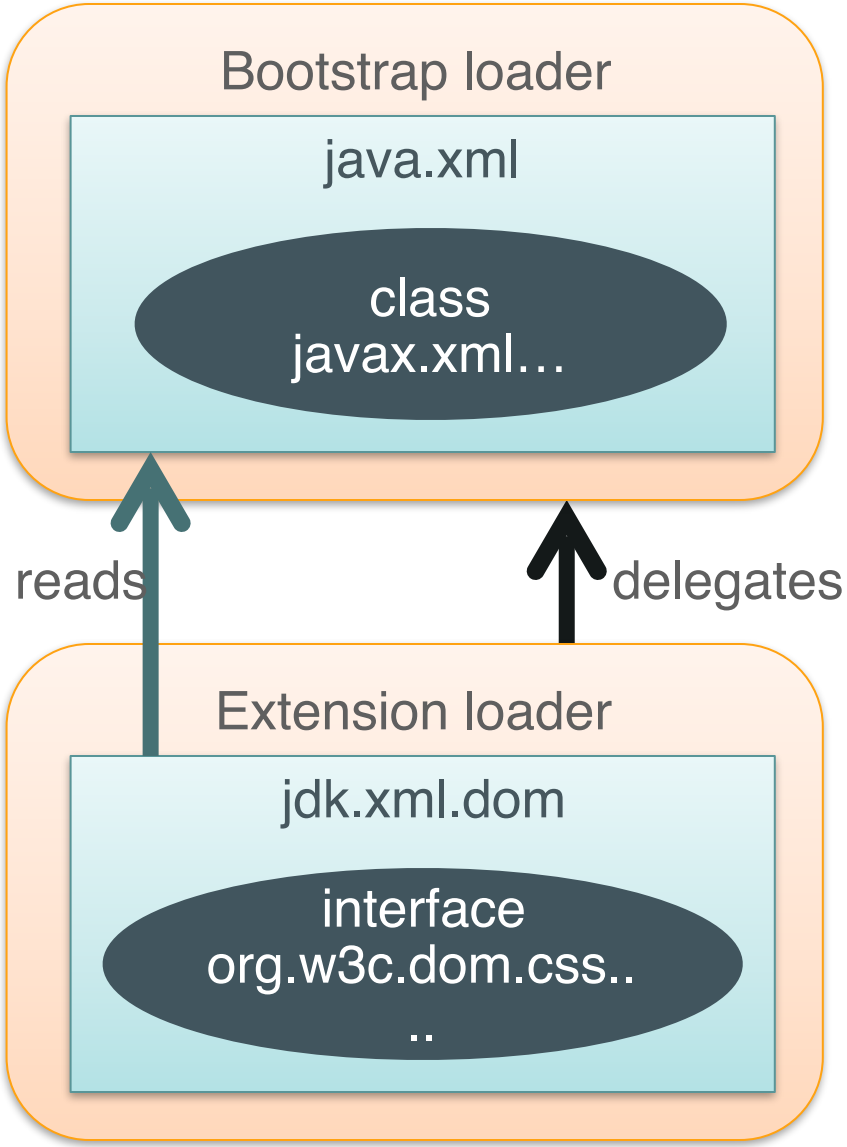
Example: DOM APIs



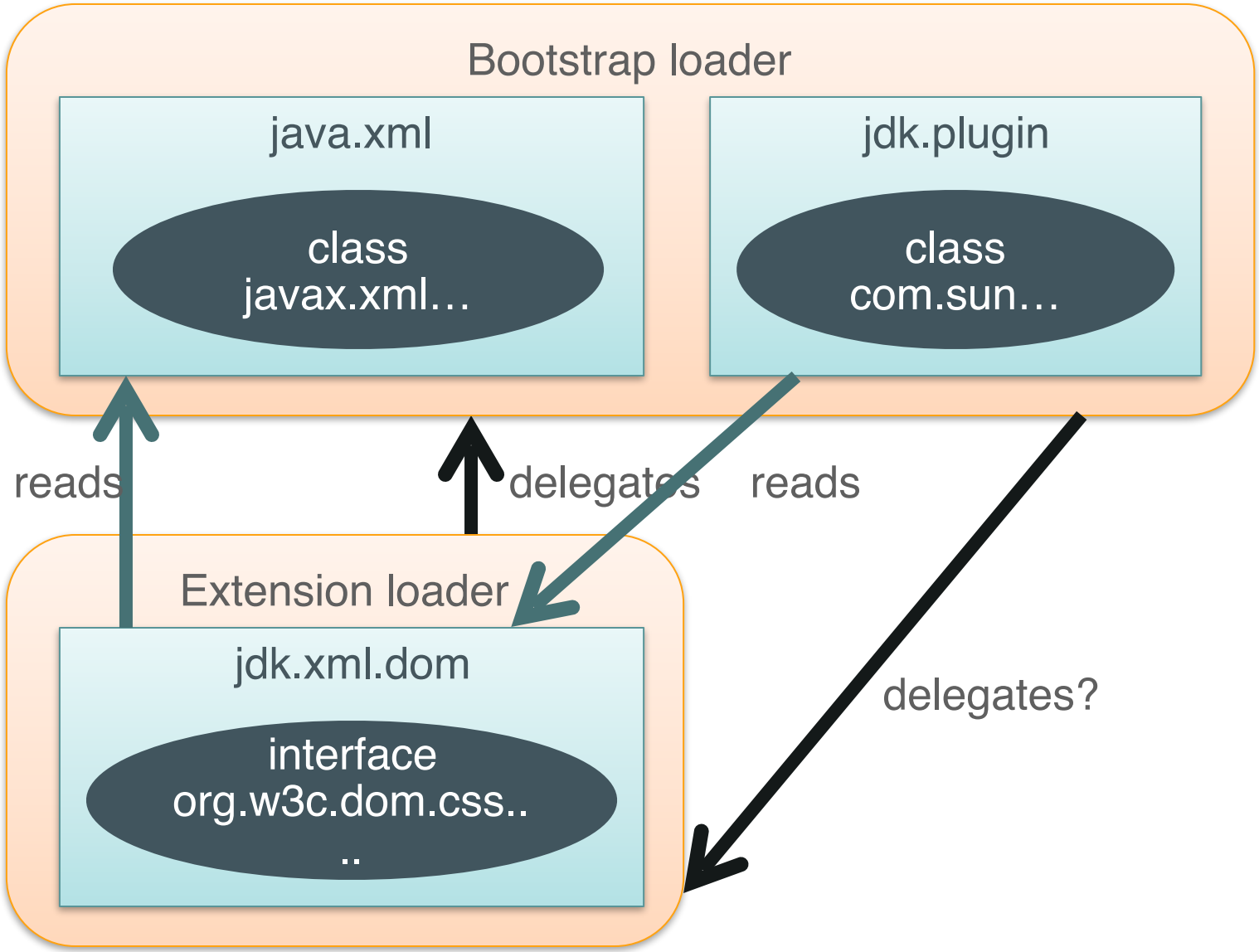
#Jfokus #Jigsaw

Example: DOM APIs

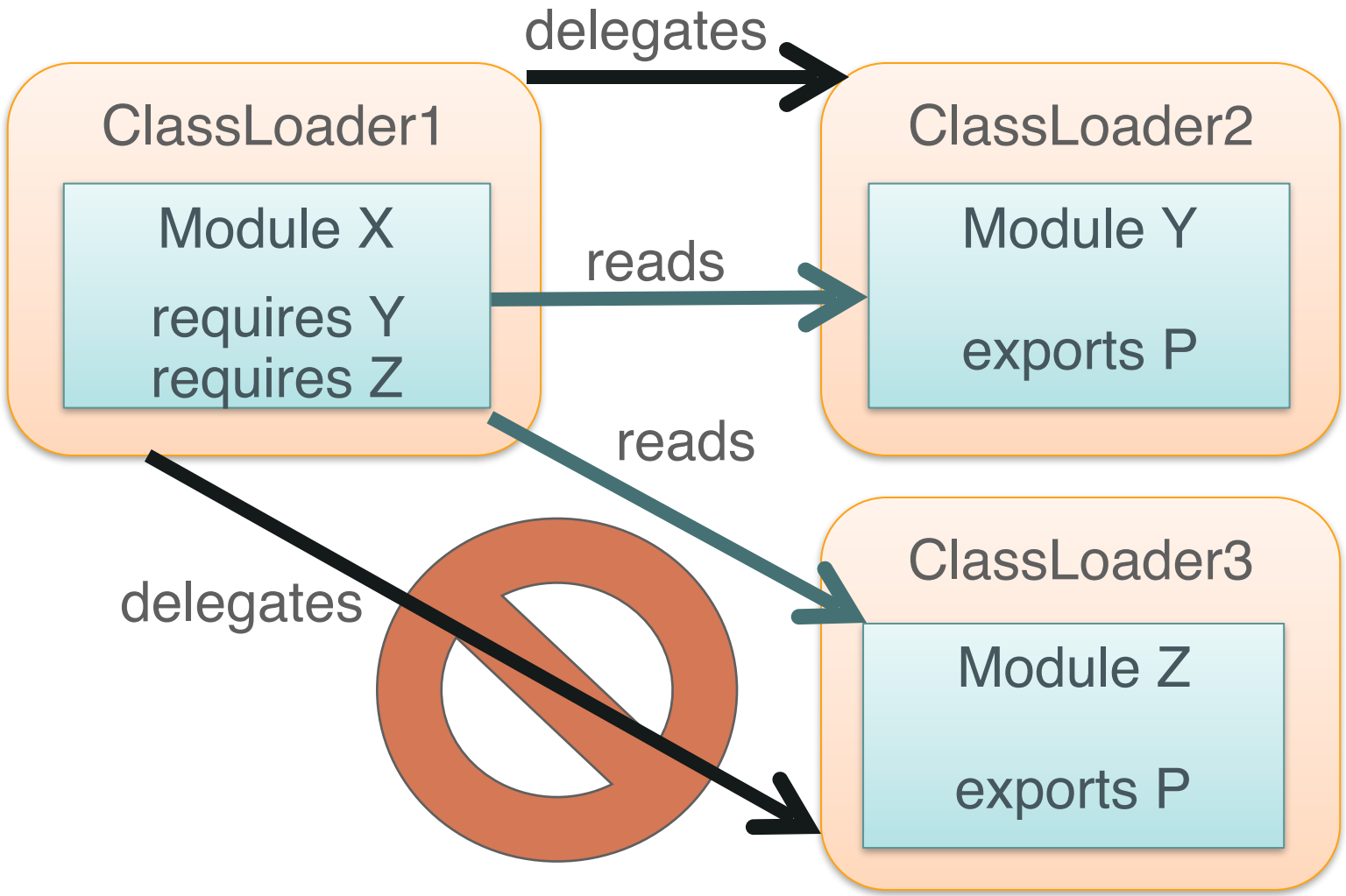
```
module jdk.xml.dom {
  requires public java.xml;
  exports org.w3c.dom.css;
  exports org.w3c.dom.html;
  exports org.w3c.dom.stylesheets;
  exports org.w3c.dom.xpath;
}
```



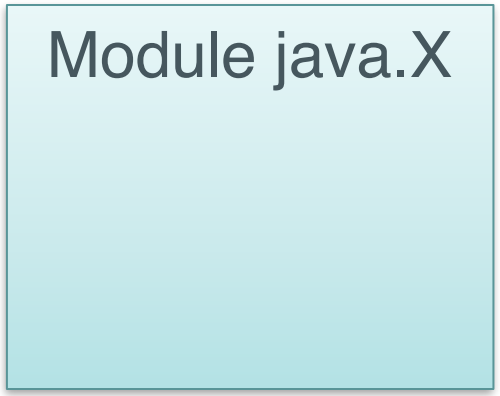
Example: DOM APIs



Loader delegation respects module readability



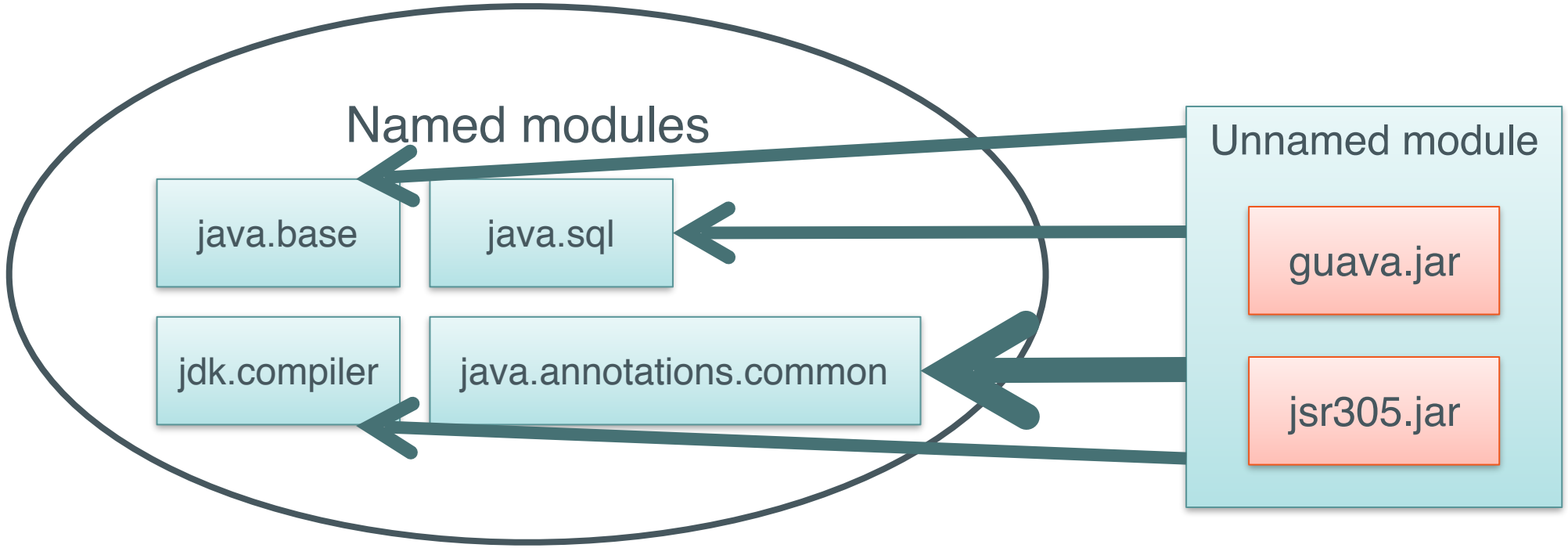
Split packages (missing class)



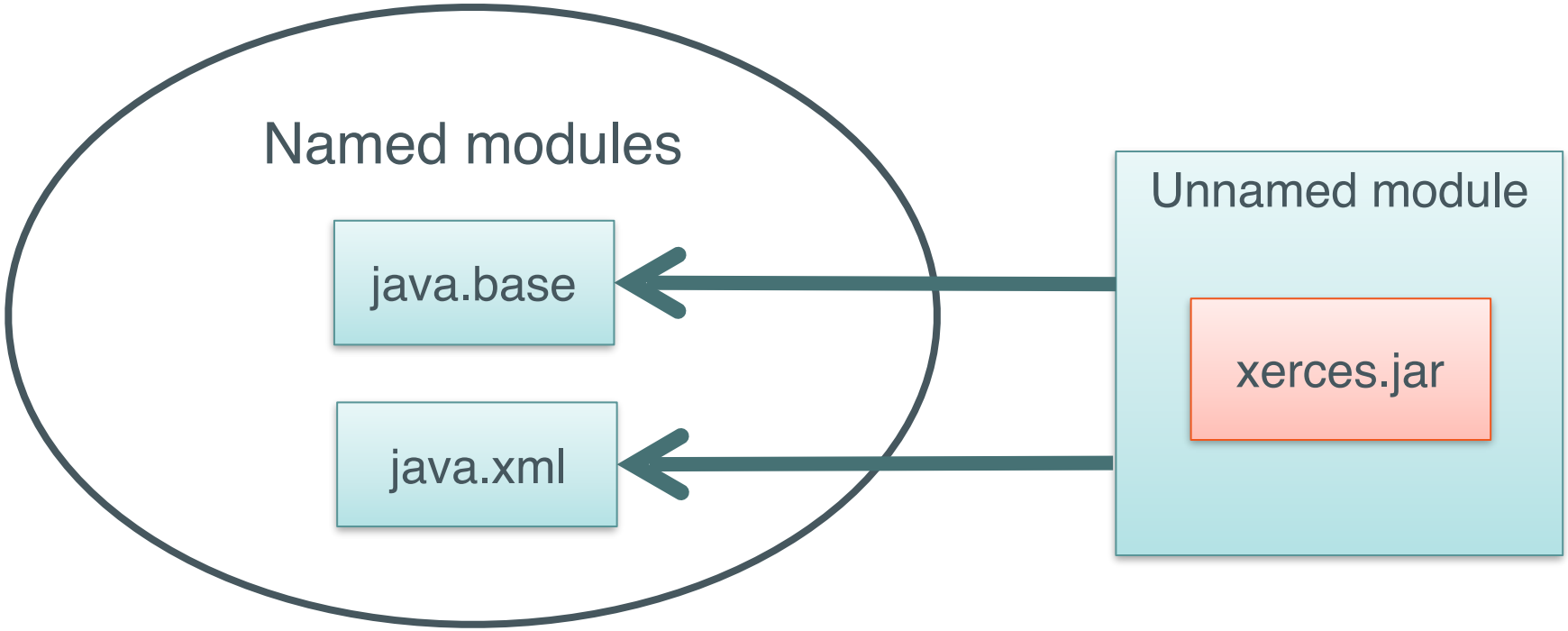

```
module java.X {
  exports javax.annotation;
}
```

```
javax/annotation/MyAnno1.class
javax/annotation/MyAnno2.class
```

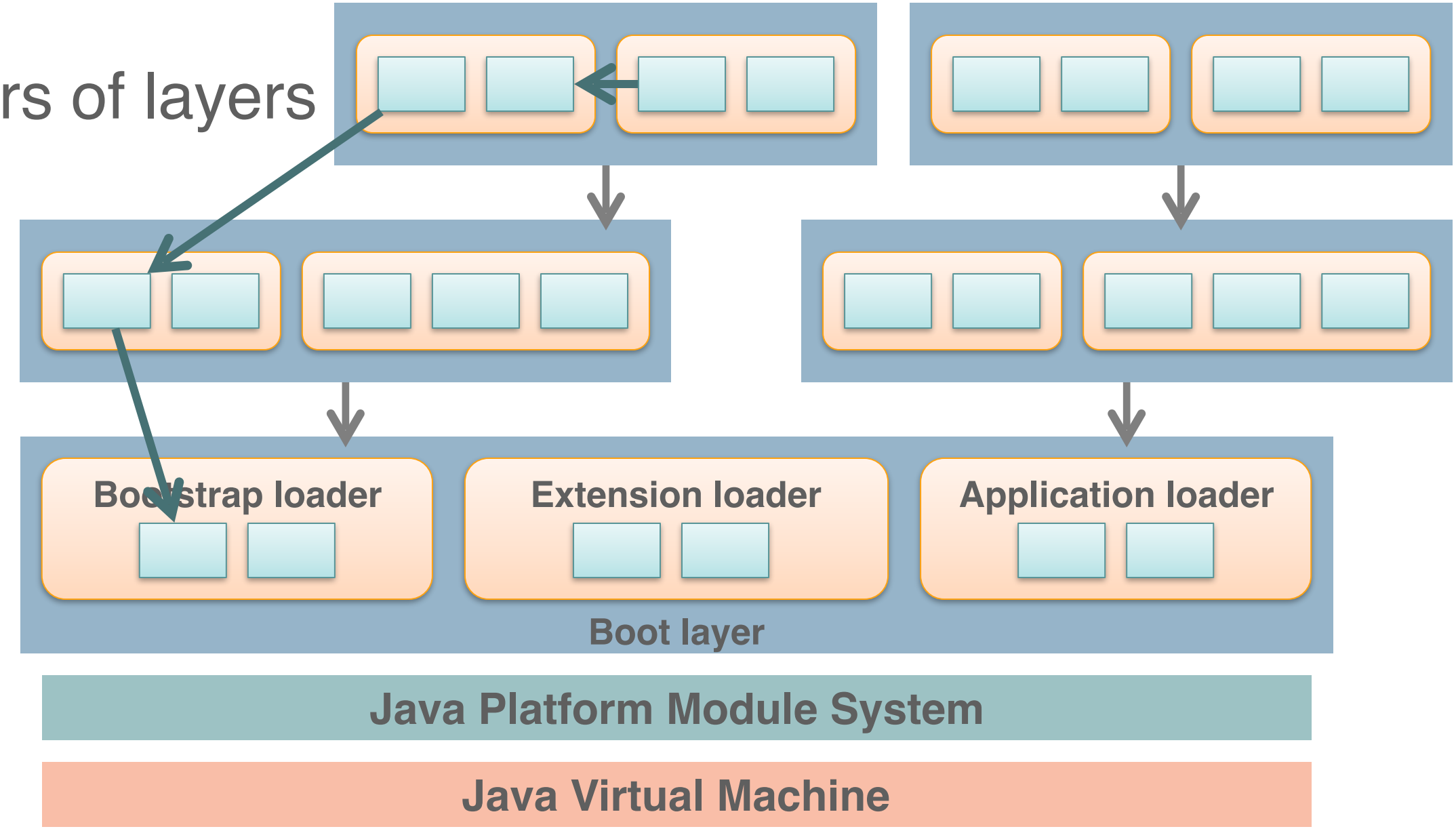
Split packages (missing class)



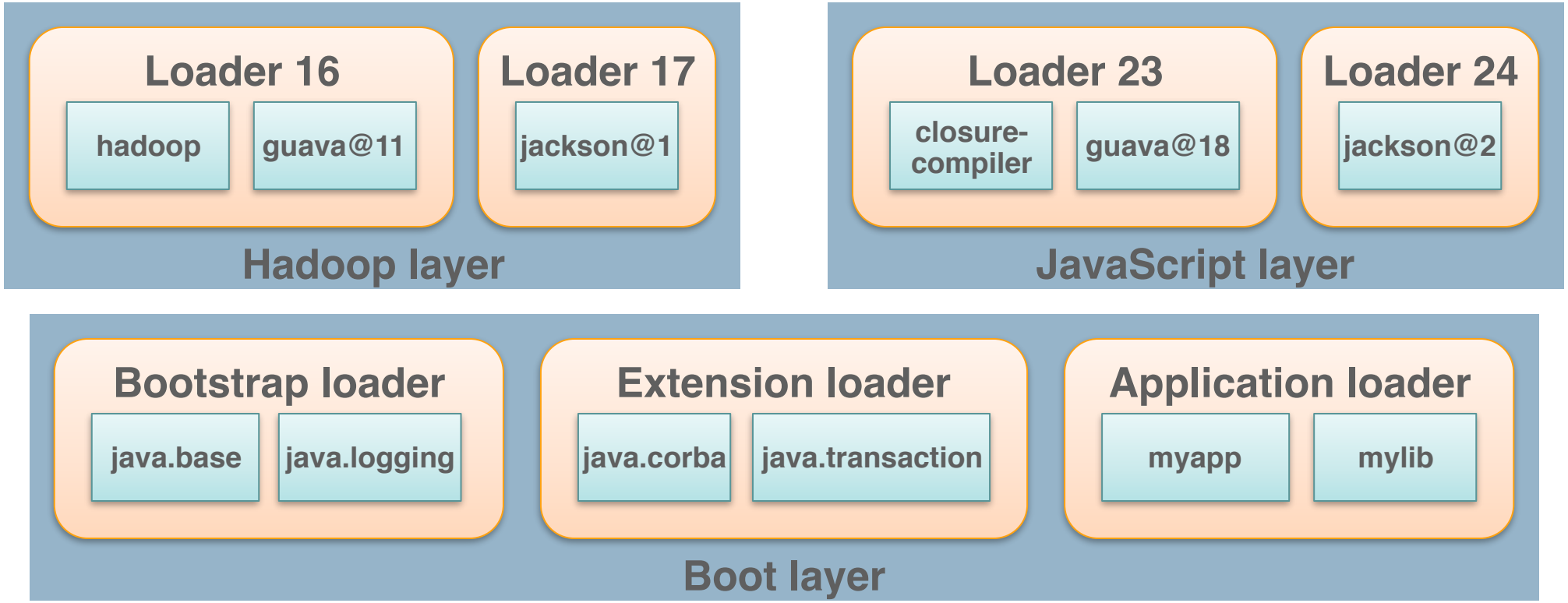
Split packages (duplicate class)



Layers of layers



Layers and Versions

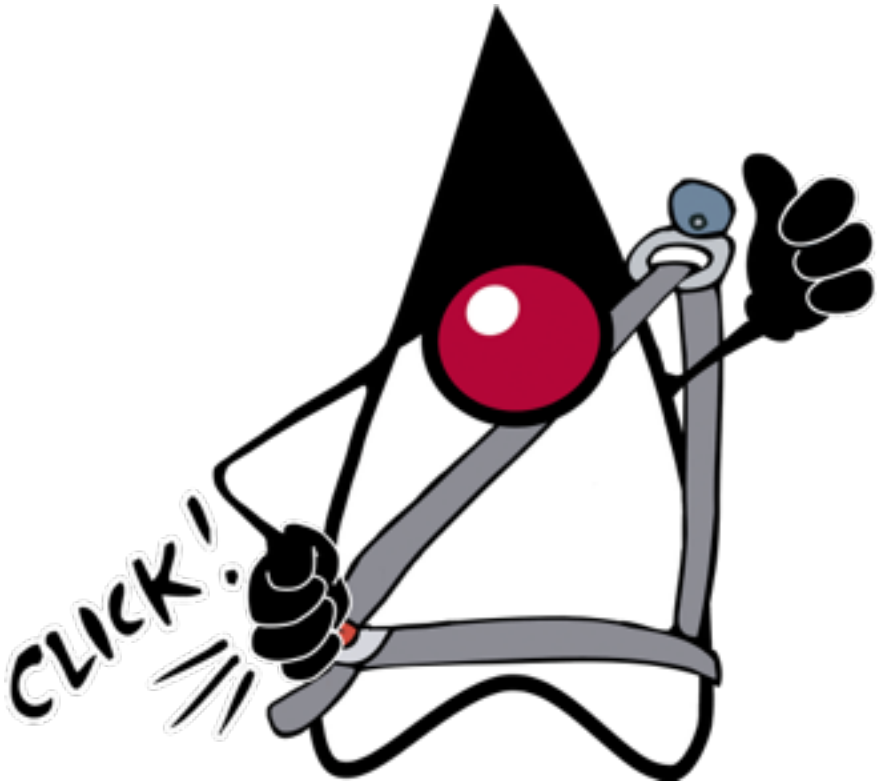


Summary of Part III: Loaders and Layers

- Modules do a better job of encapsulation than class loaders, but class loaders are still necessary.
- Layers control the relationship between modules and class loaders.
- **Assuming class loaders respect the module graph, the system is safe by construction—there are never any cycles or split packages.**

Summary of Summaries

- **Modules are strongly encapsulated by the compiler, the VM, and Core Reflection.**
- **Unnamed and automatic modules help with migration.**
- **The system is safe by construction—there are never any cycles or split packages.**



What can you do to prepare for JDK 9?

- Try JDK 9 with Jigsaw
  - http://openjdk.java.net/projects/jigsaw/ea
- Run jdeps on your code and on your classpath
- Subscribe to jigsaw-dev@openjdk.java.net to report problems and share experiences

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