Project Jigsaw: Under The Hood

Alex Buckley
Java Platform Group, Oracle
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The Modularity Landscape

- Java Platform Module System
  - JSR 376, started February 2015 – targeted for Java SE 9
- Java SE 9 Platform
  - JSR not started yet – will own the modularization of the Java SE API
- Project Jigsaw
  - Reference Implementation of JSR 376 in OpenJDK (JEP 261)
  - Modularization of the JDK (JEP 200, JEP 201, JEP 260)
  - New run-time image format (JEP 220)

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

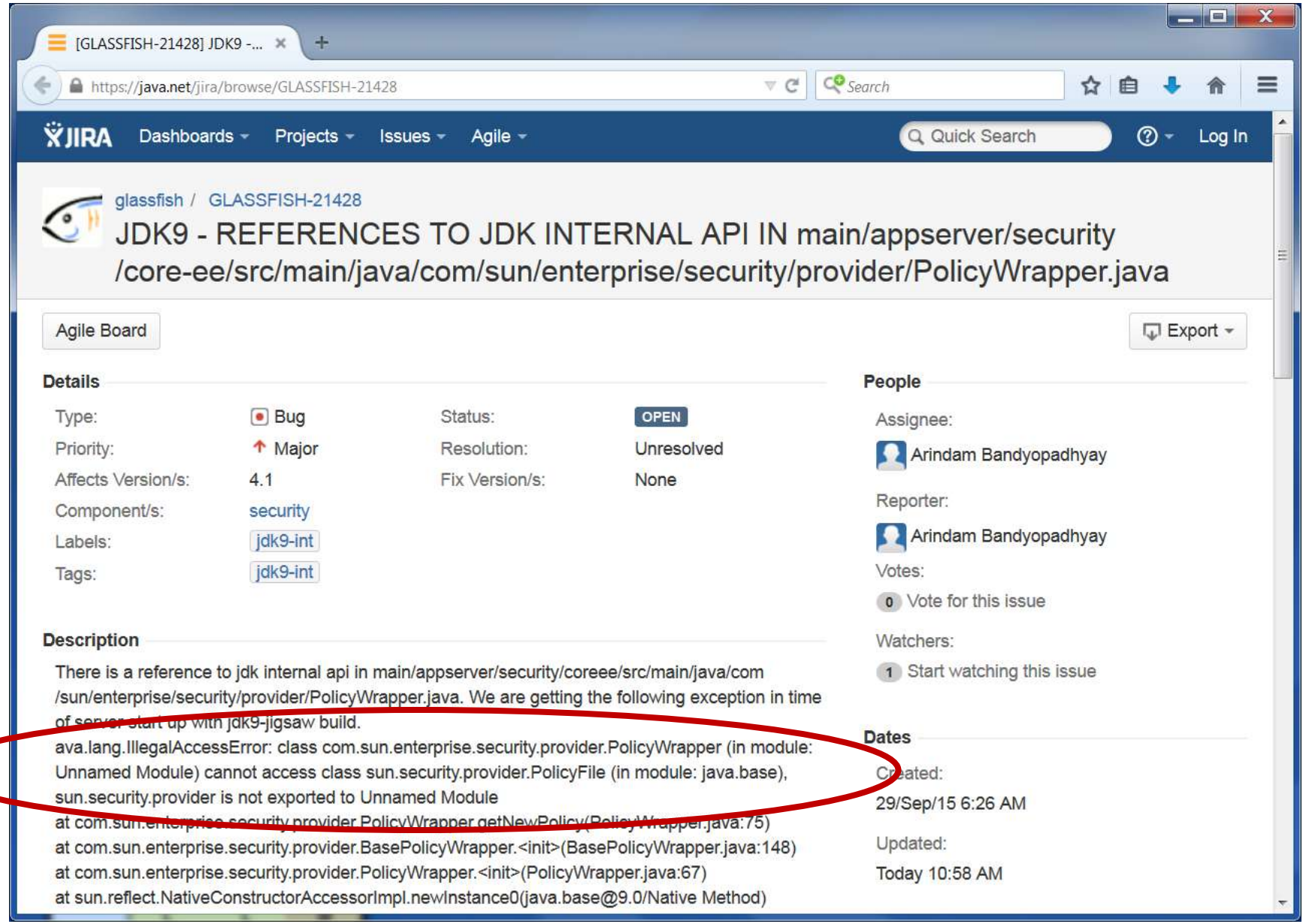
- public
- protected
- <package>
- private

Accessibility 2015-

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

‘public’ no longer means “accessible”.

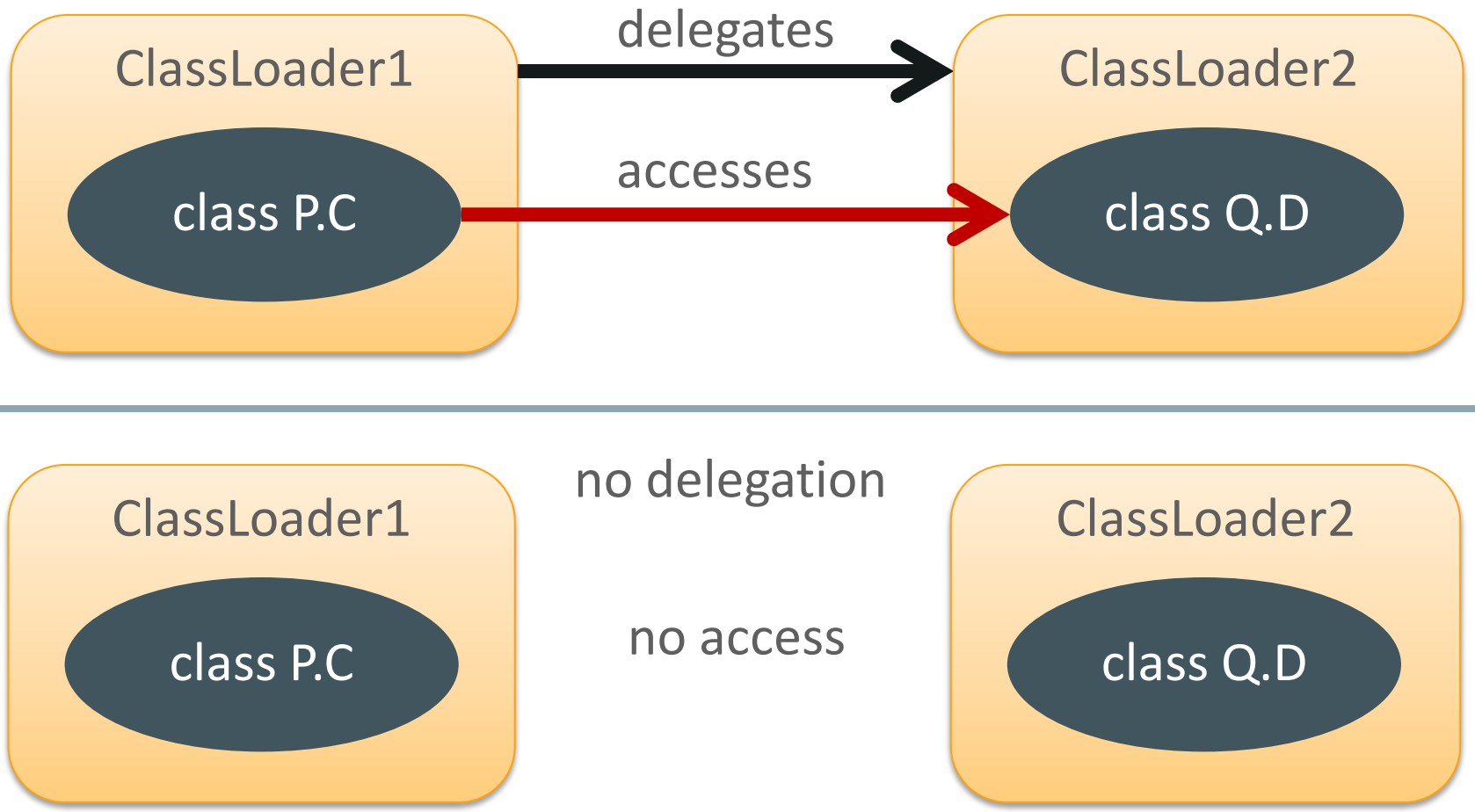
The result:



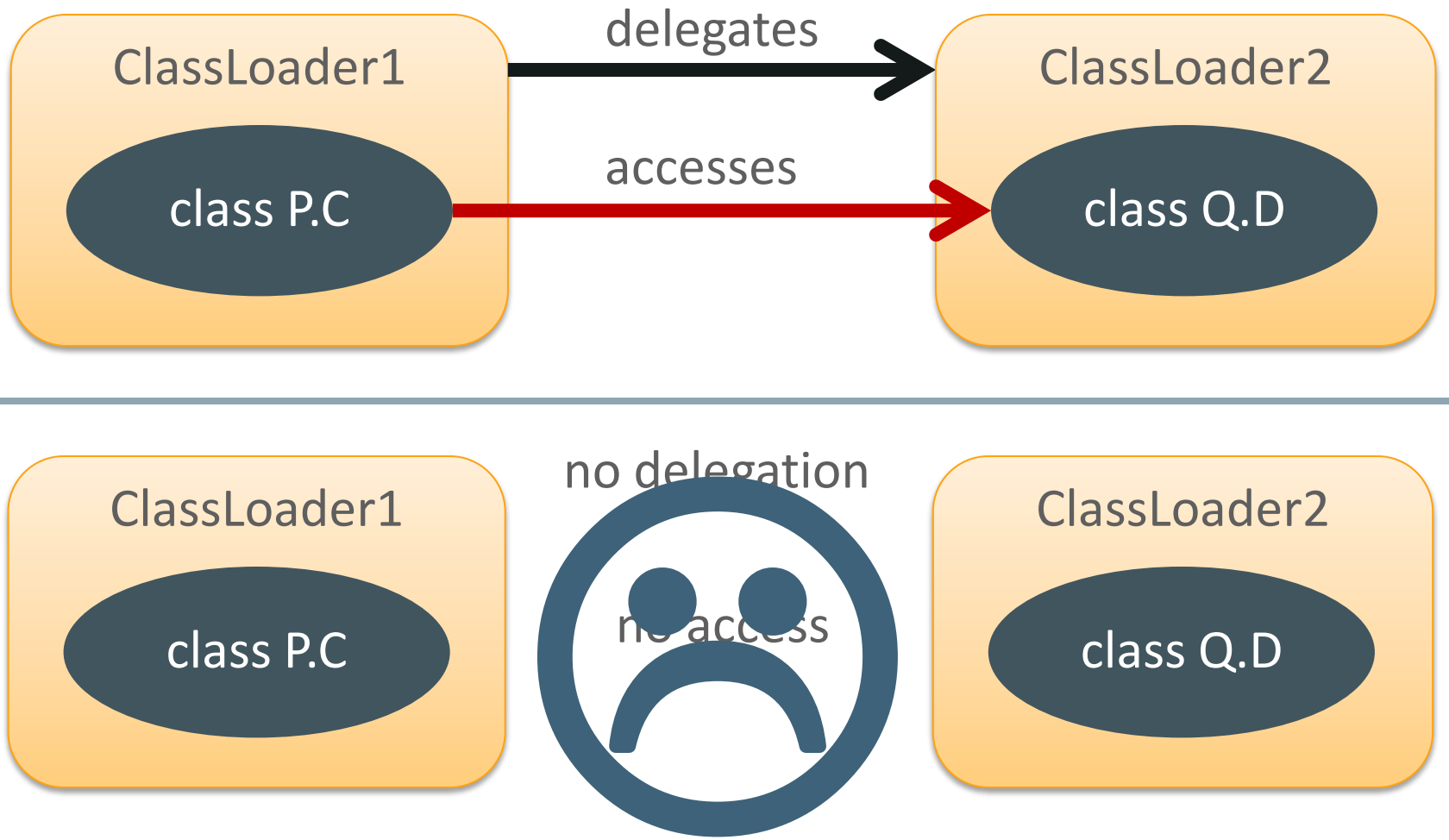
Accessibility and Module Declarations

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

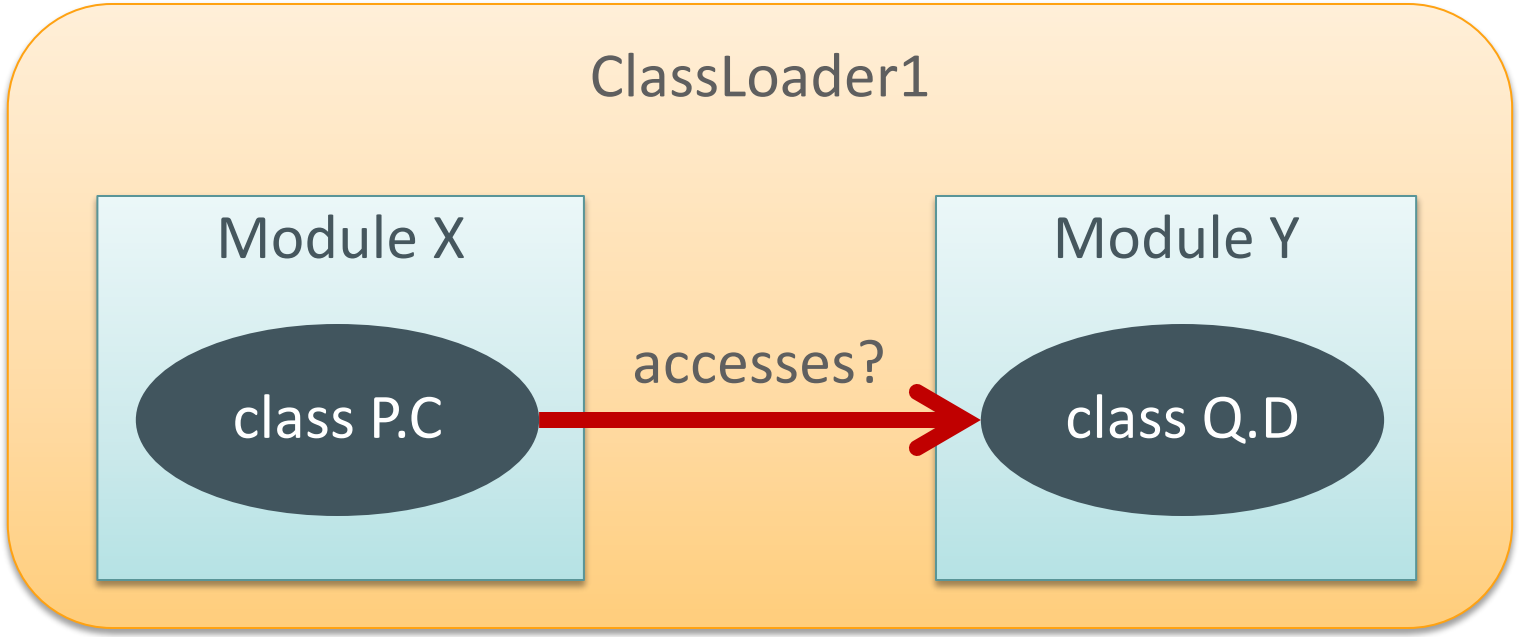
Accessibility and Class Loaders



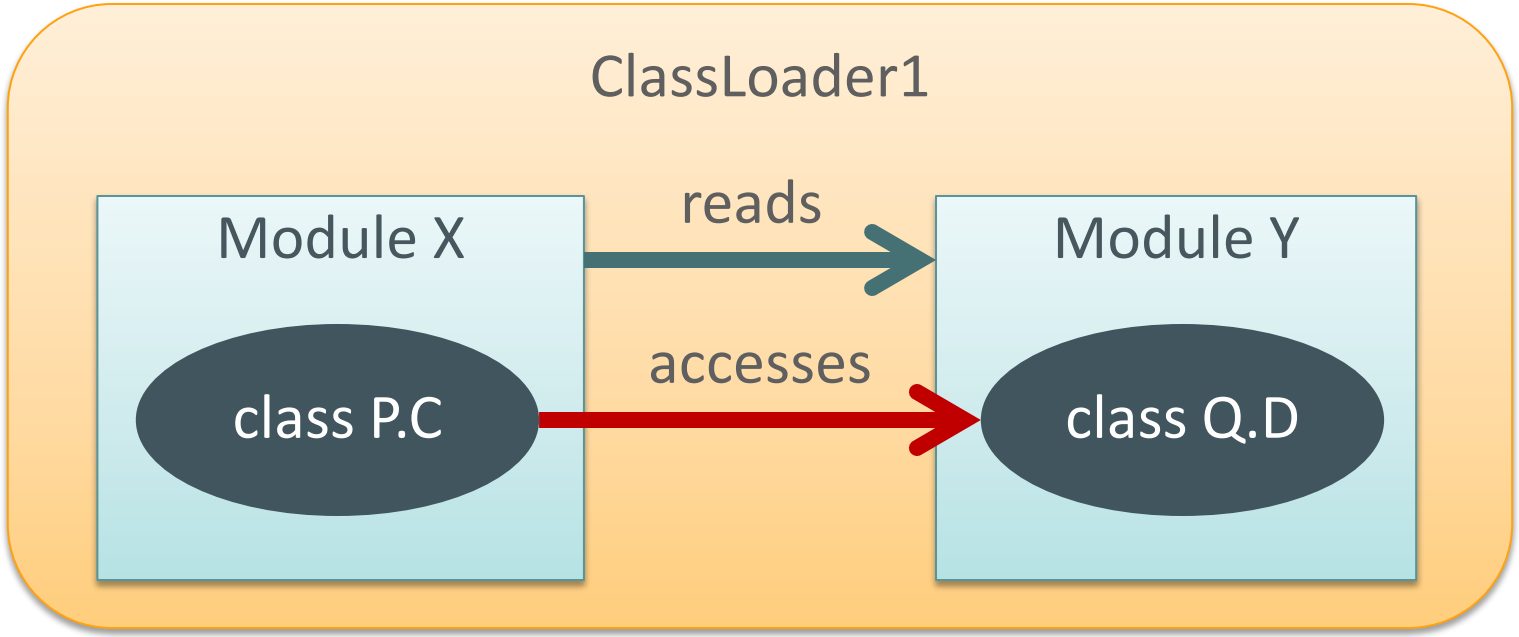
Accessibility and Class Loaders



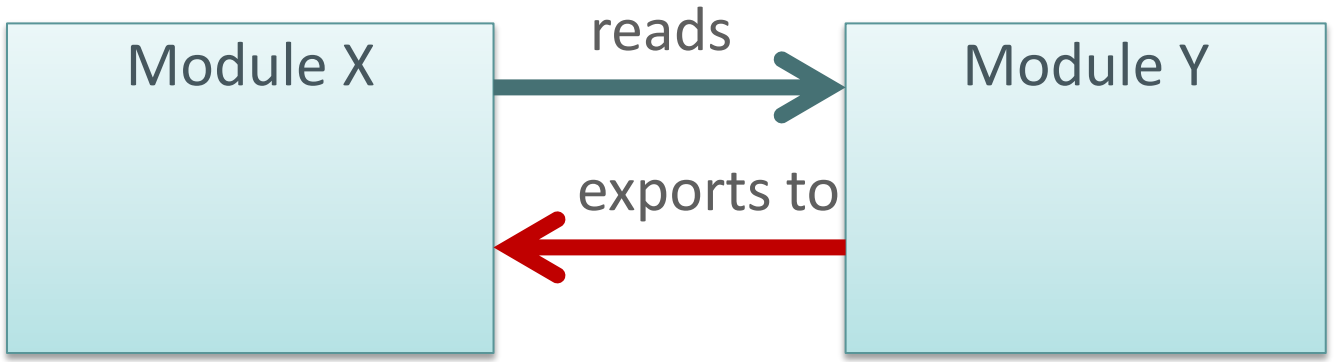
One Class Loader, Many Modules



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;
}
```

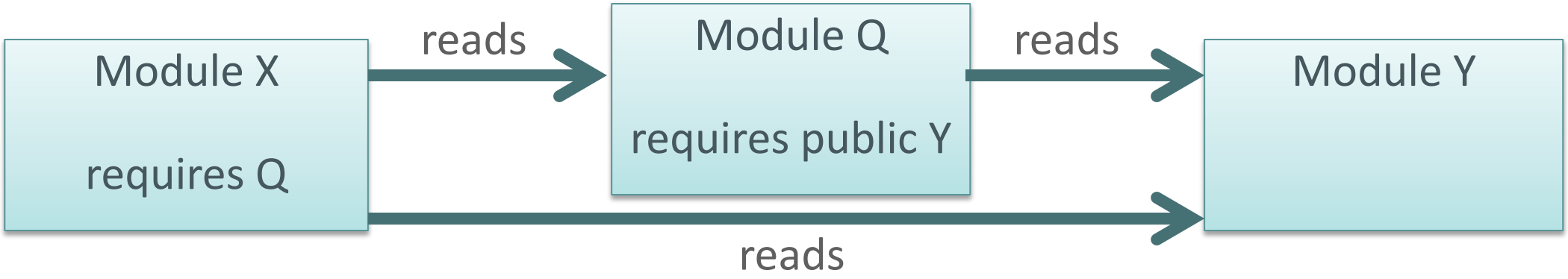
```
module java.sql.time {
  exports java.sql.time;
}
```

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(…);
}
```

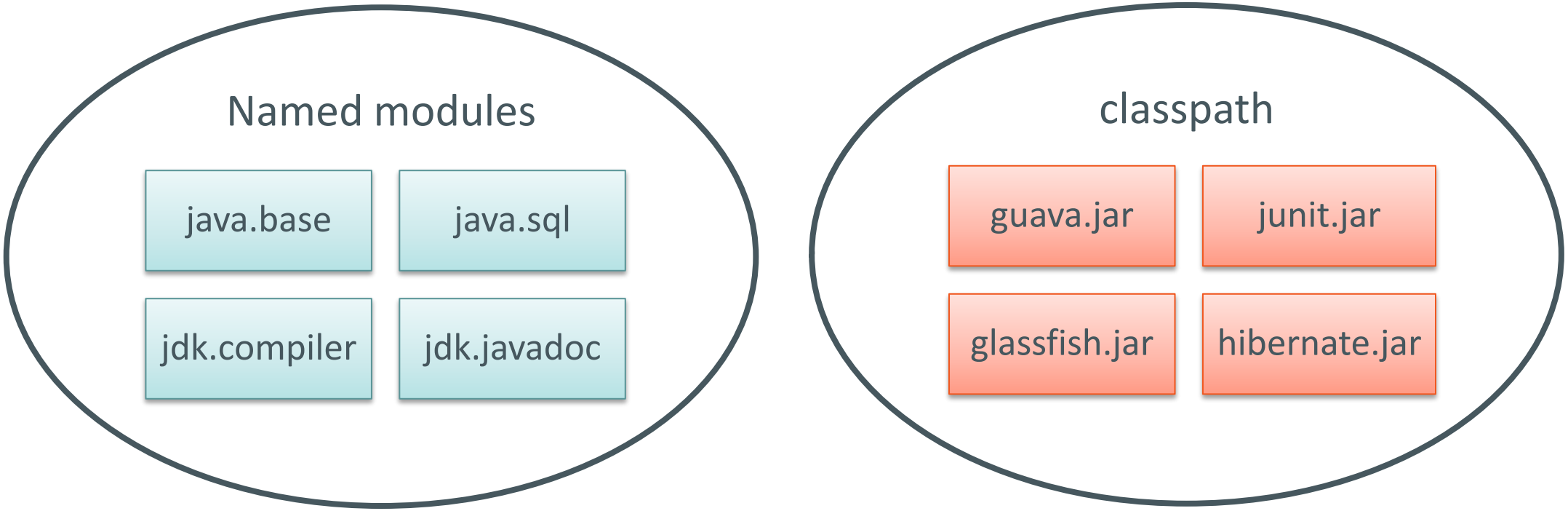
Core Reflection

Summary of Part I: Accessibility and Readability

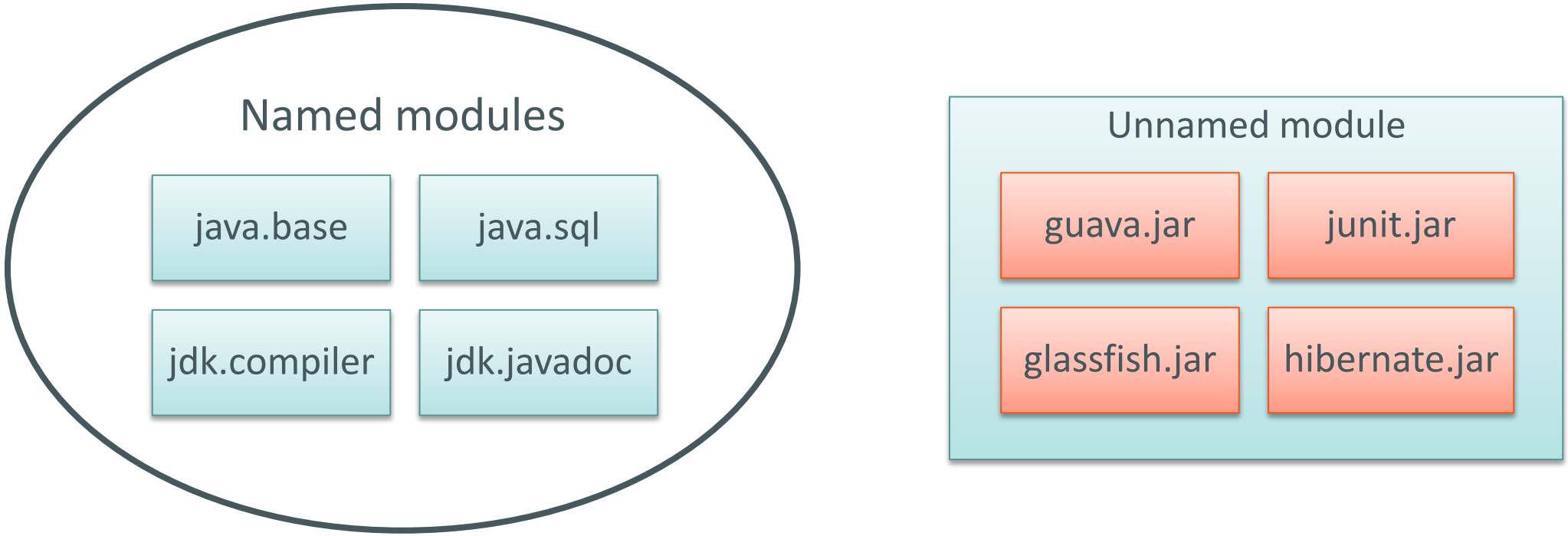
- Accessibility used to be a simple check for ‘public’ or “same package”.
- In Java SE 9, accessibility strongly encapsulates module internals.
- Accessibility relies on readability, which can be direct or implied.
- **Accessibility is enforced by the compiler, VM, and Core Reflection.**

Part II: Different Kinds of Modules

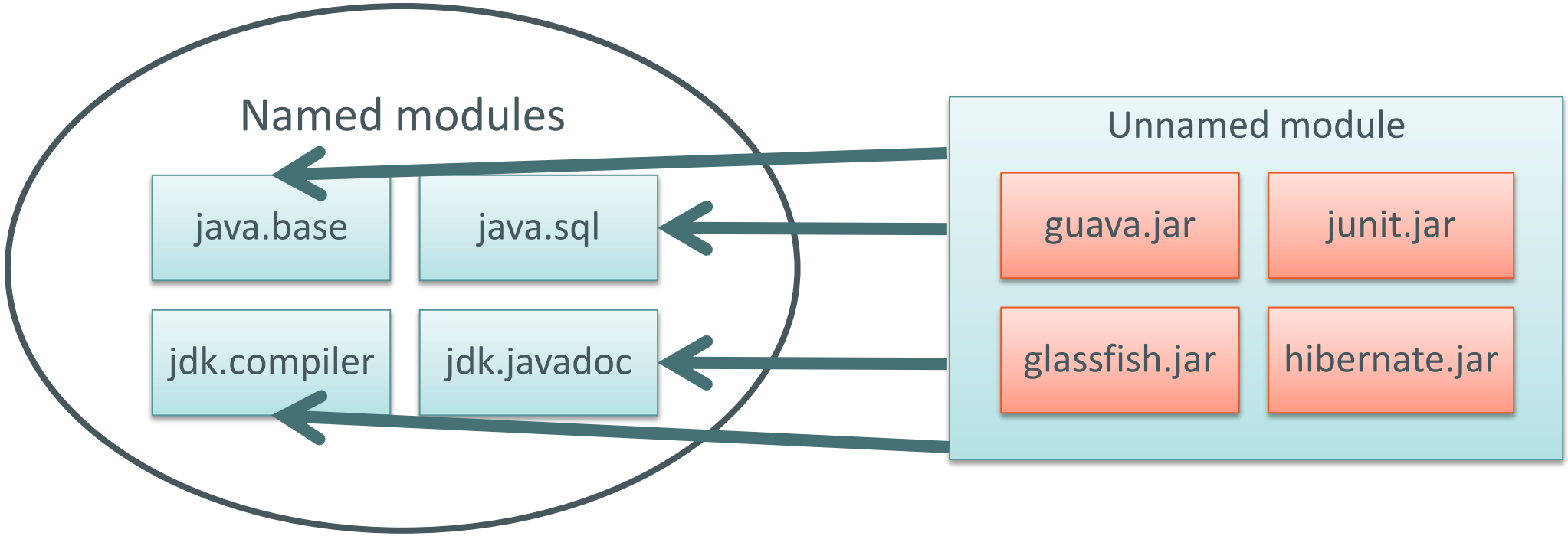
Named Modules



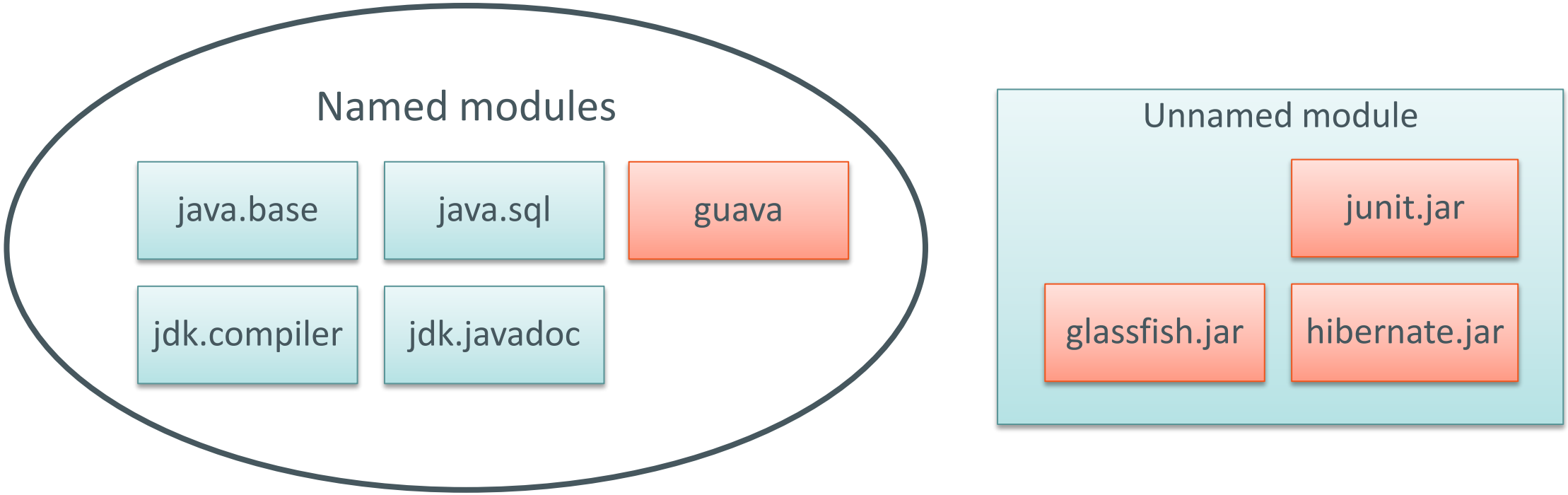
The Unnamed Module



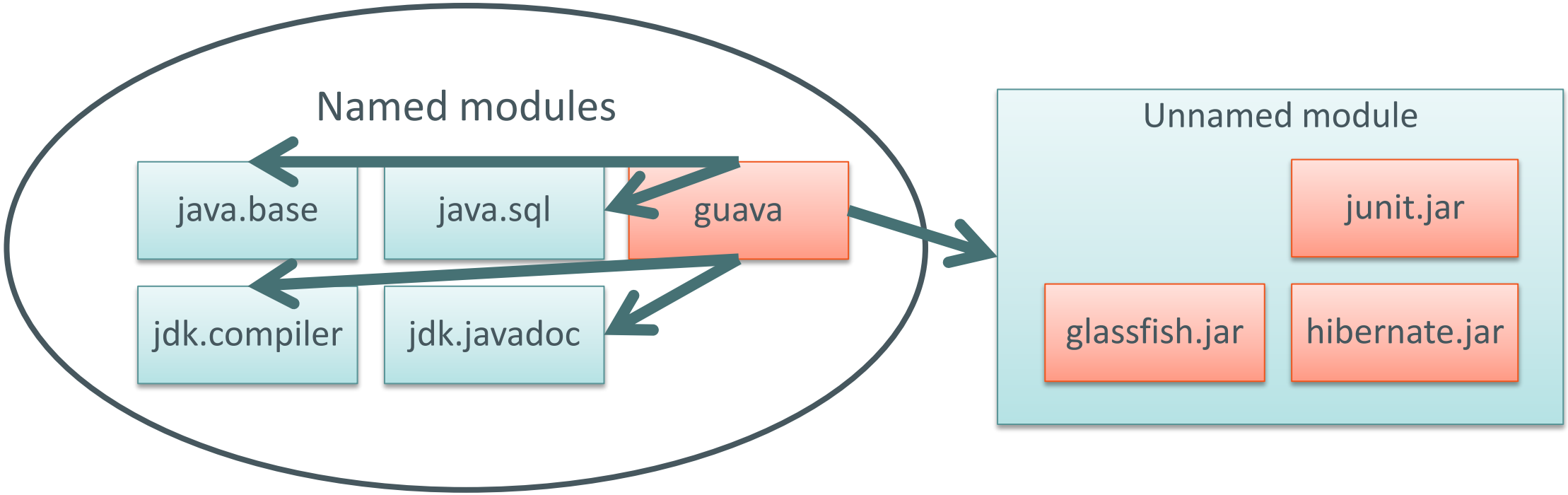
The Unnamed Module



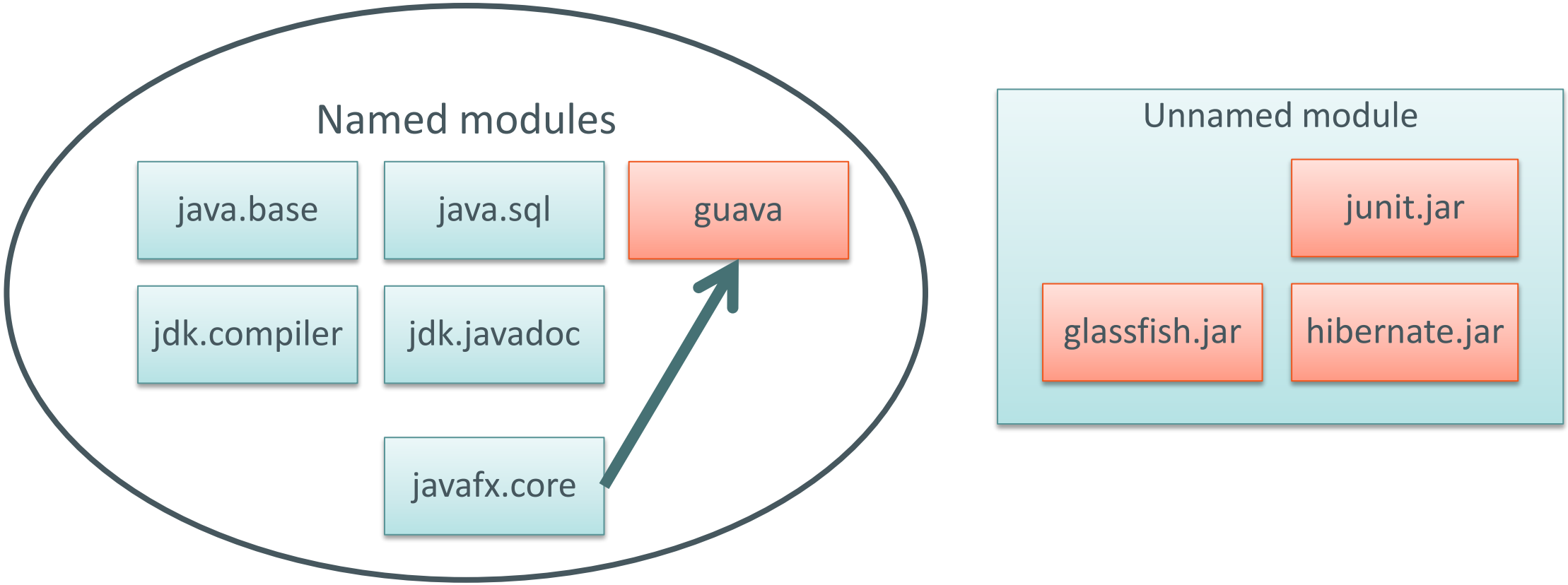
Automatic Modules



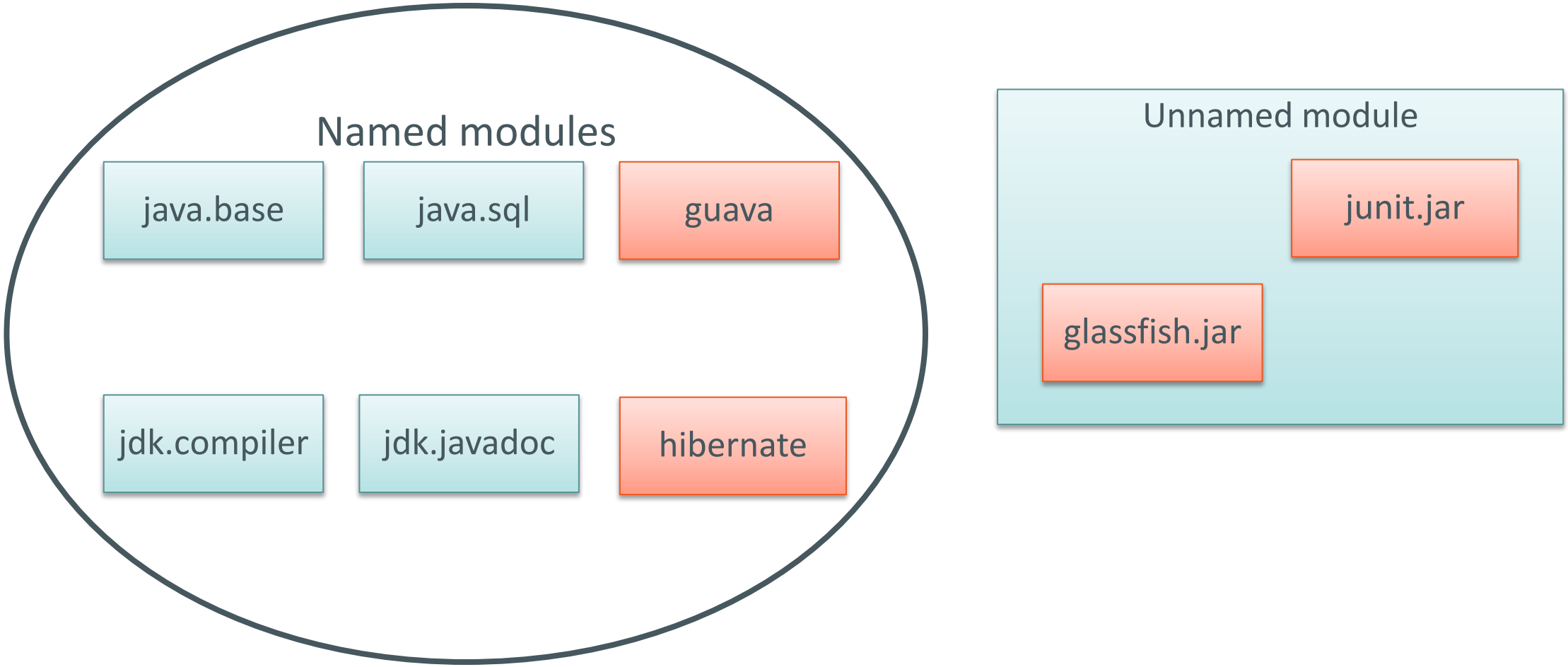
Automatic Modules



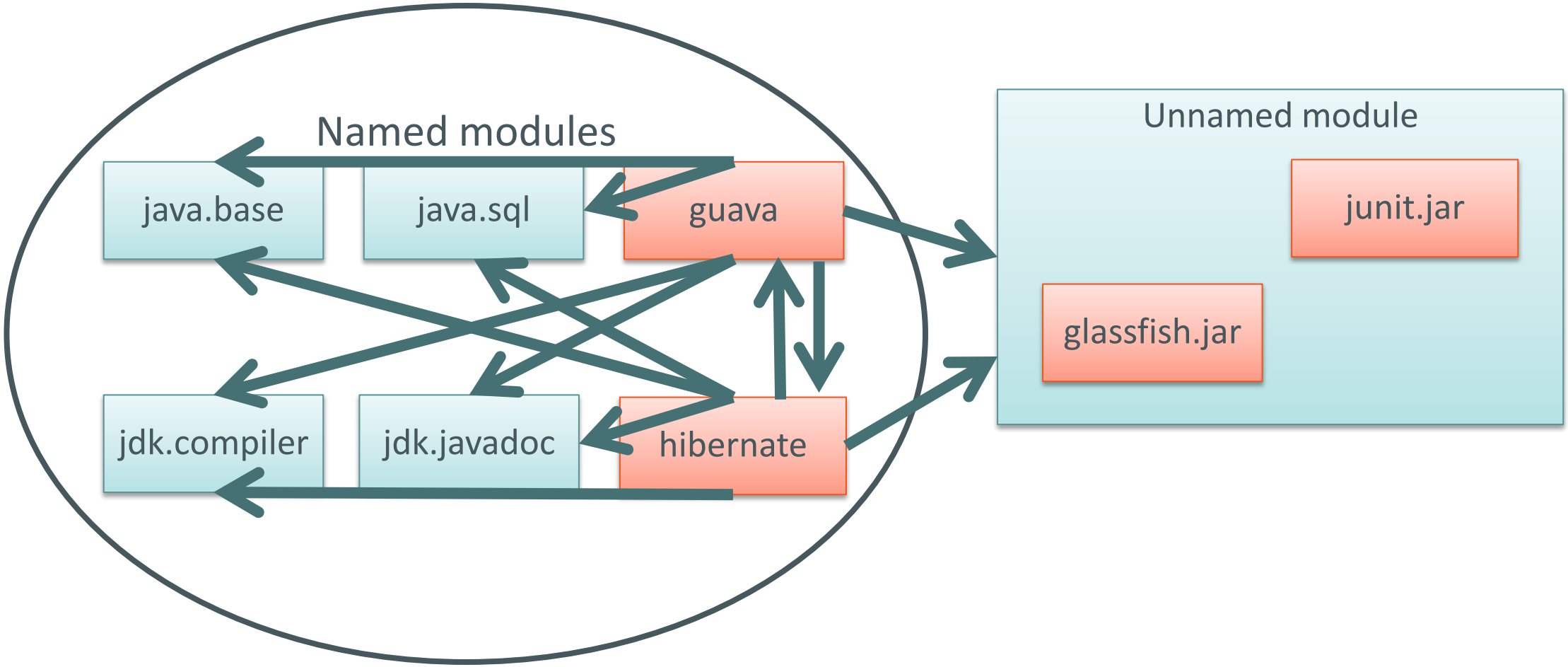
Automatic Modules



Multiple Automatic Modules



Multiple Automatic Modules



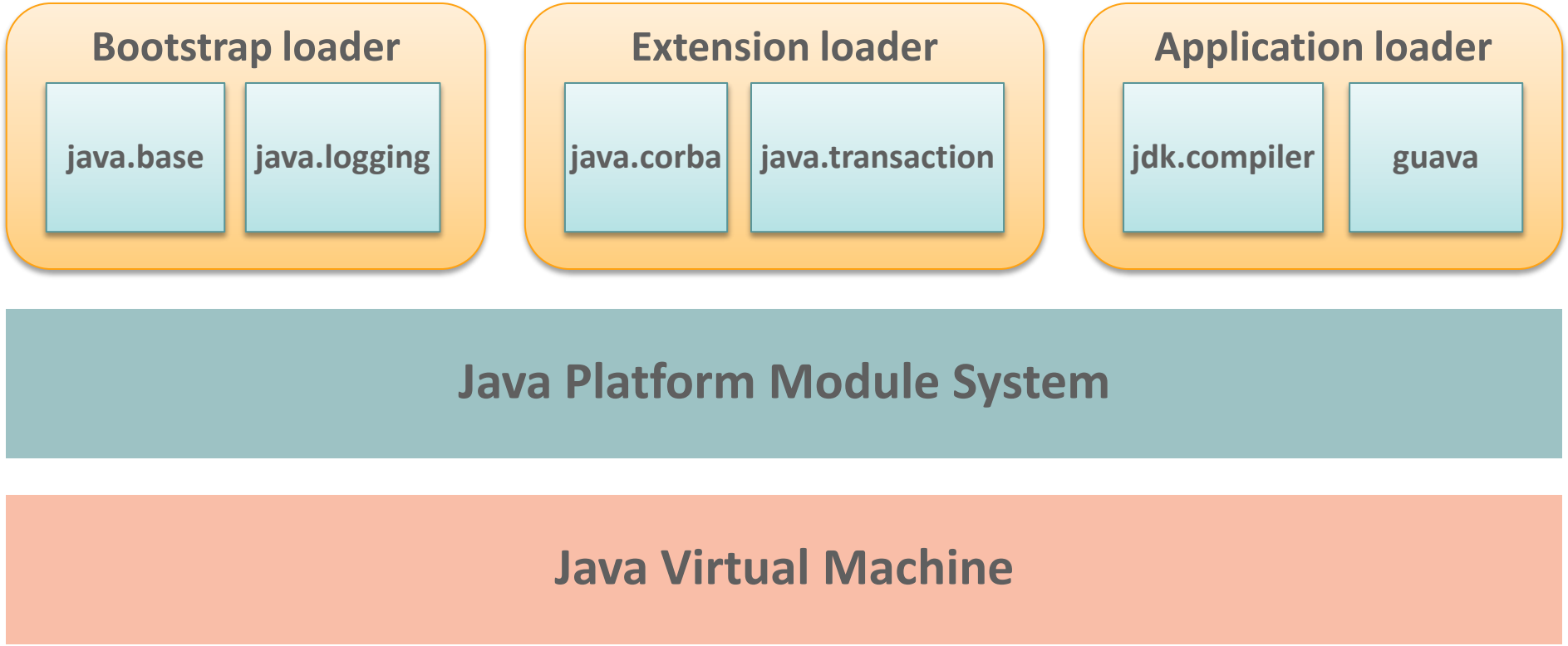
Summary of Part II: Different Kinds of Modules

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

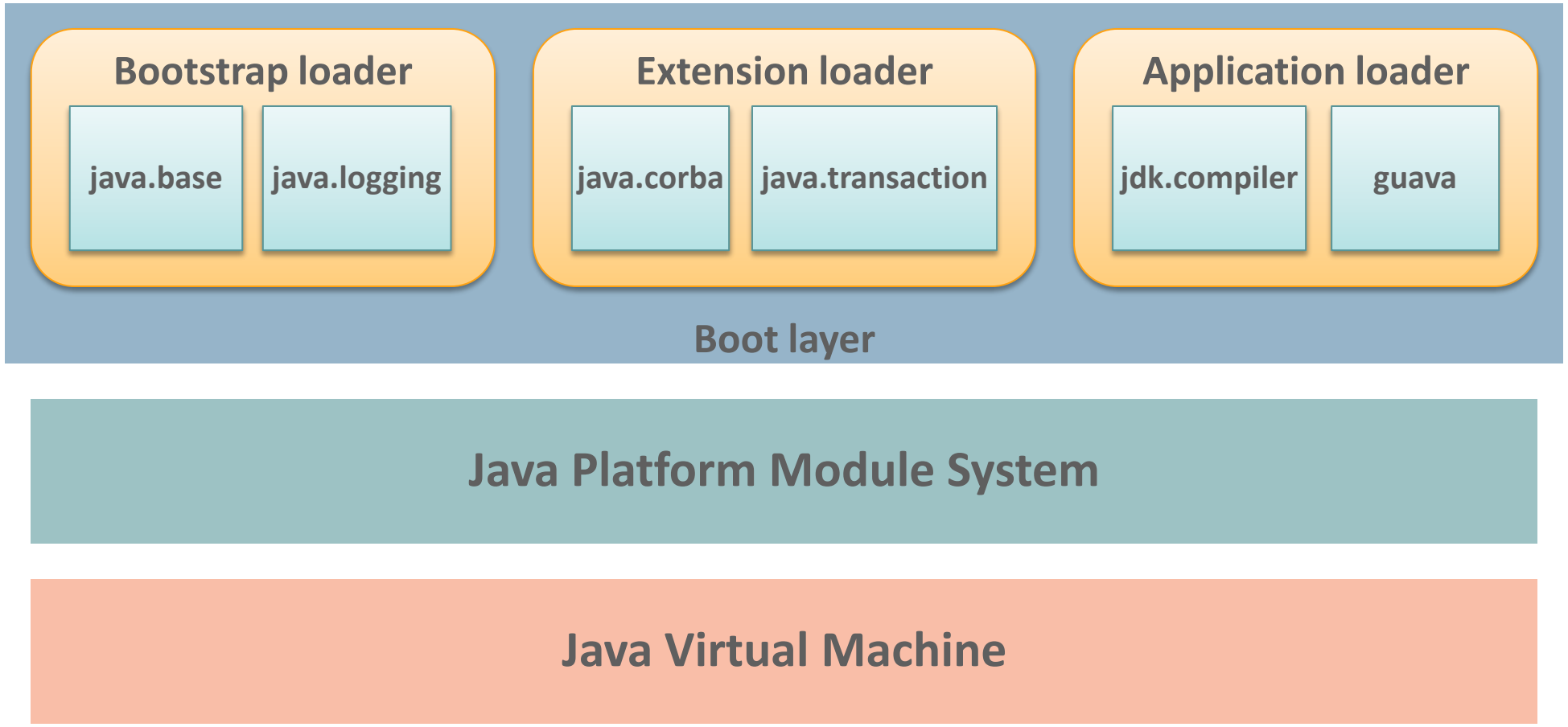
Part III: Loaders and Layers

Class loading doesn’t change.

Class Loaders in the JDK

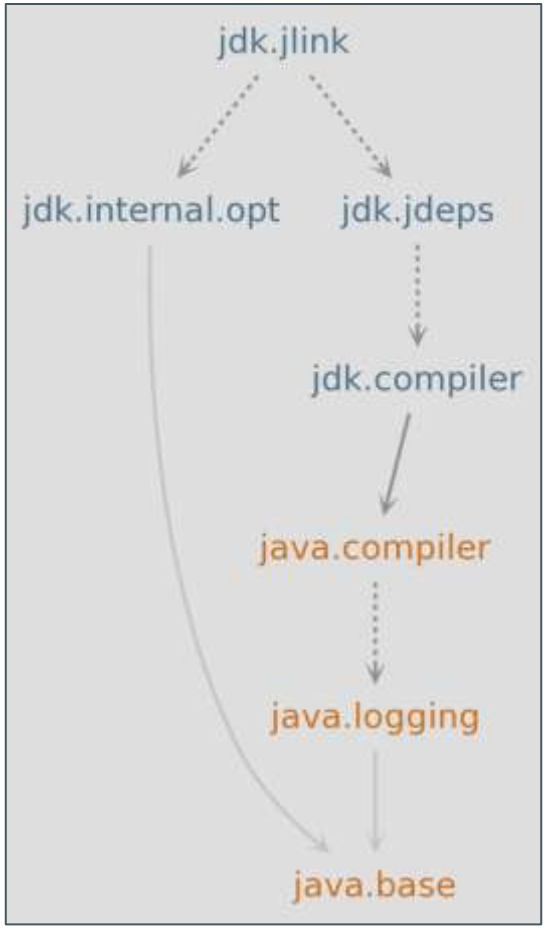


Layers



Layer creation

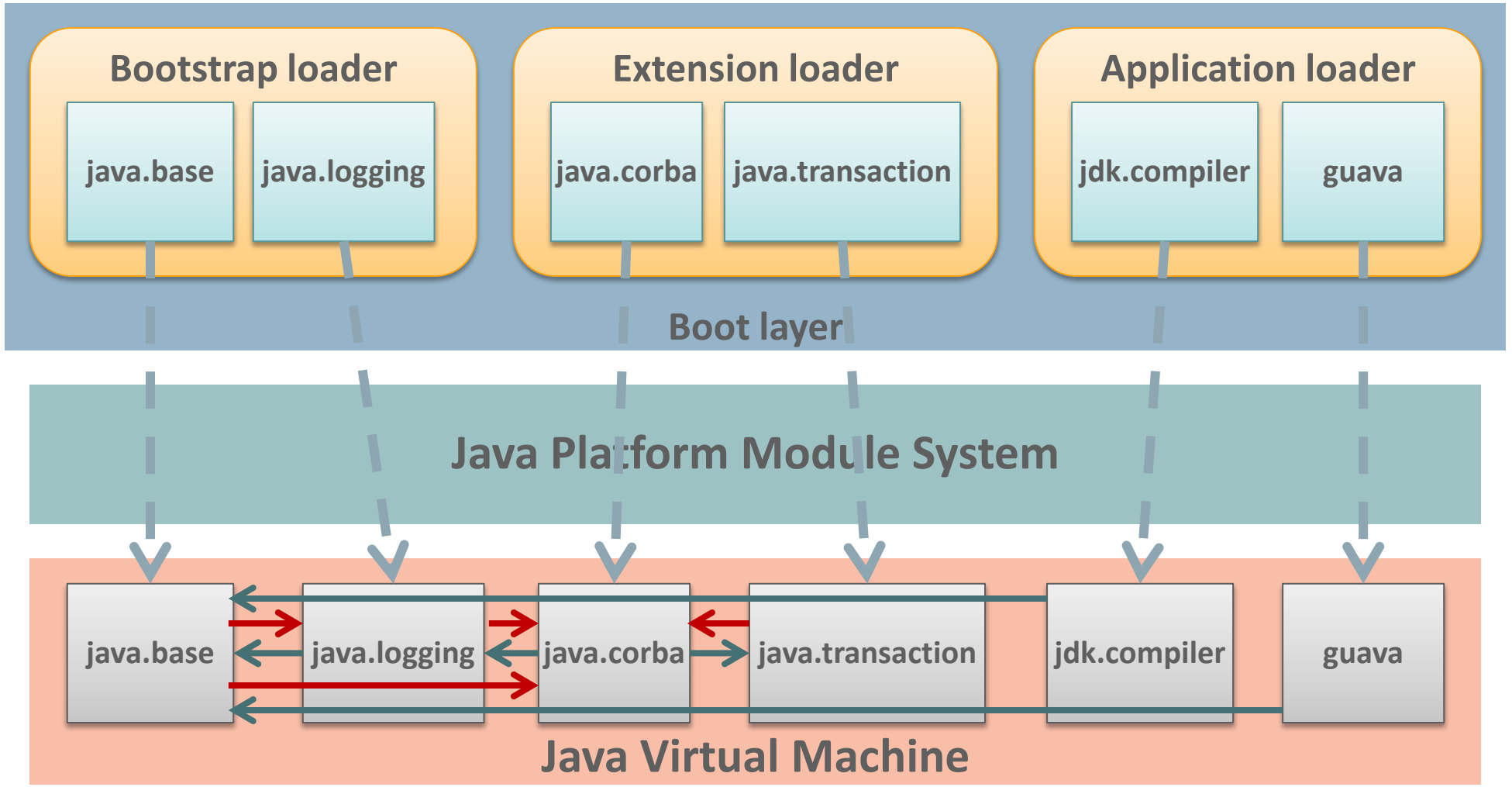
(1)



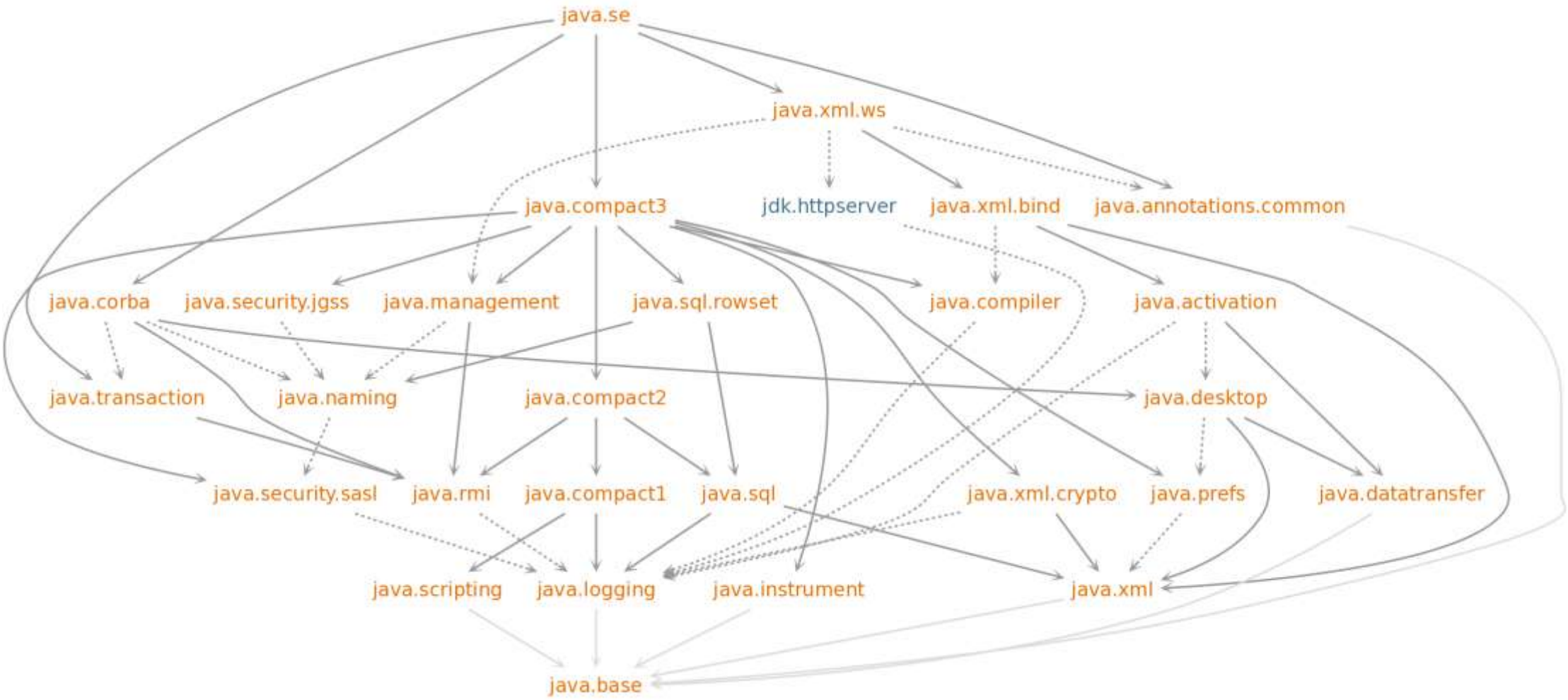
(2)

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

Layers and the VM

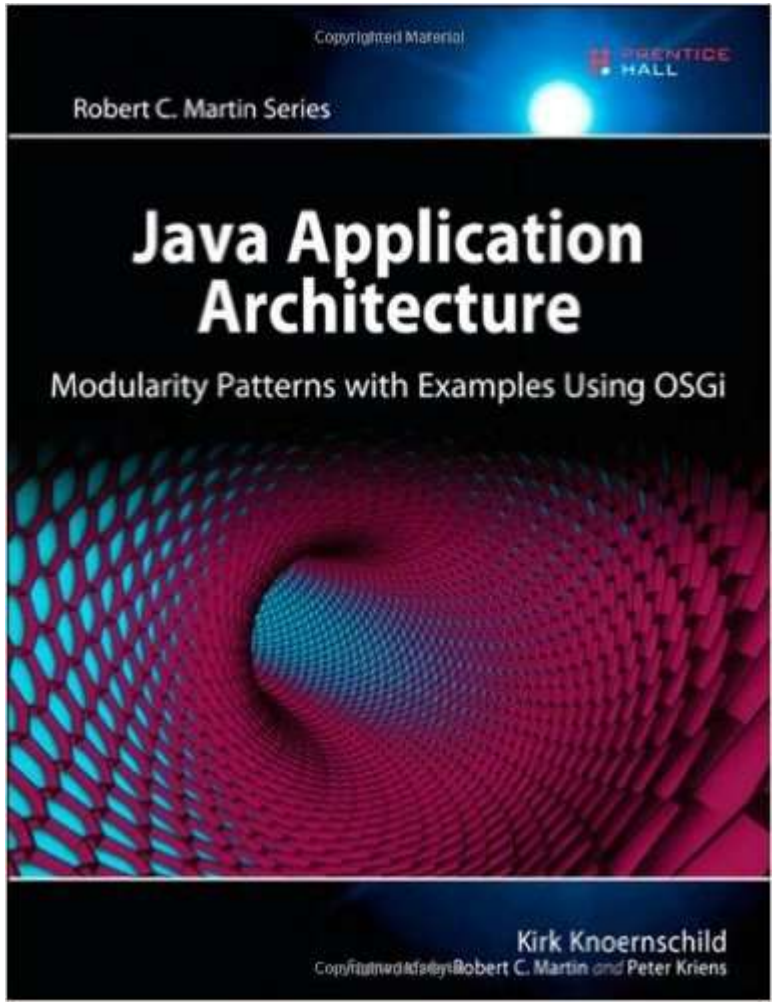


Well-formed graphs



Well-formed graphs

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



Well-formed graphs

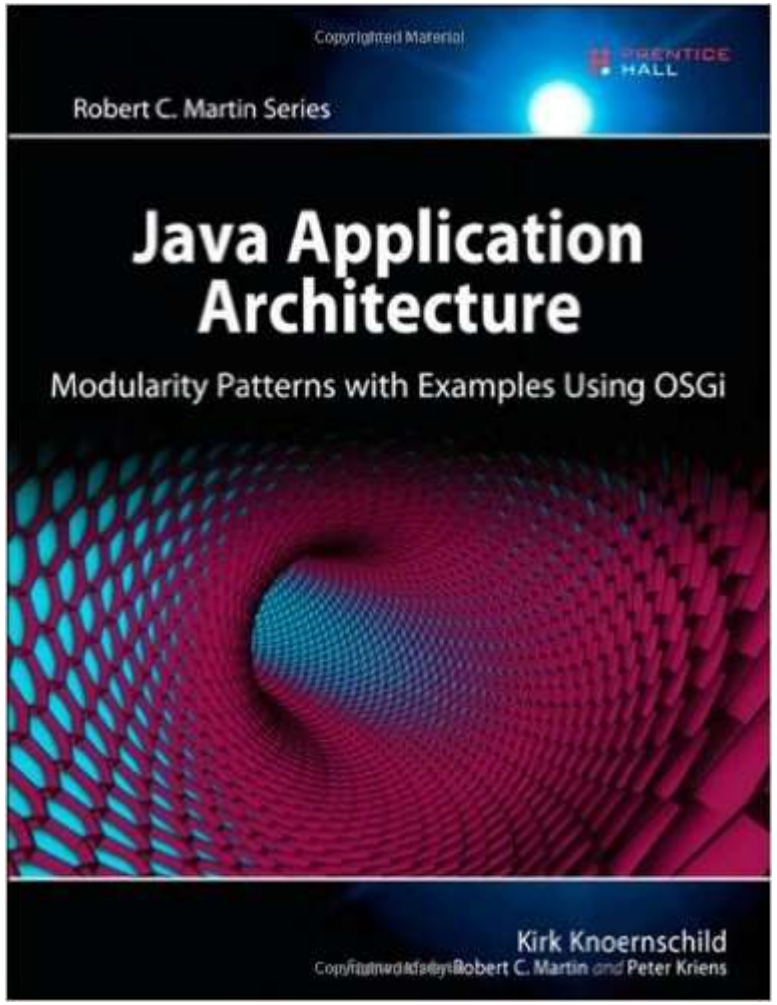
"Generally speaking, cycles are always bad!

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.

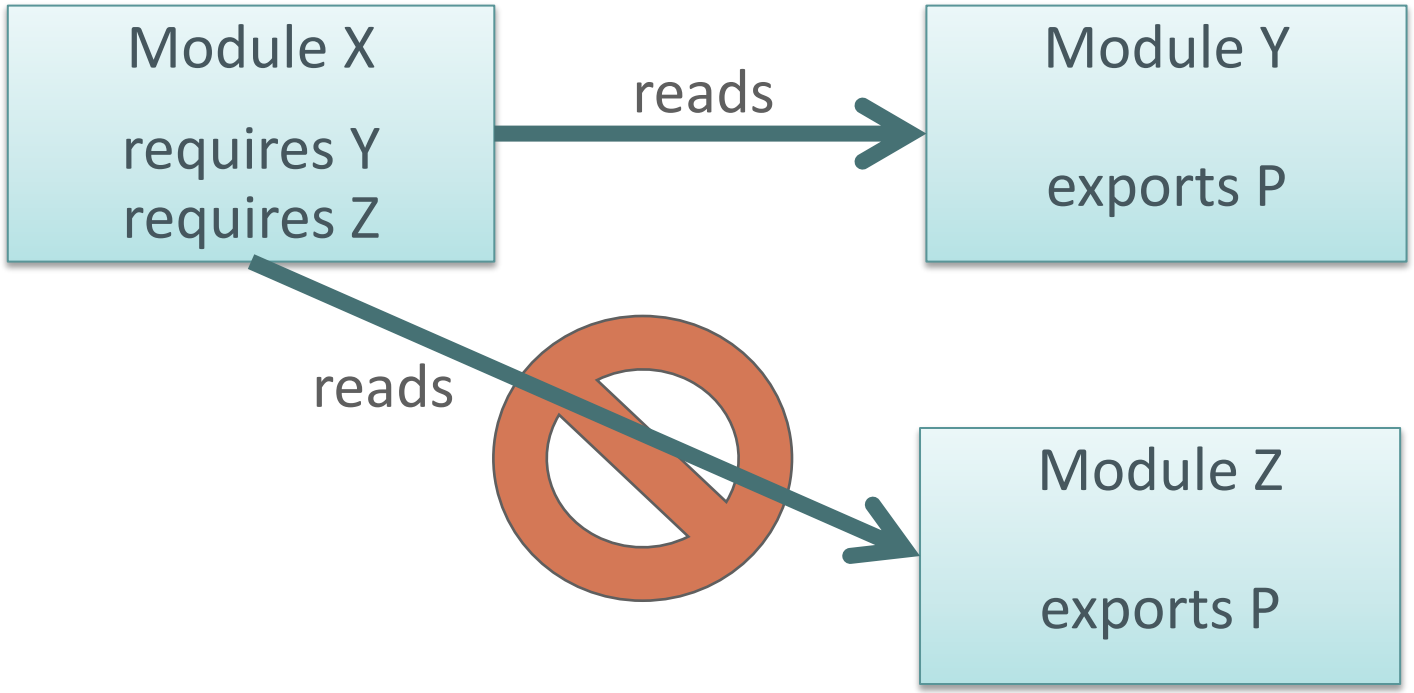
Cycles among packages may also be tolerable, assuming they don't cause cycles among the modules containing them.

Module relationships must never be cyclic."



Well-formed graphs

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

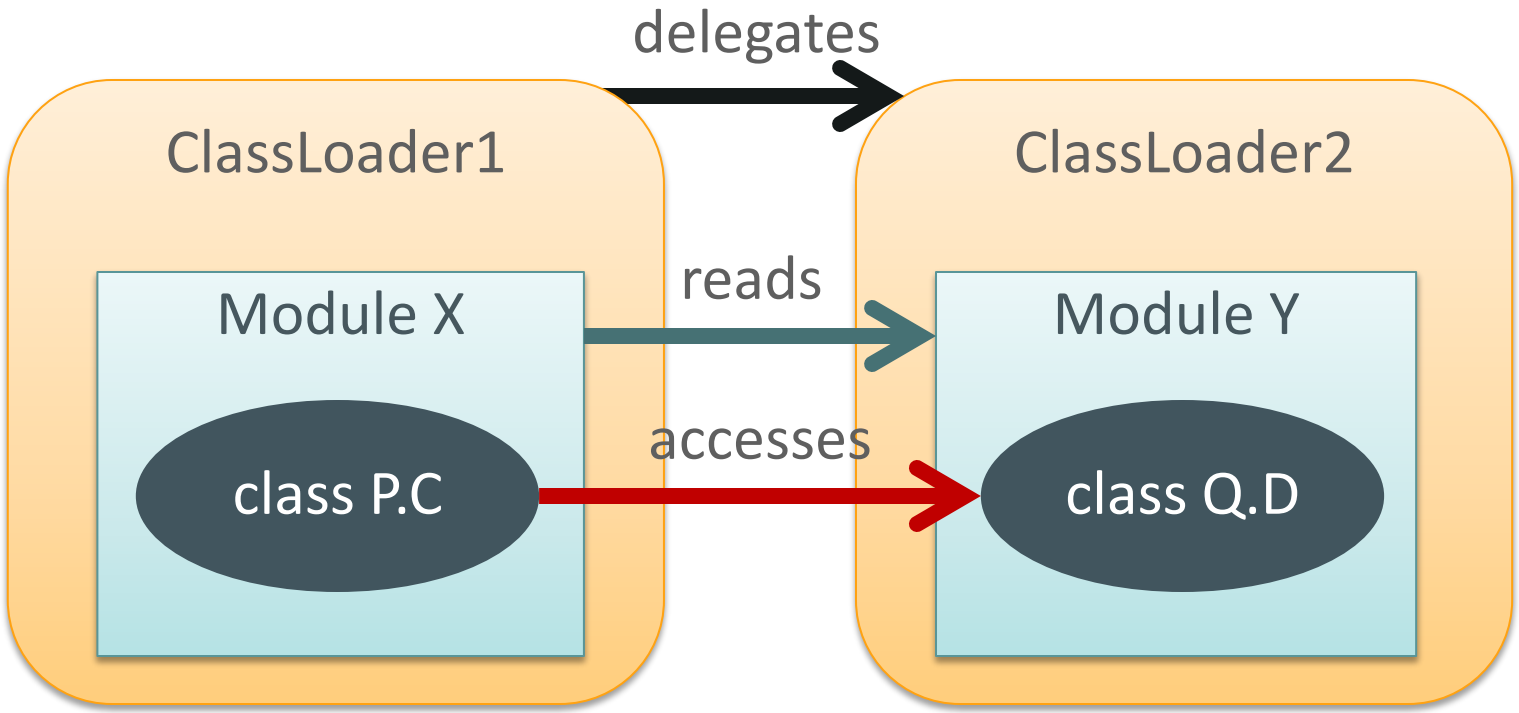


Well-formed maps

```
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

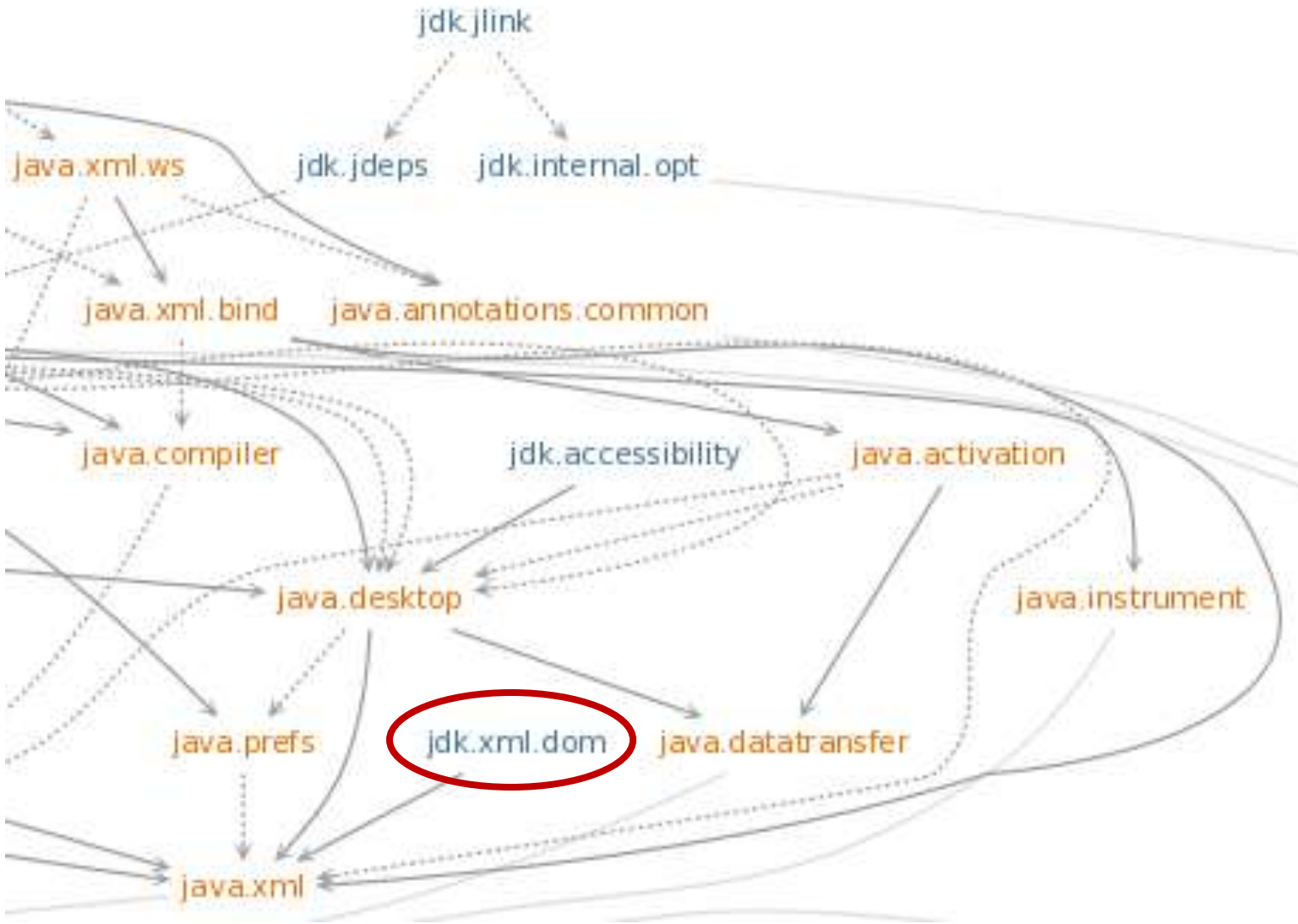
org.w3c.dom.css

org.w3c.dom.html

org.w3c.dom.stylesheets

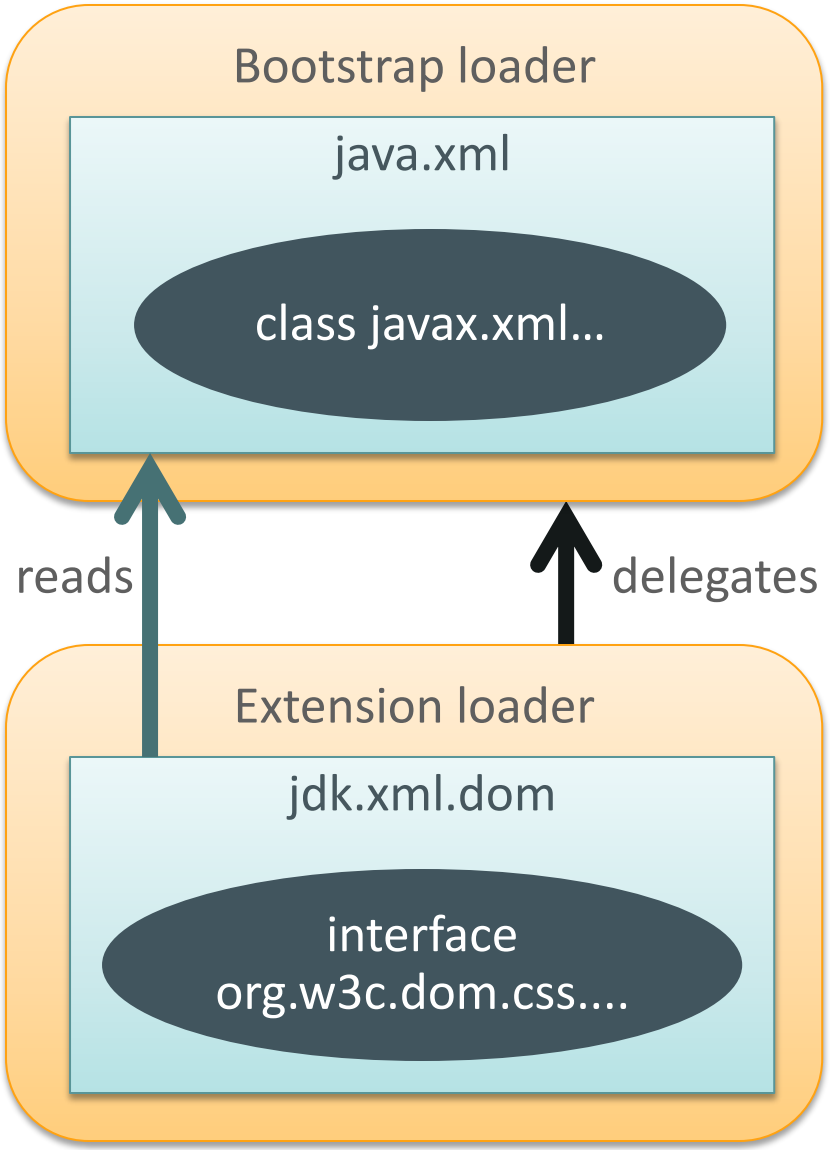
org.w3c.dom.xpath

Example: DOM APIs

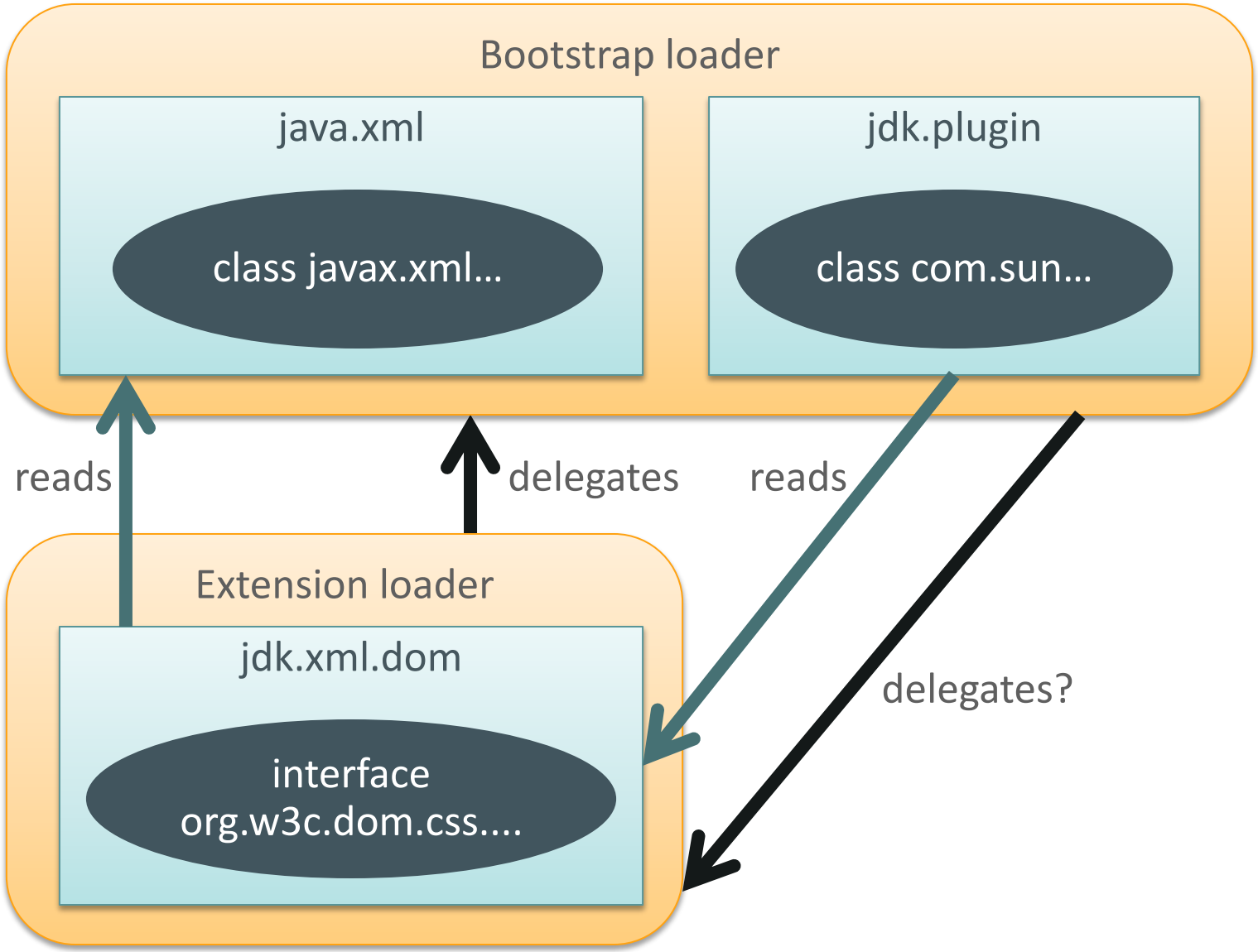


Example: DOM APIs

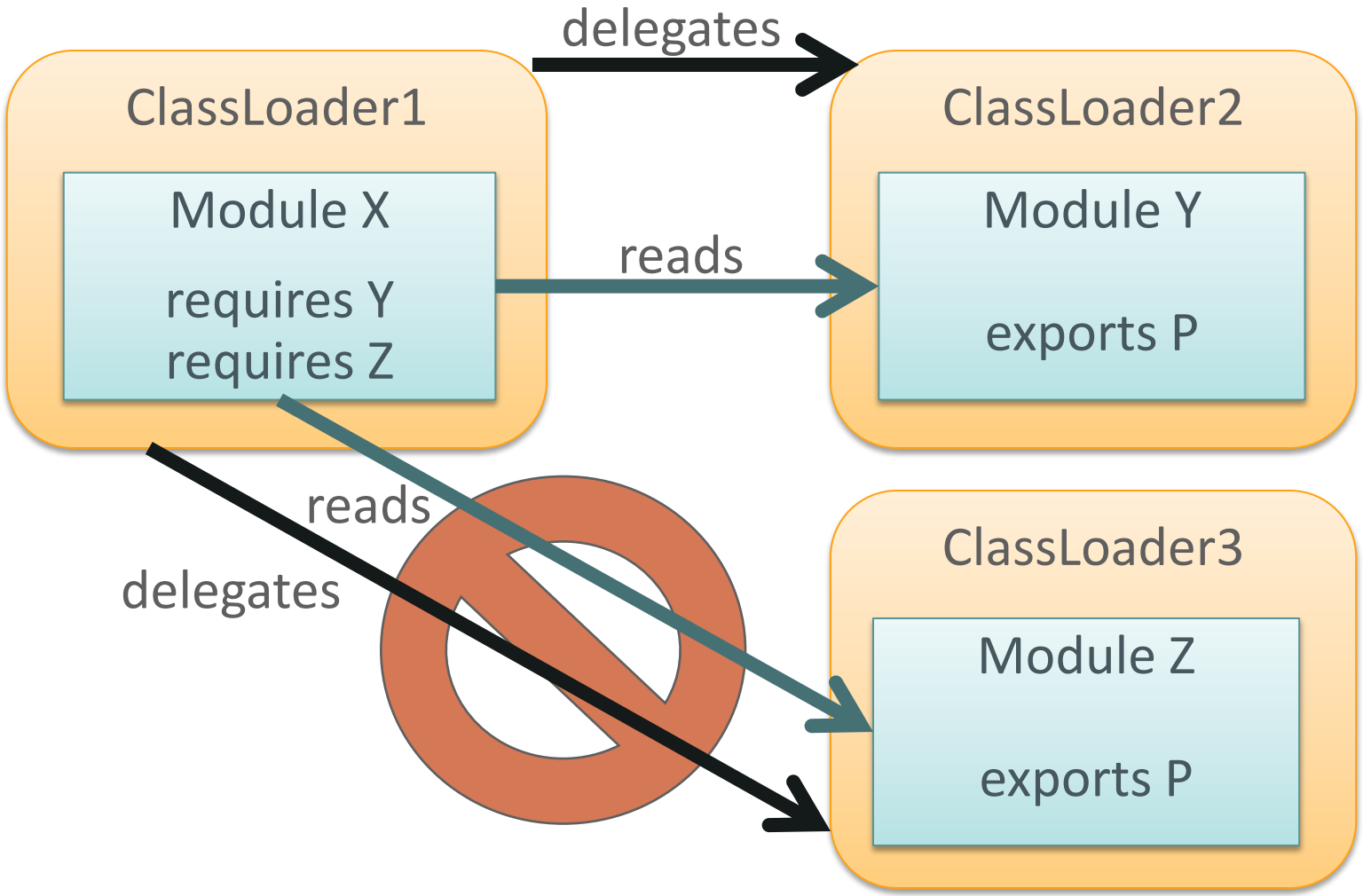
```
module jdk.xml.dom {
  requires public java.xml;

  exports org.w3c.dom.css;
  exports org.w3c.dom.html;
  exports org.w3c.dom.stylesheets;
  exports org.w3c.dom.xpath;
}
```



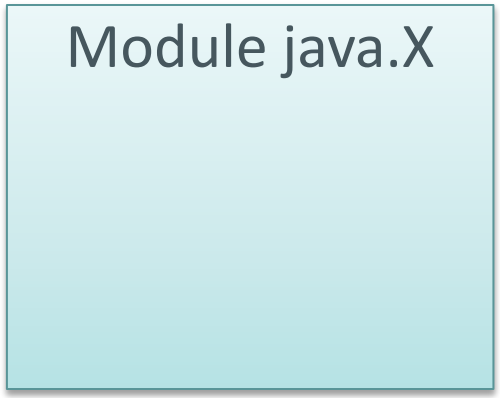
Example: DOM APIs



Loader delegation respects module readability



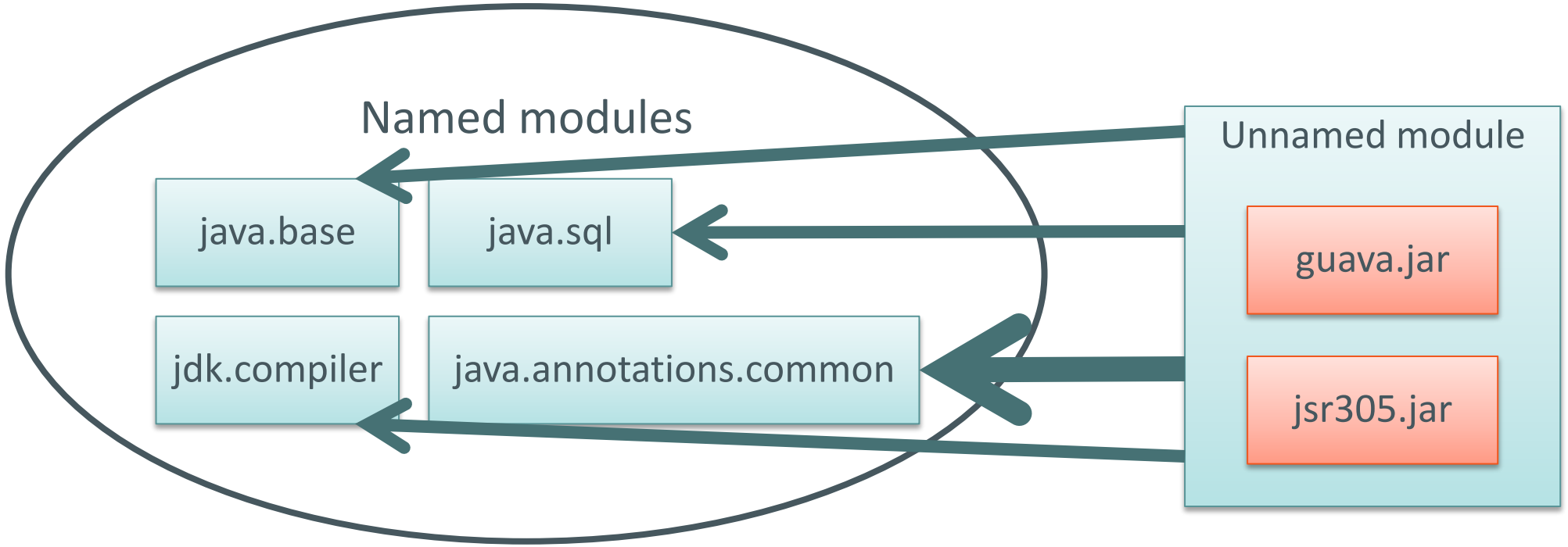
Split packages (missing class)



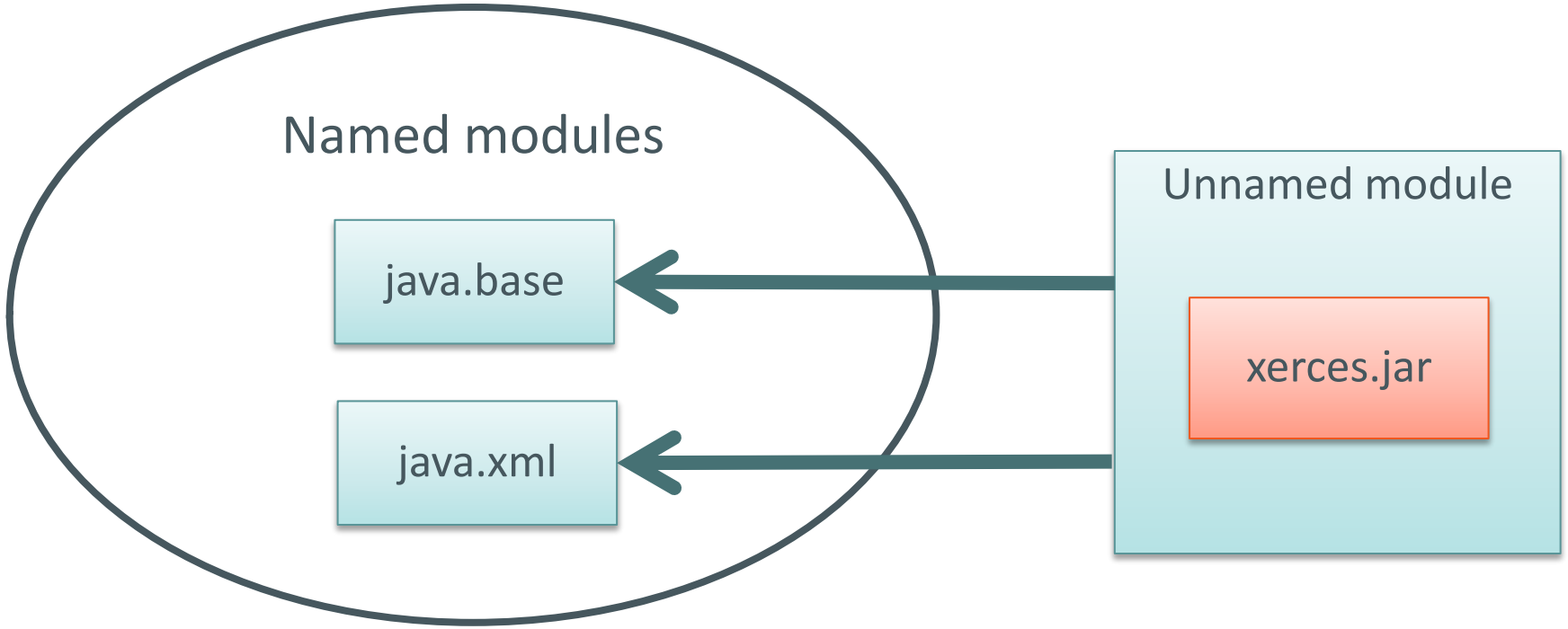

```
module java.X {
  exports javax.annotation;
}
```

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

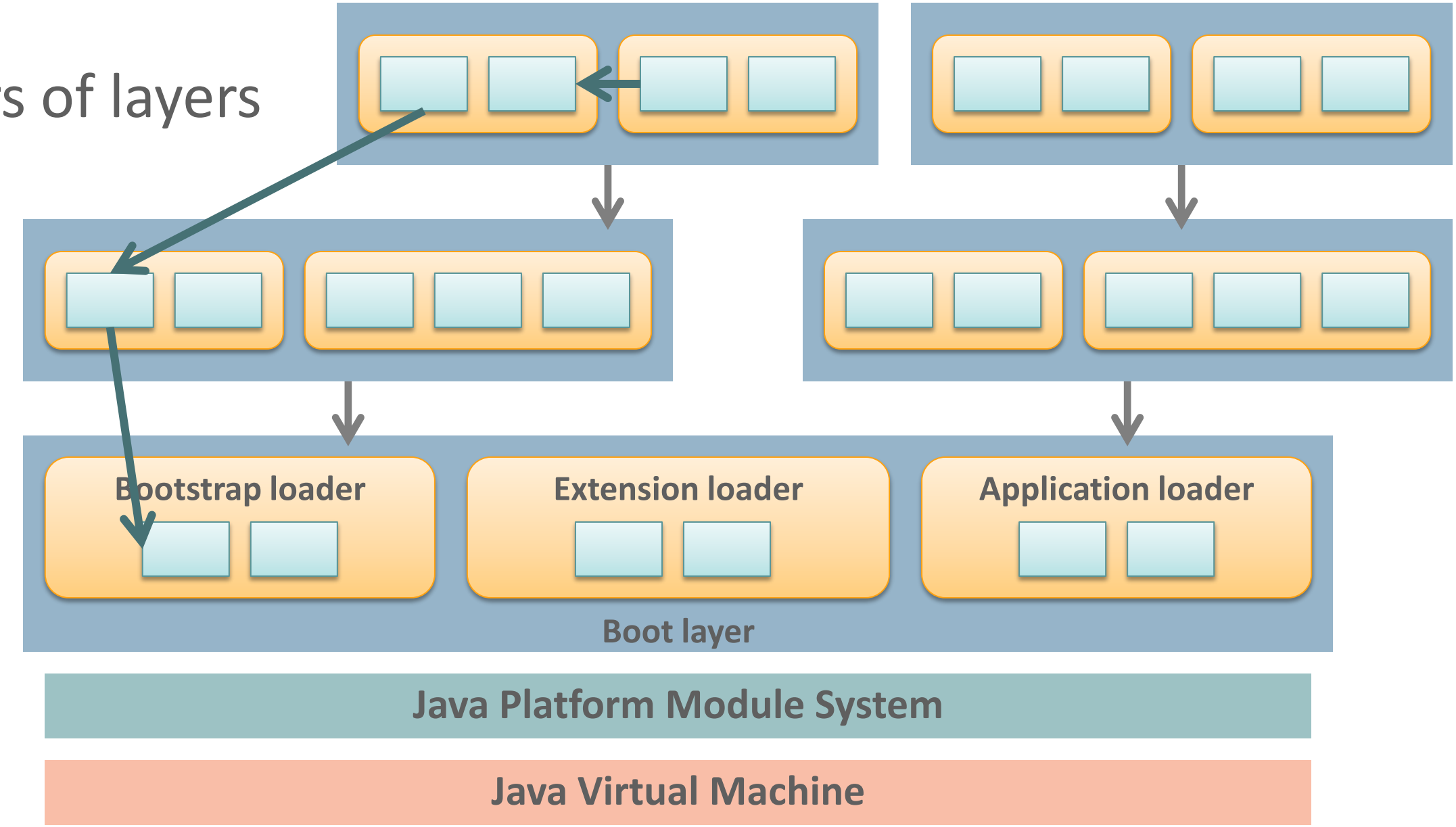
Split packages (missing class)



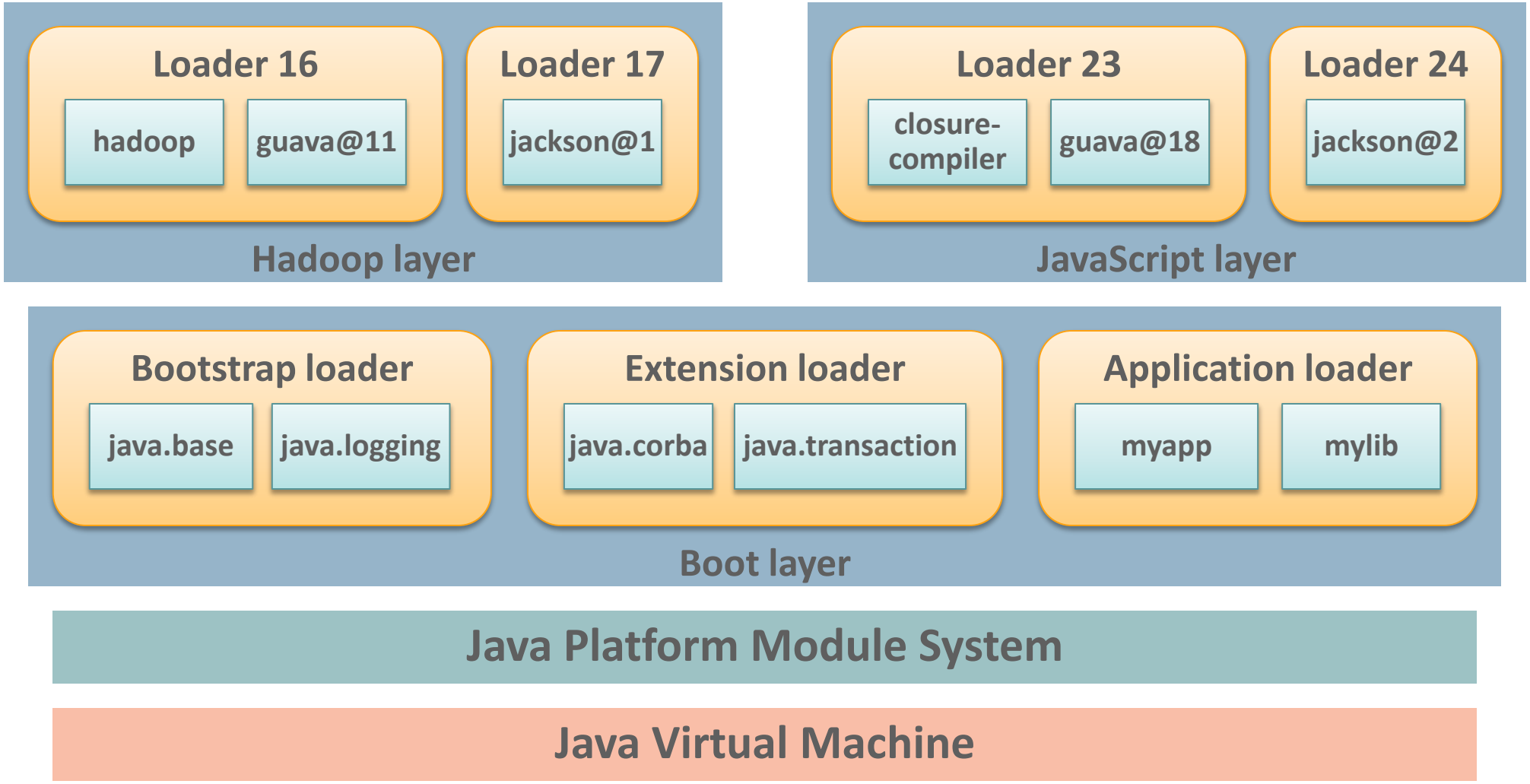
Split packages (duplicate class)



Layers of layers



Layers and Versions



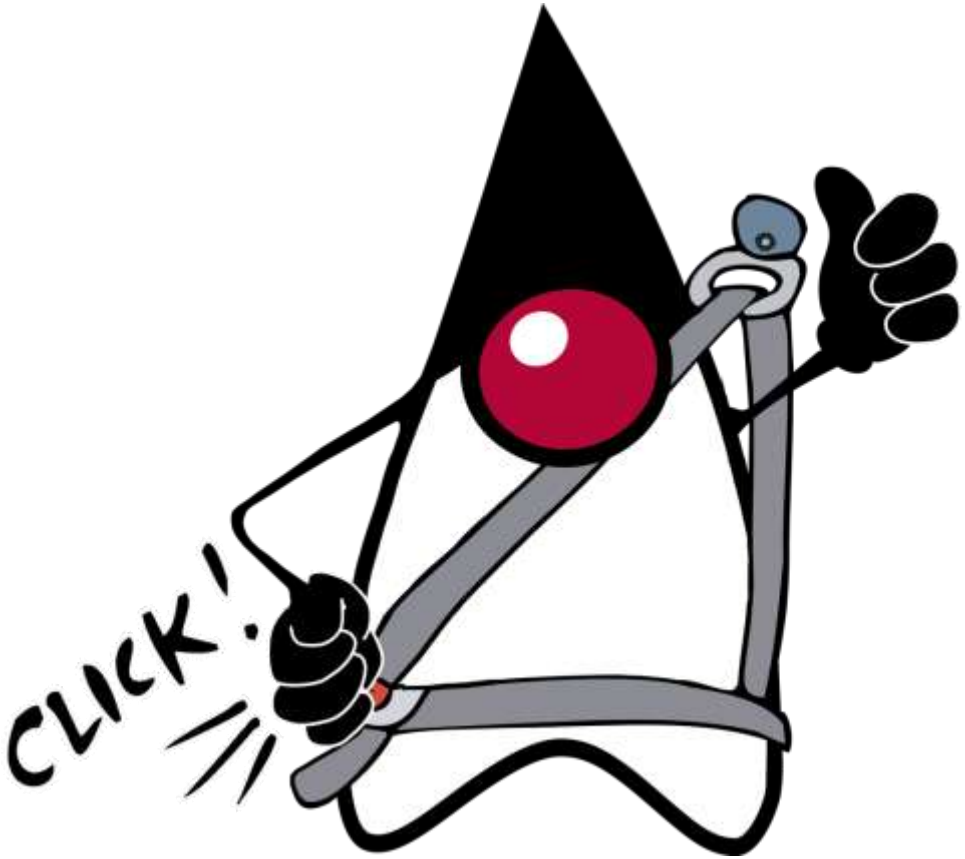
Summary of Part III: Loaders and Layers

- 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 – no cycles or split packages.**

Summary of Summaries

- **Strong encapsulation of modules by the compiler, VM, Core Reflection.**
- **Unnamed and automatic modules help with migration.**
- **The system is safe by construction – no cycles or split packages.**

The module system: a seat belt, not a jetpack



Meta

Personal photo of speaker, France, 2001

What can you do to prepare for JDK 9?

- Try JDK 9 with Jigsaw – jdk9.java.net/jigsaw
- Run jdeps on your code and on your classpath.
- Subscribe to jigsaw-dev @ OpenJDK to see common problems + solutions.

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