Declarative, Formal, and Extensible Syntax Definition for AspectJ

A Case for Scannerless Generalized-LR Parsing

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What is the problem? 1

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public aspect Caching {
  private Map<Integer, Integer> cache =
      new HashMap<Integer, Integer>();

  pointcut cached(int value):
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Lexical syntax is context-sensitive

- Java context:

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int x = get* y + z;
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- Pointcut context:

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pointcut g(): call(* get*(..));
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Keywords cannot be reserved globally

- `get(* Foo.*)`, `target(e)`, `args(event)` ...

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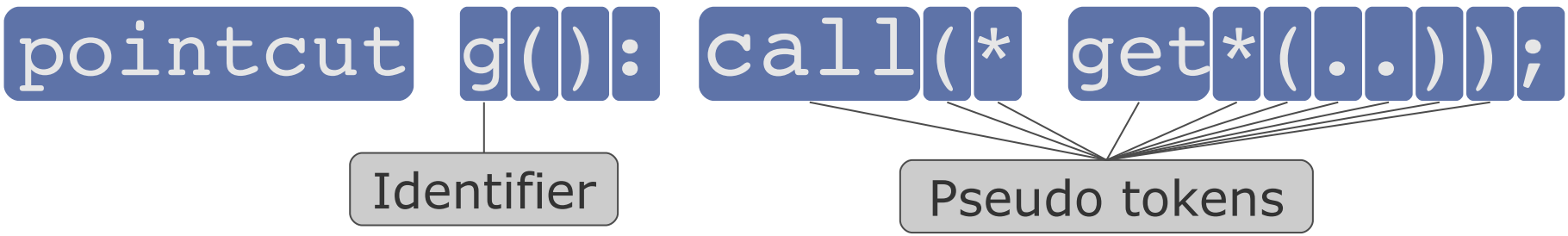
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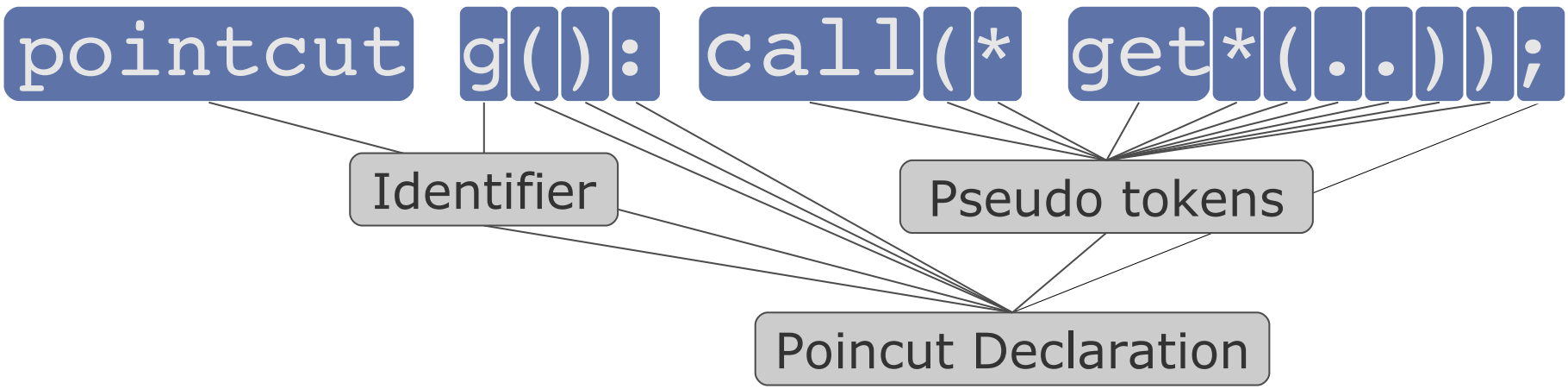
Identifier
Pseudo tokens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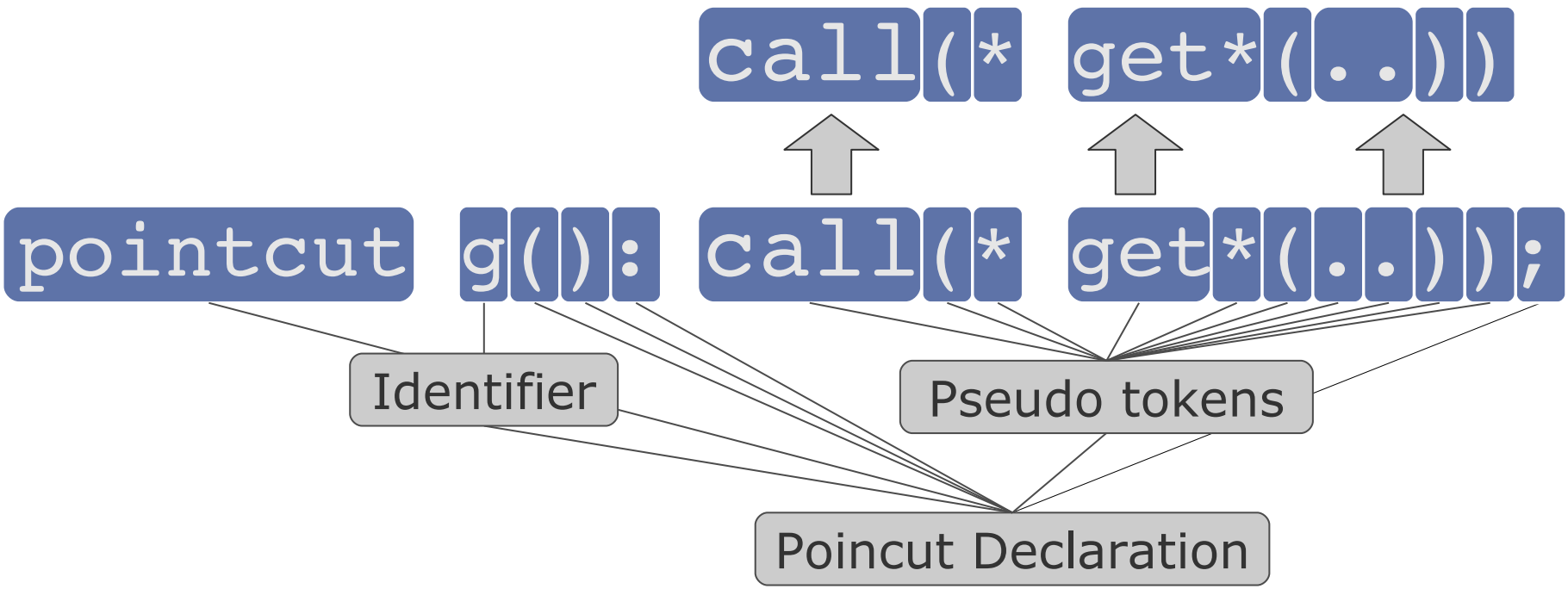
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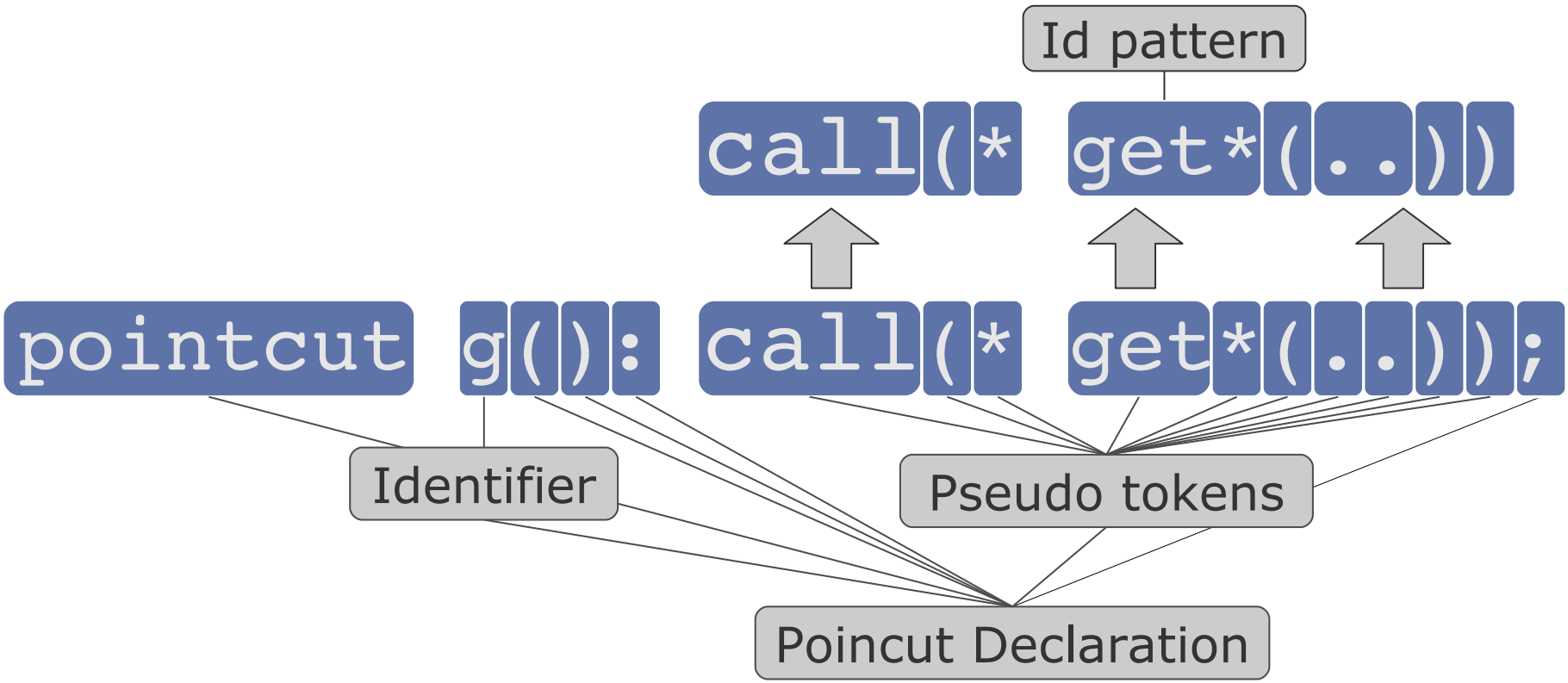
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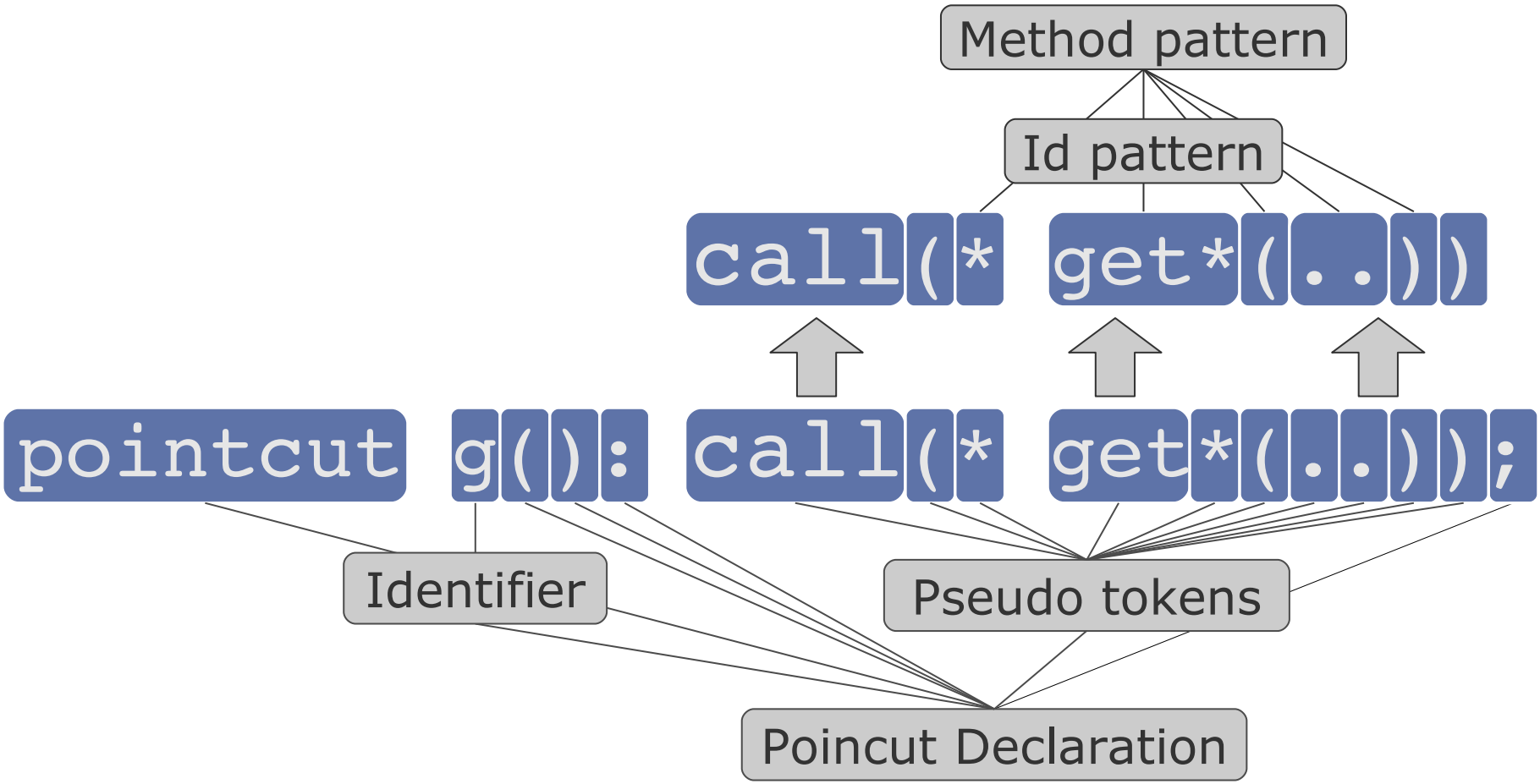
Method pattern
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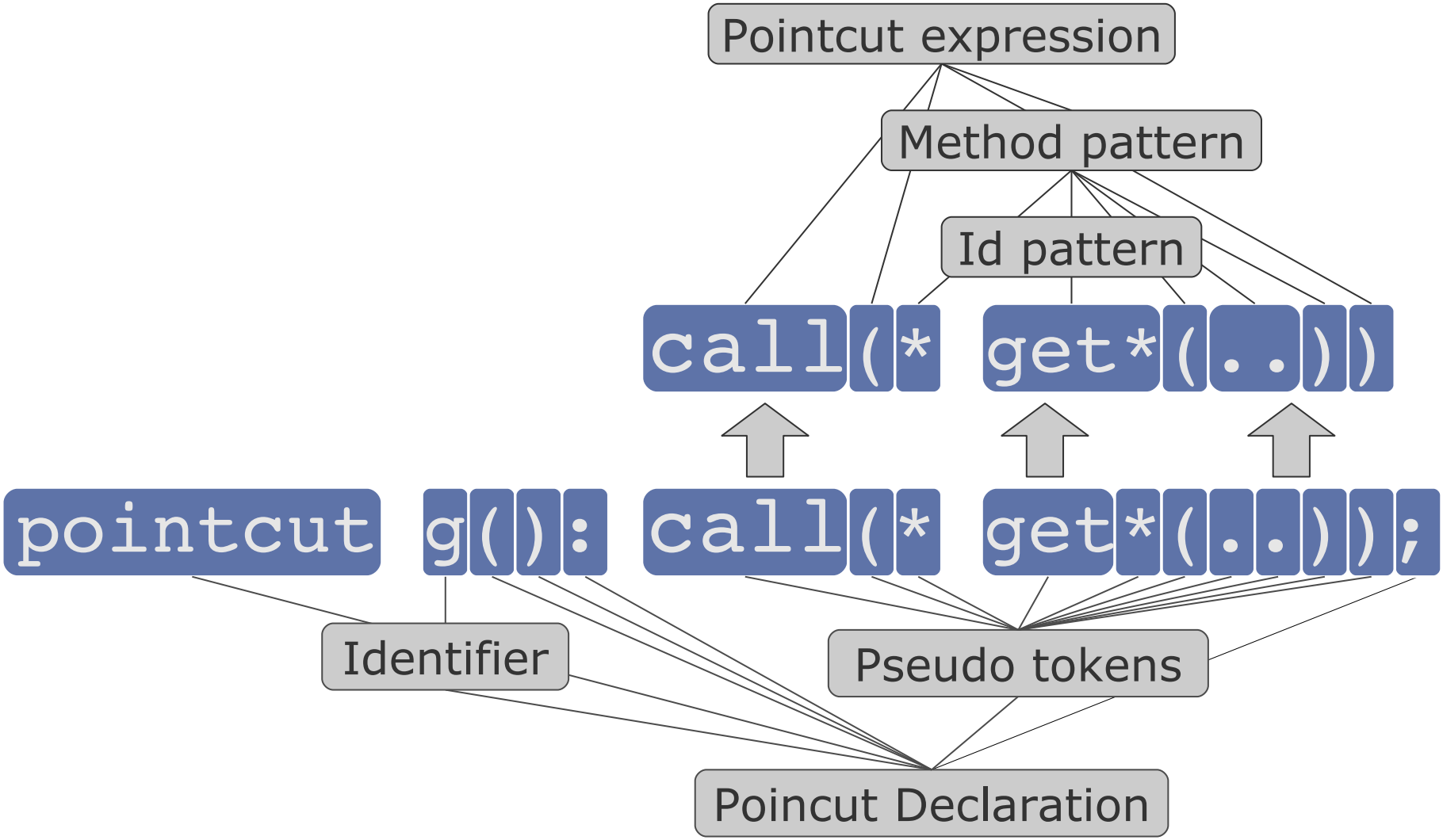
Pointcut expression
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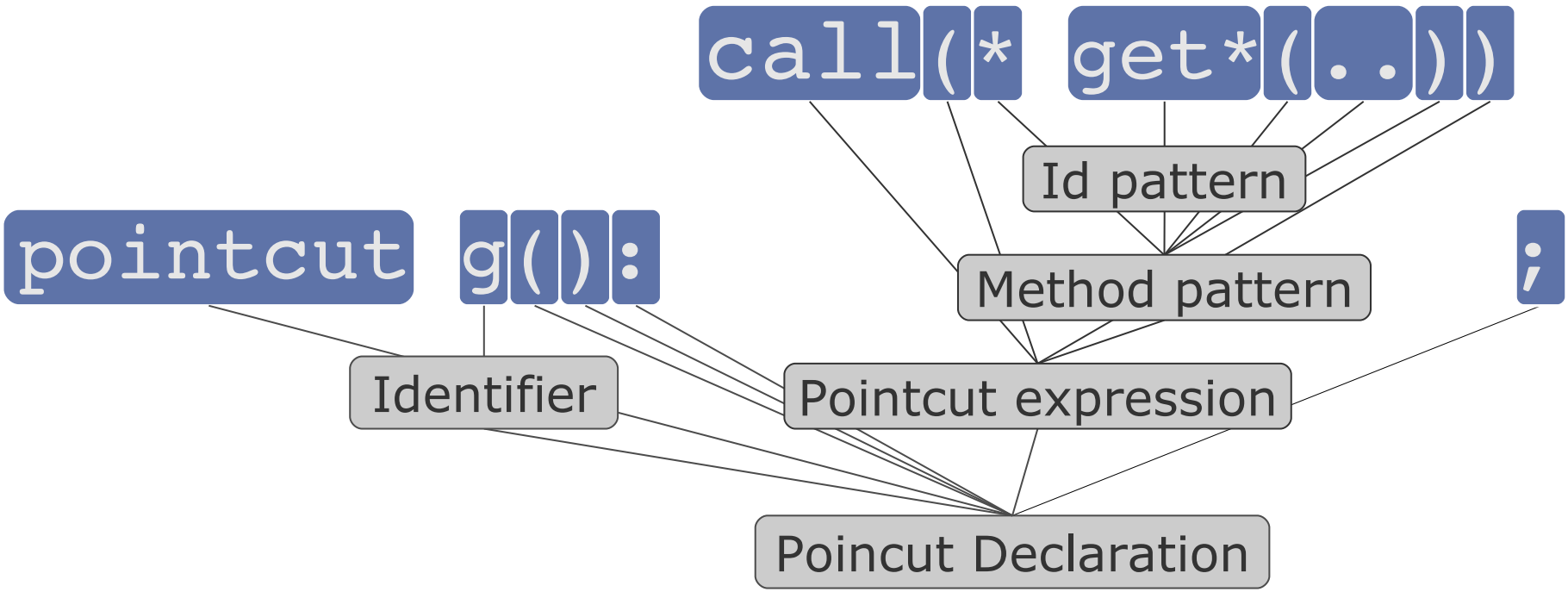
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- **More invalid tokenizations**

```
call(* *1.Function+.apply(..))
call(* *1.F unction+.apply(..))
```

- **Invalid error report**

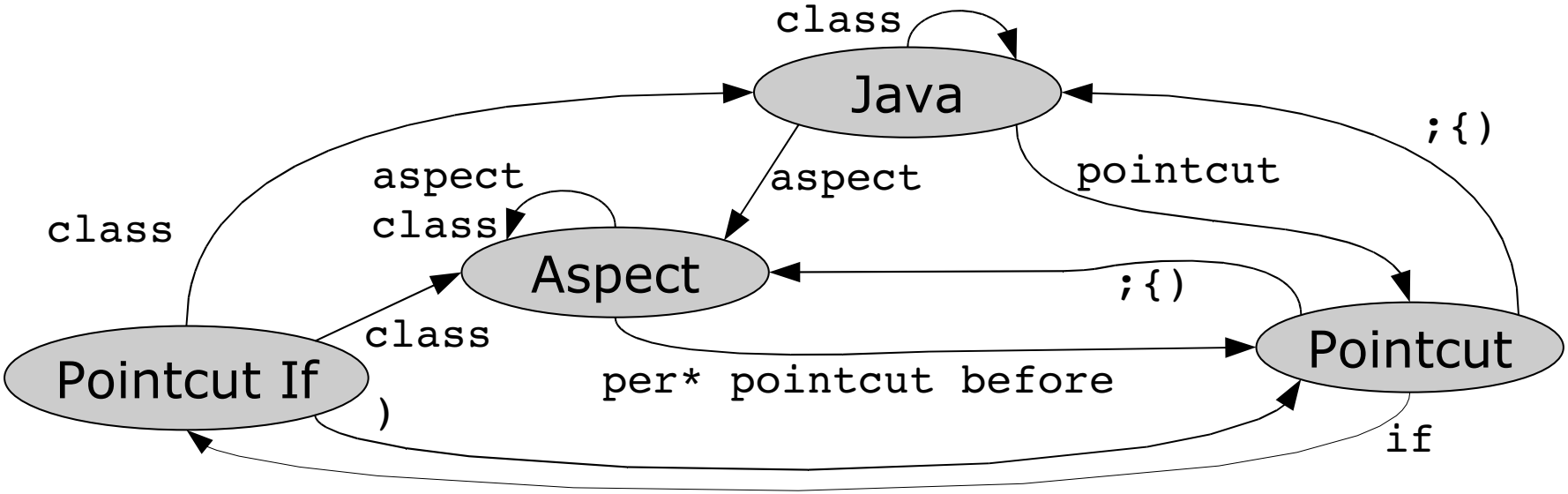
```
call(void *0.Ef())
ajc: [error] Invalid float literal number
```

- **If not allowed in method pattern**

```
call(boolean *.for*(..)) || call(boolean *.if*(..))
ajc: [error] Syntax error on token "if"
```

- **Tokenized in same way**

```
call(* *1.foo(..)) && call(* *1.f oo(..))
```


class
Java
;{)
aspect
class
aspect
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per* pointcut before
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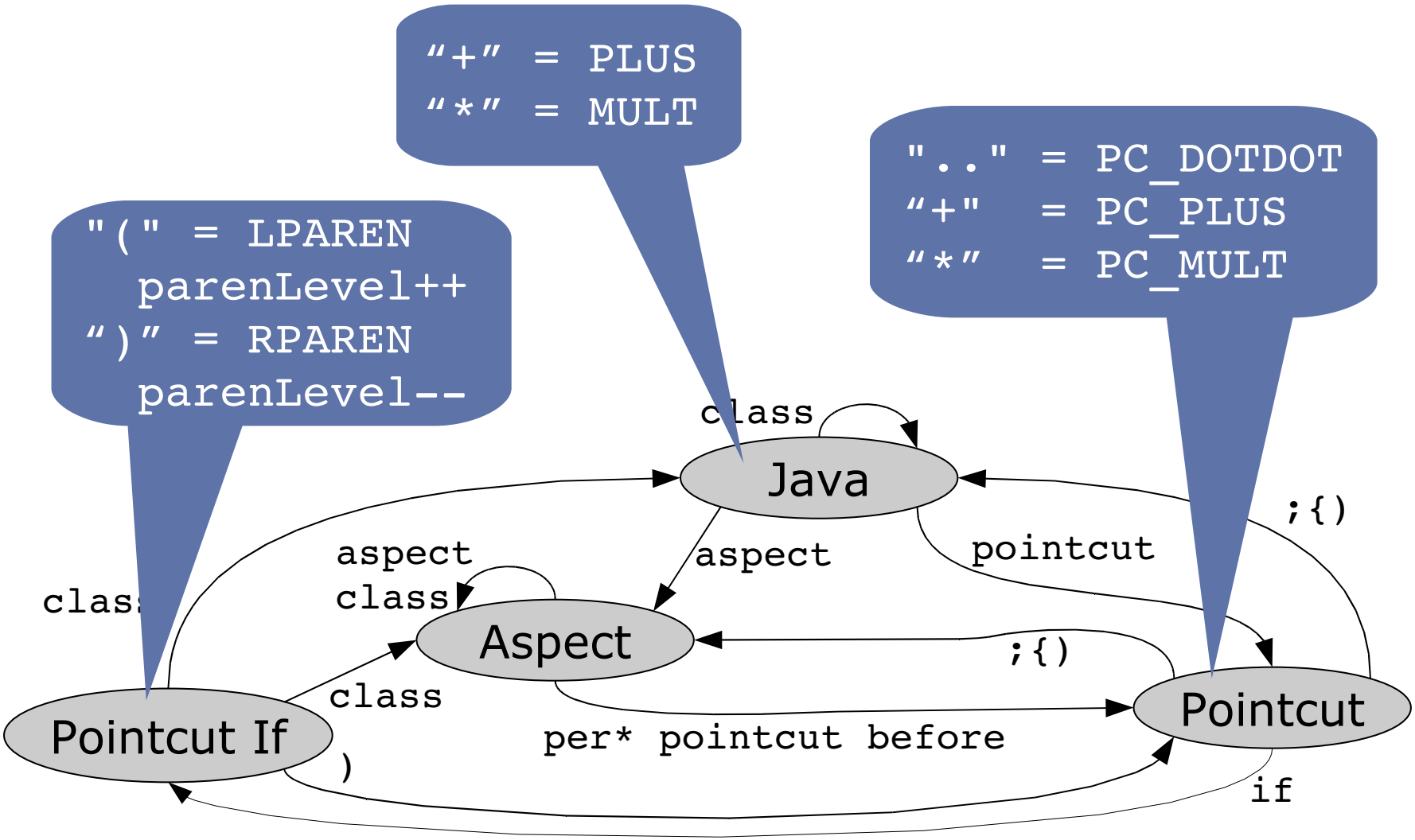
if


"+" = PLUS
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"(" = LPAREN
parenLevel++
")" = RPAREN
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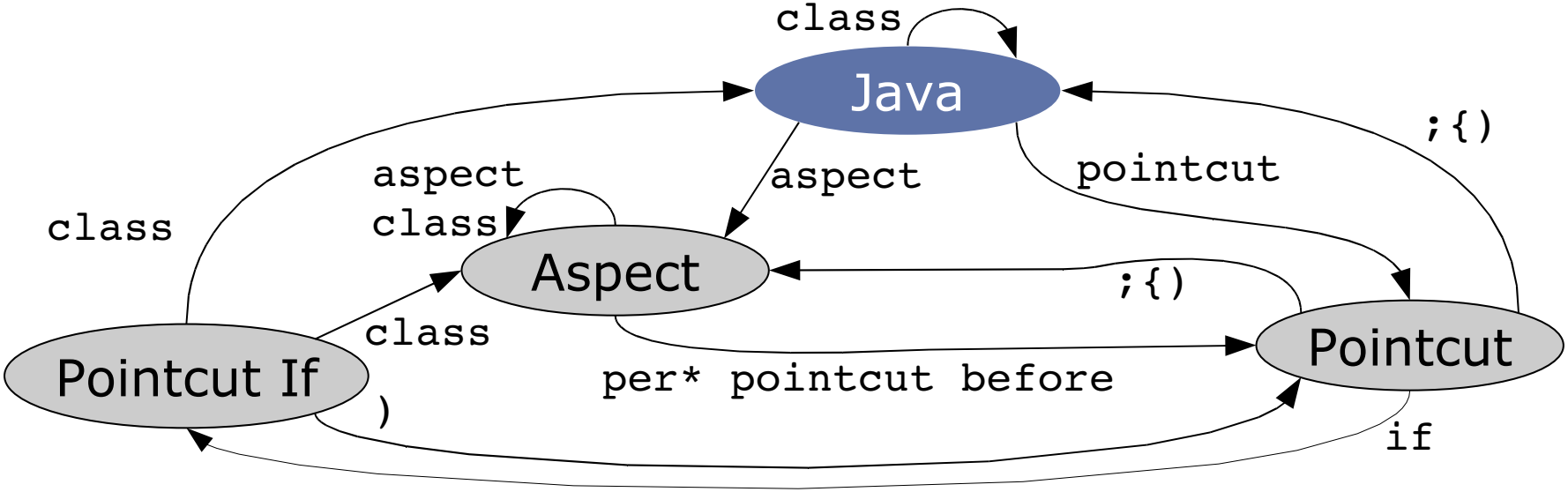

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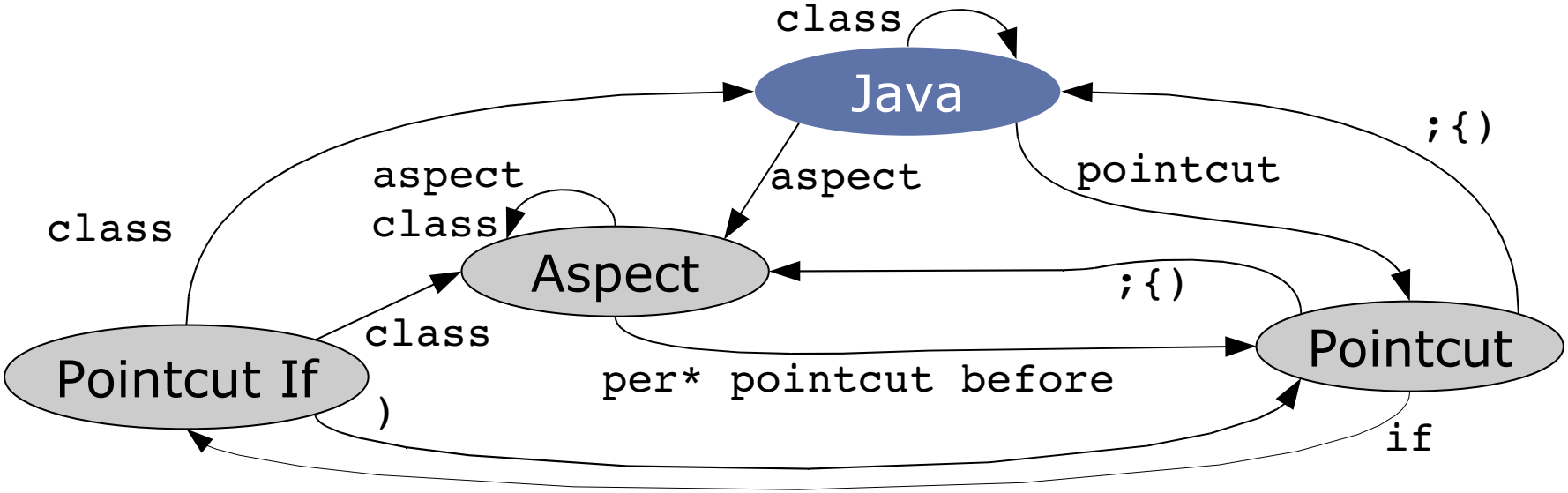

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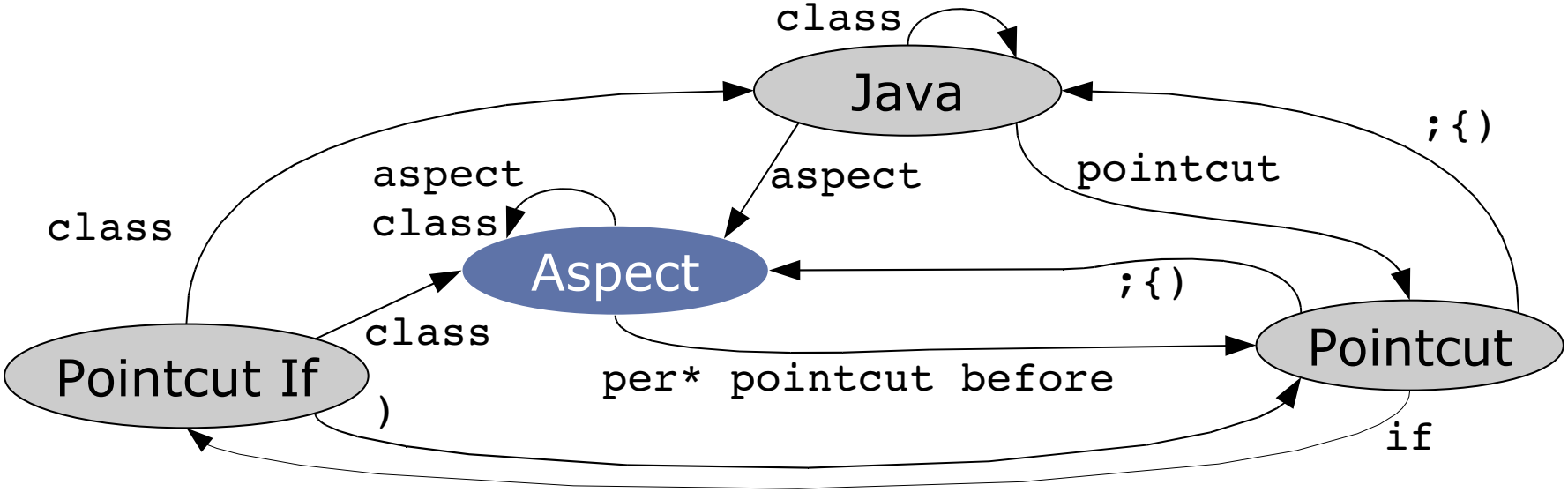

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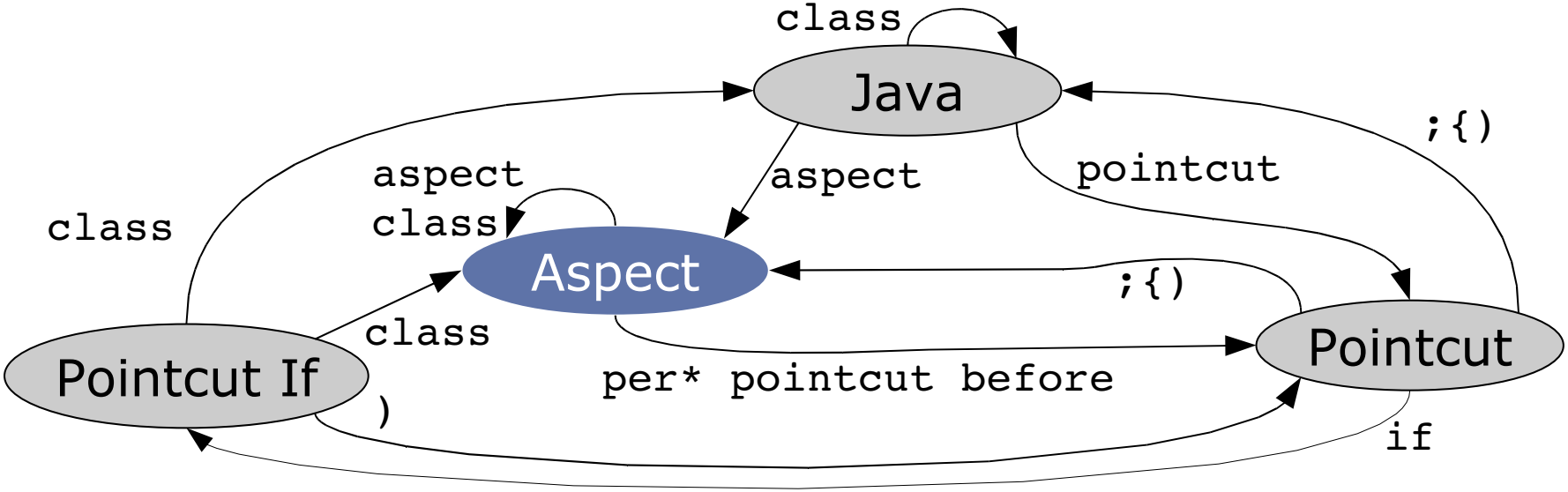

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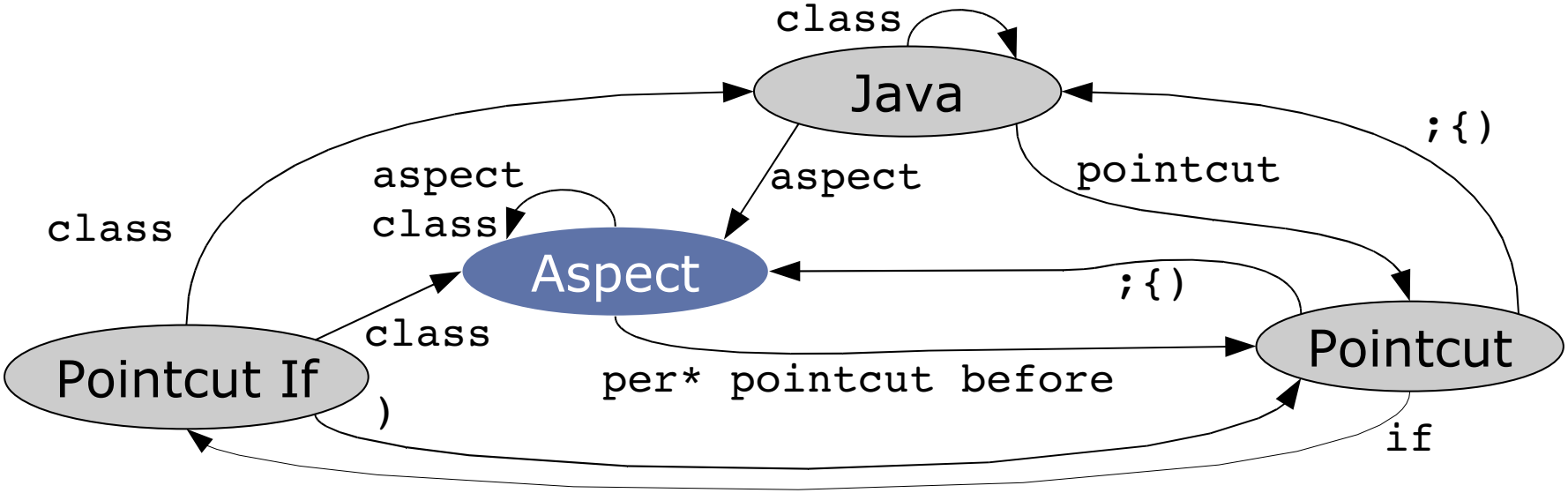

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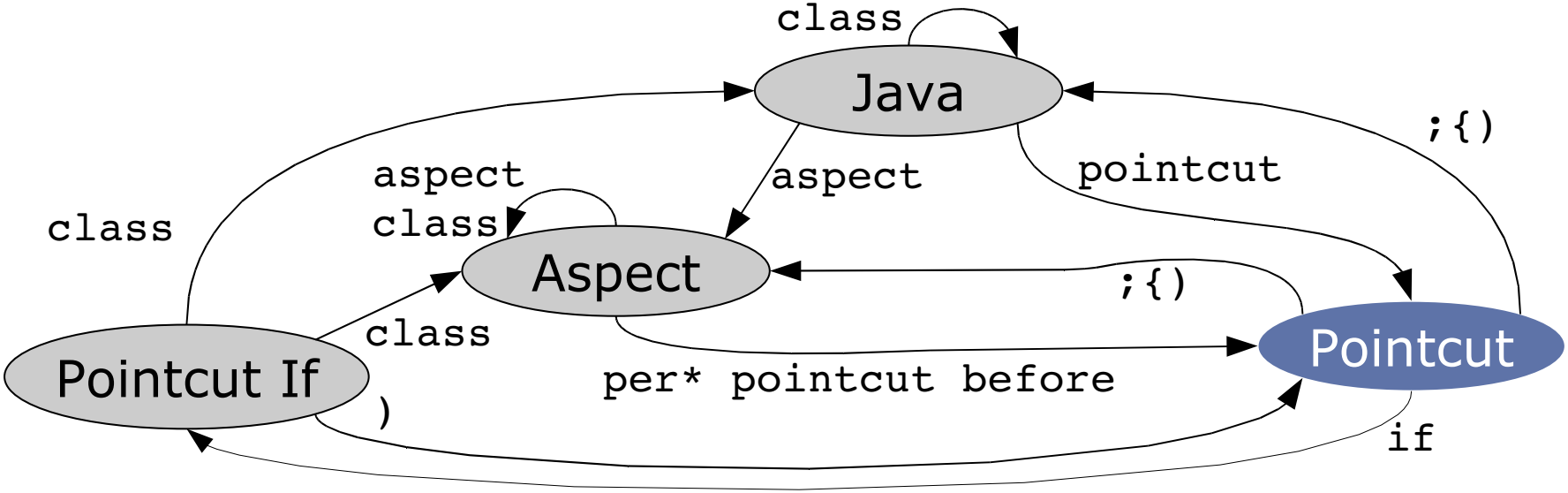

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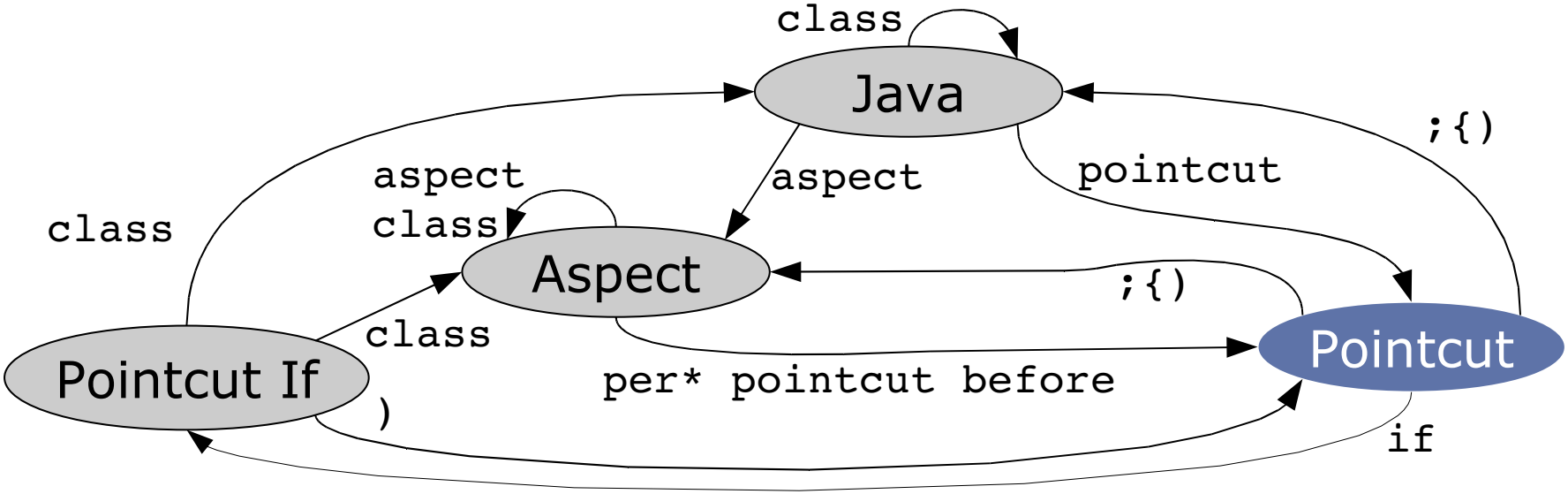

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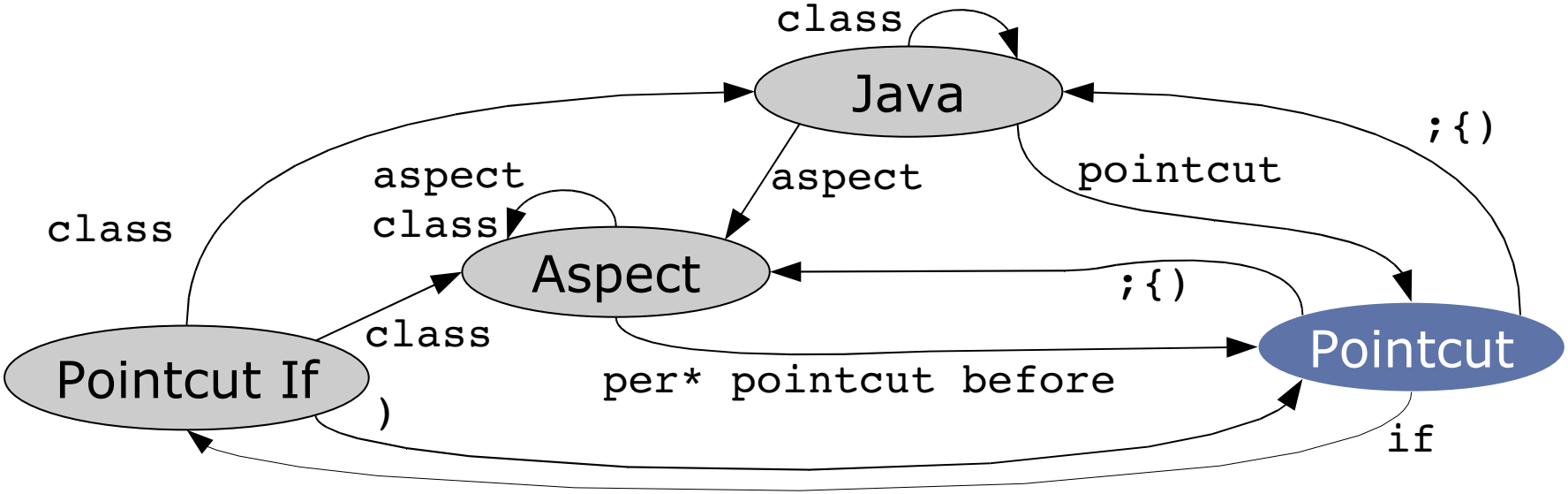

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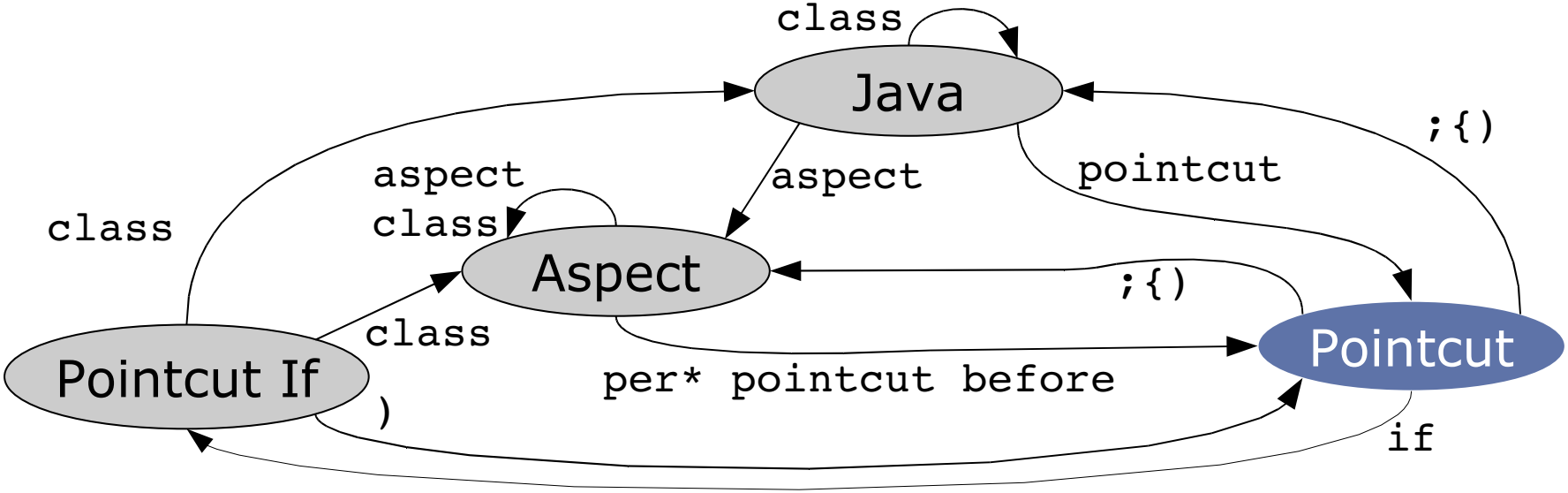

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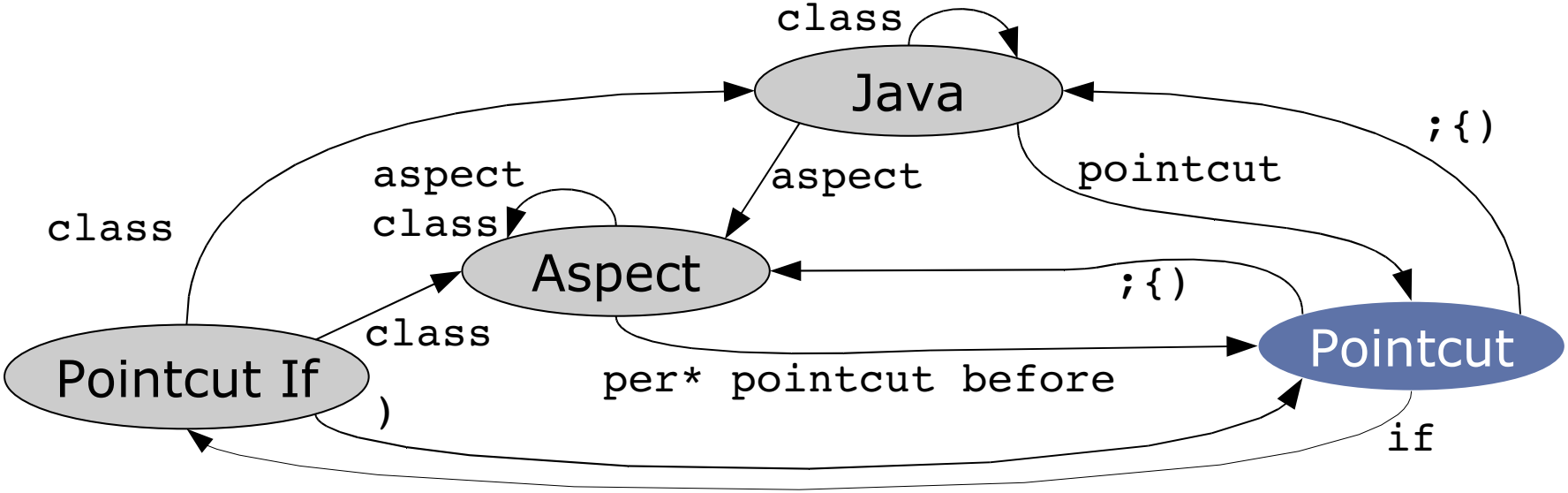

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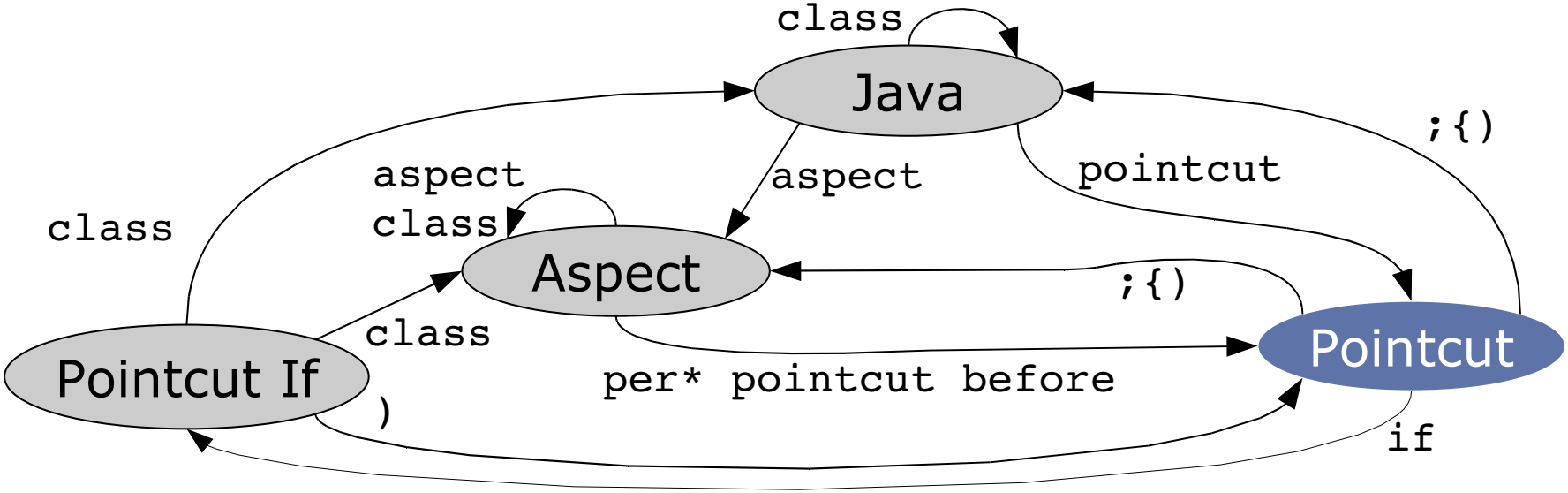

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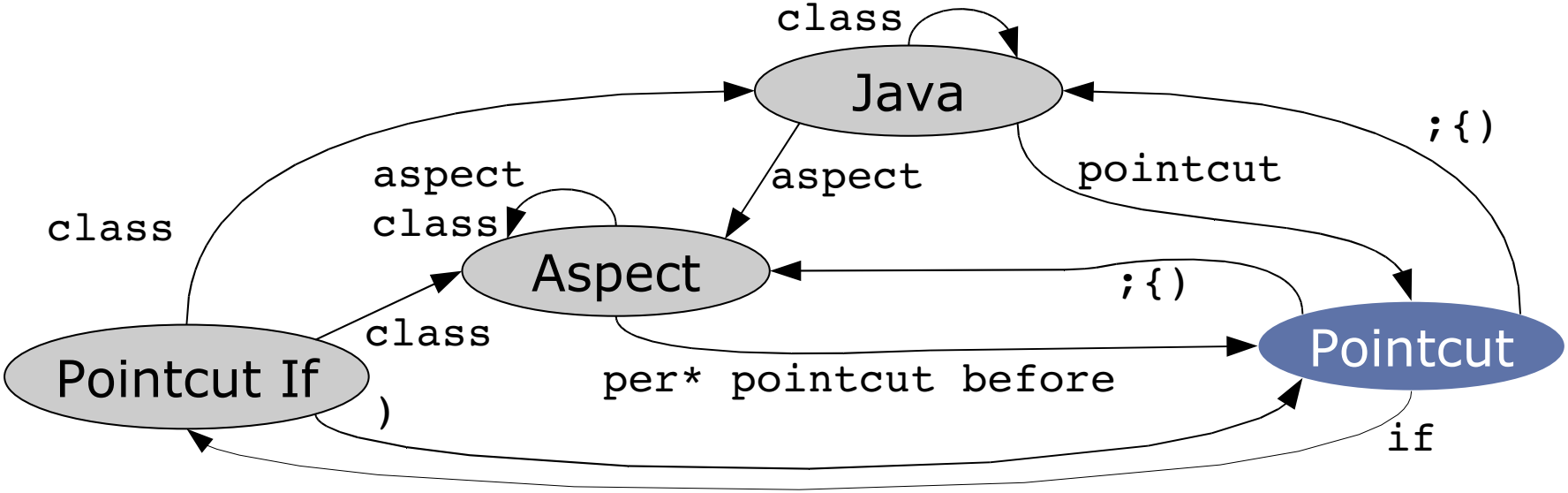

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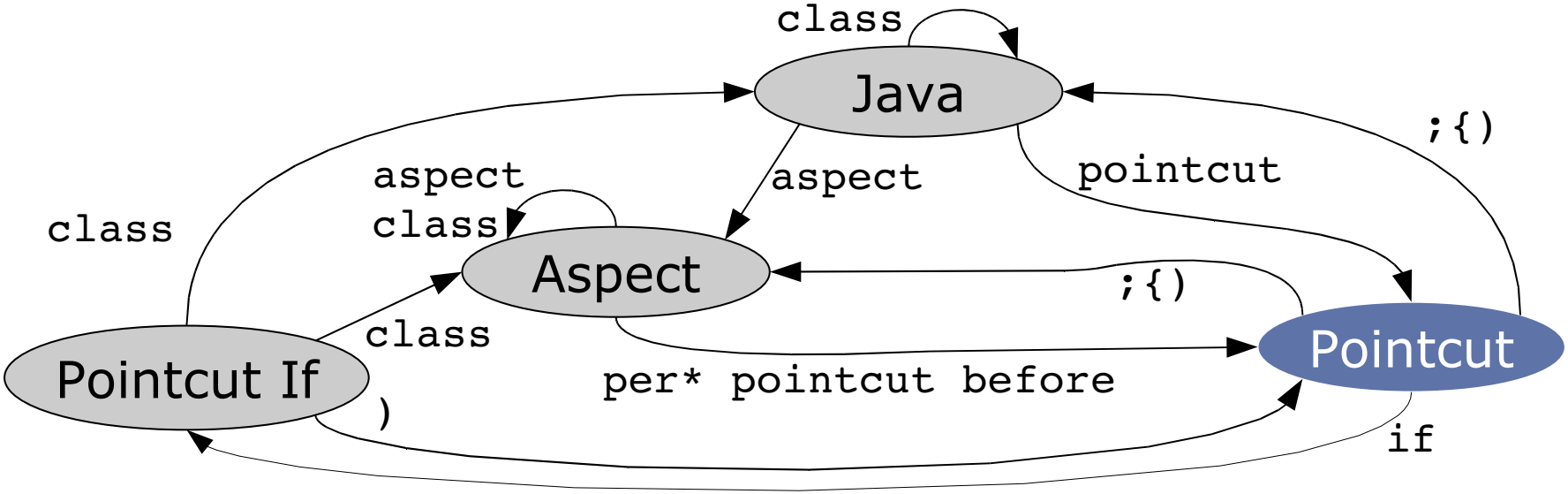

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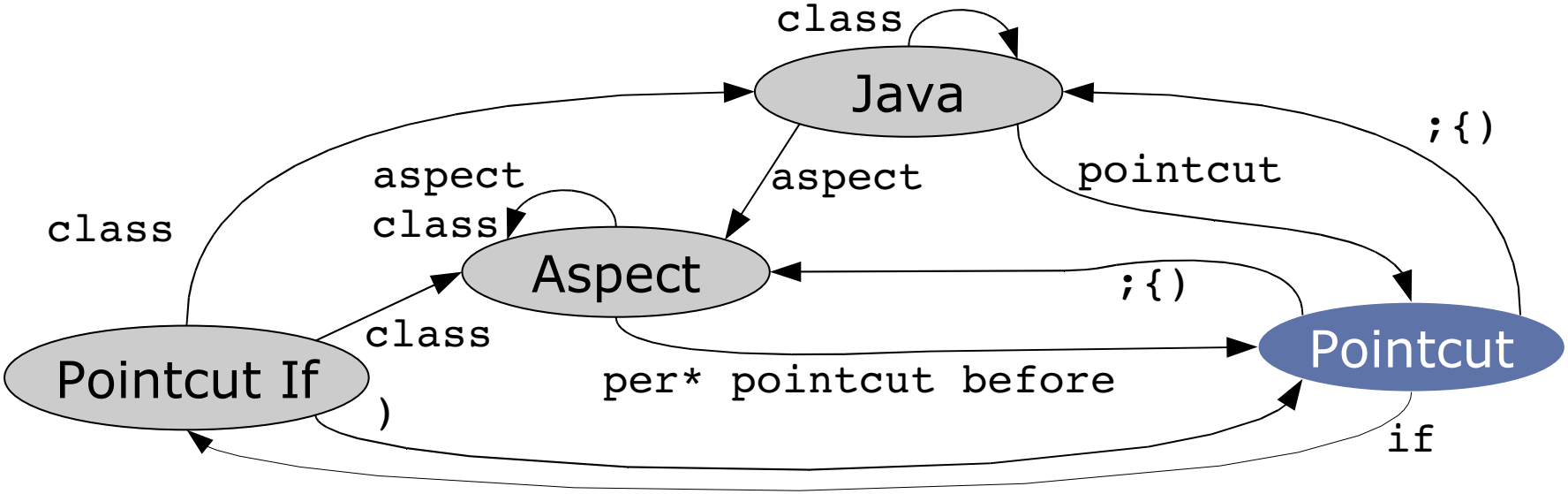

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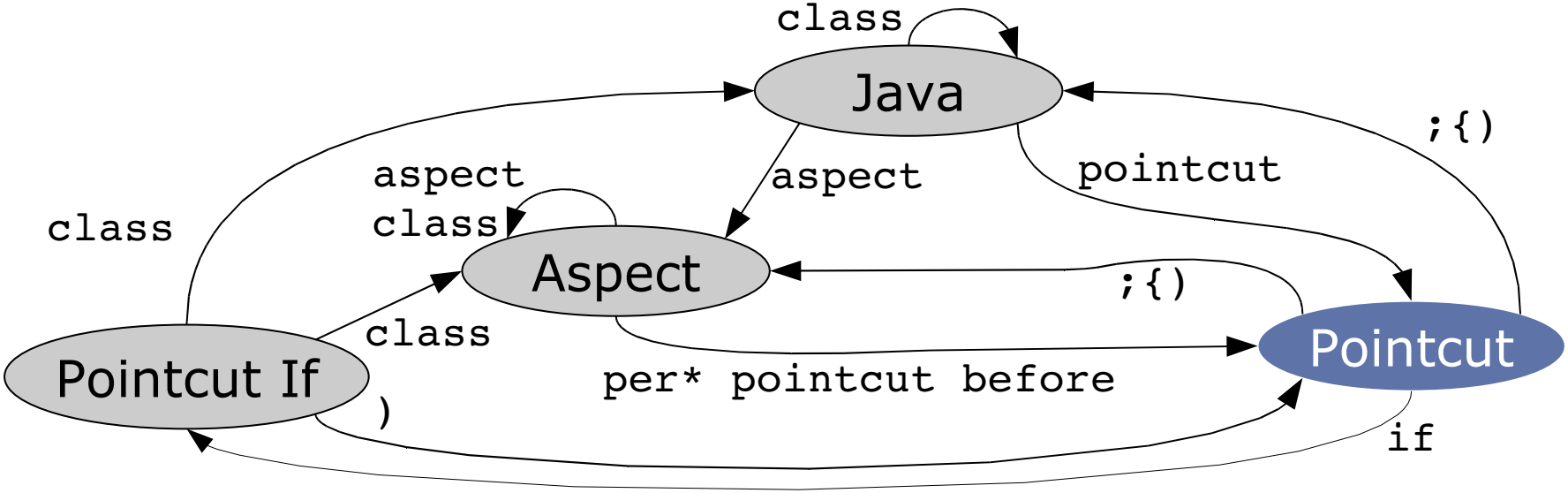

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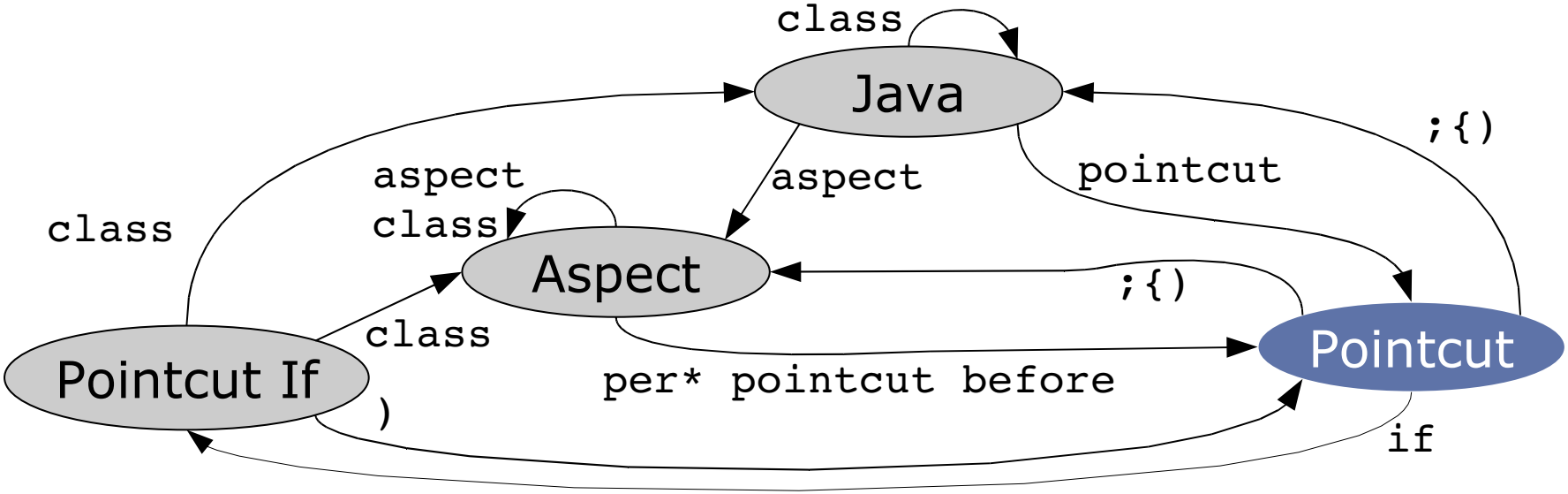

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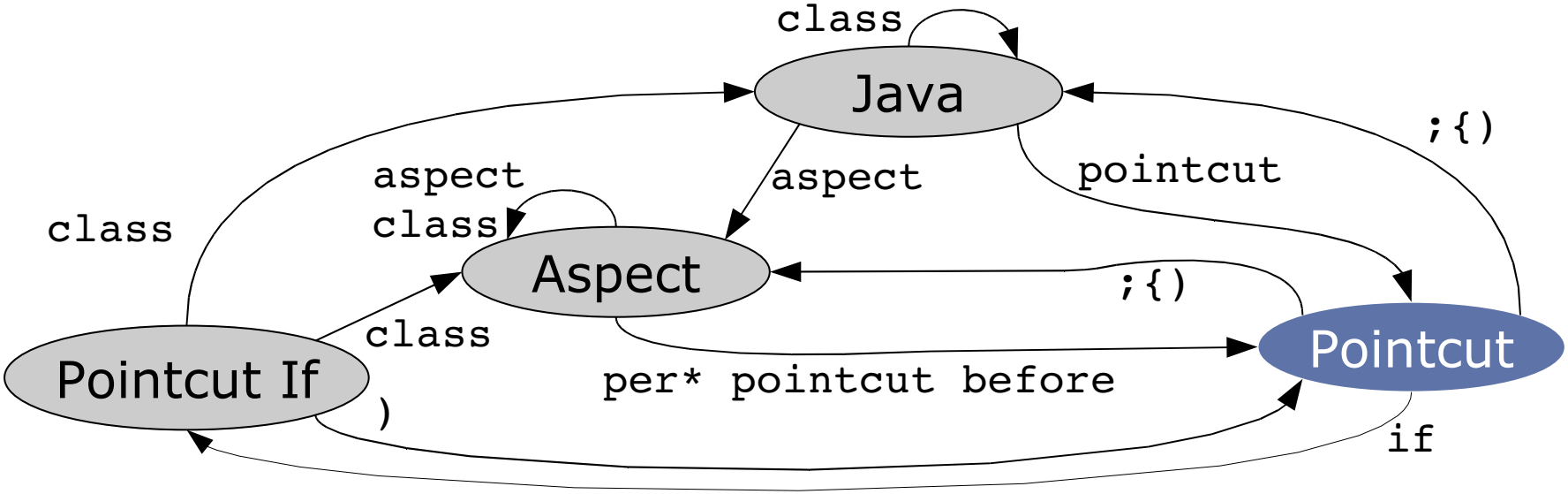

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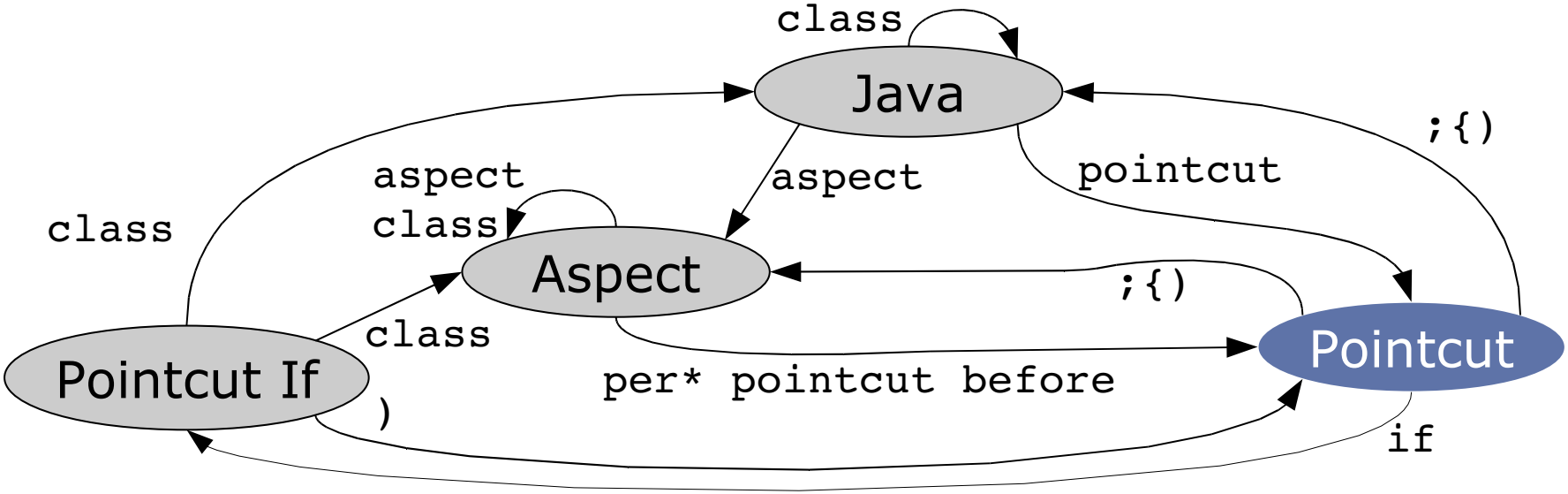

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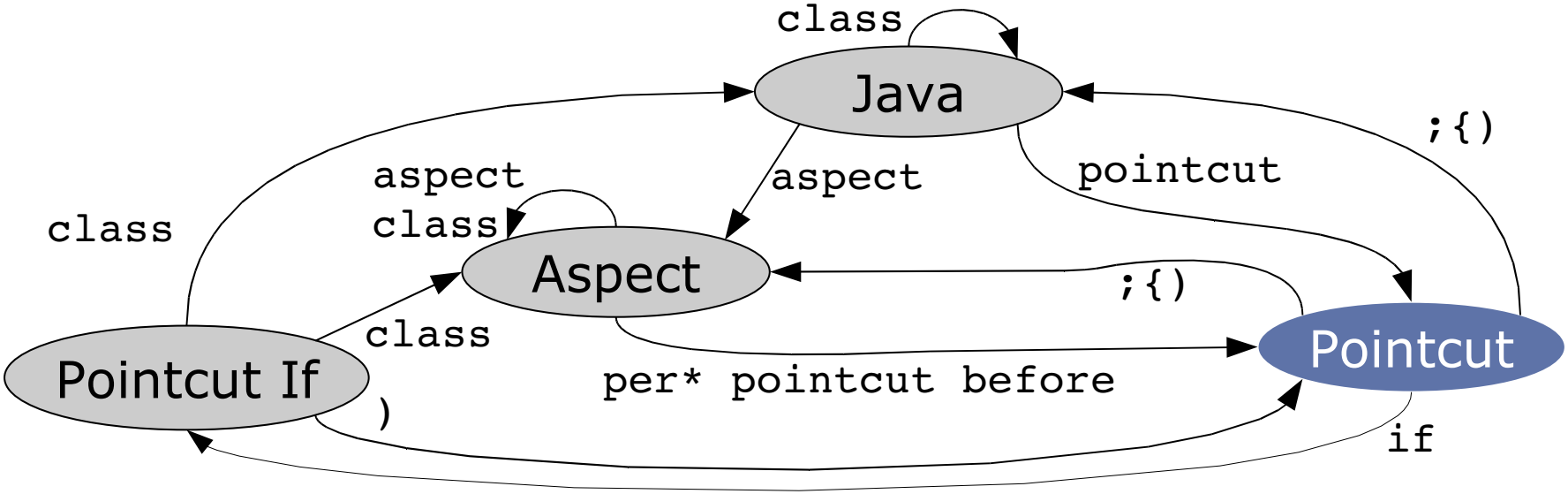

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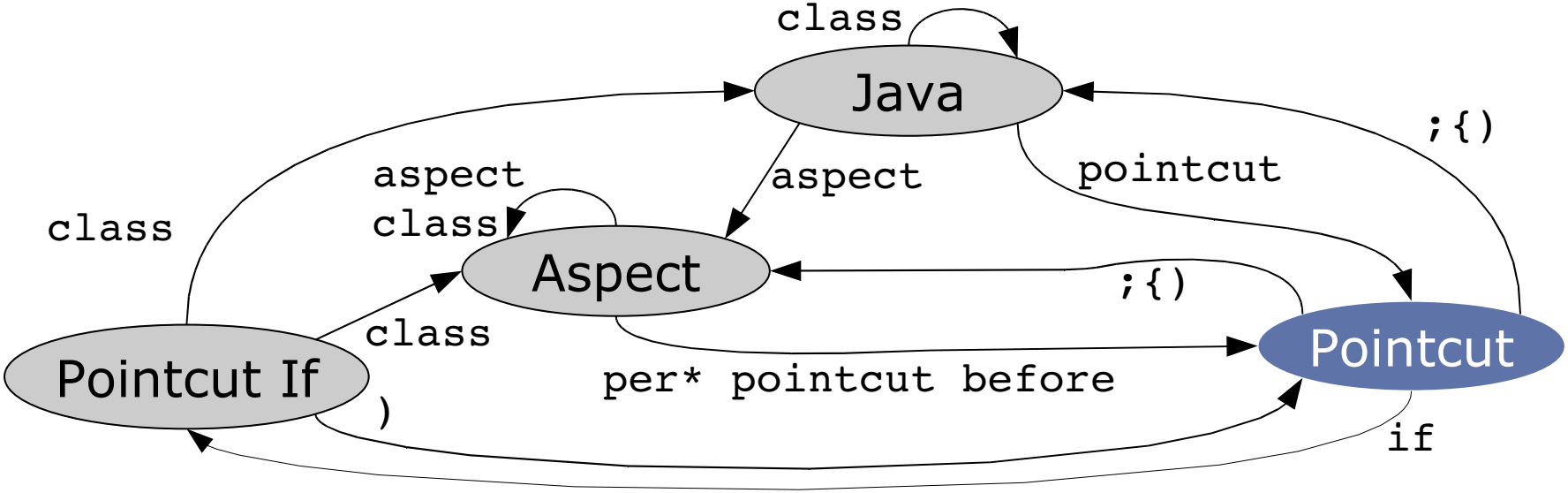

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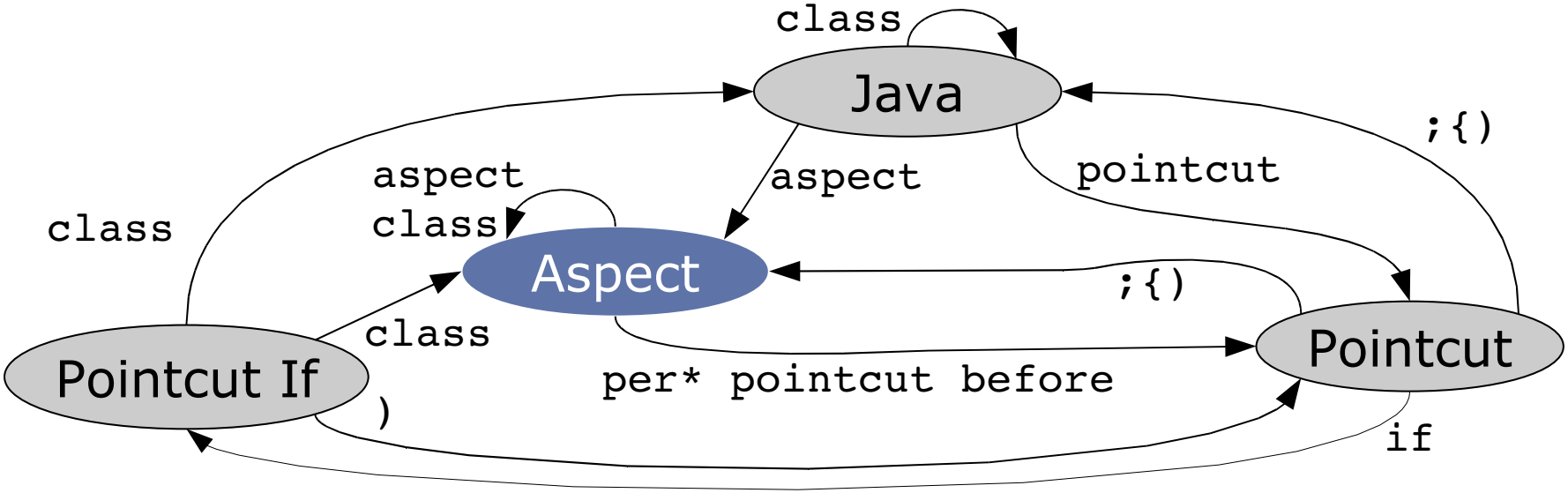

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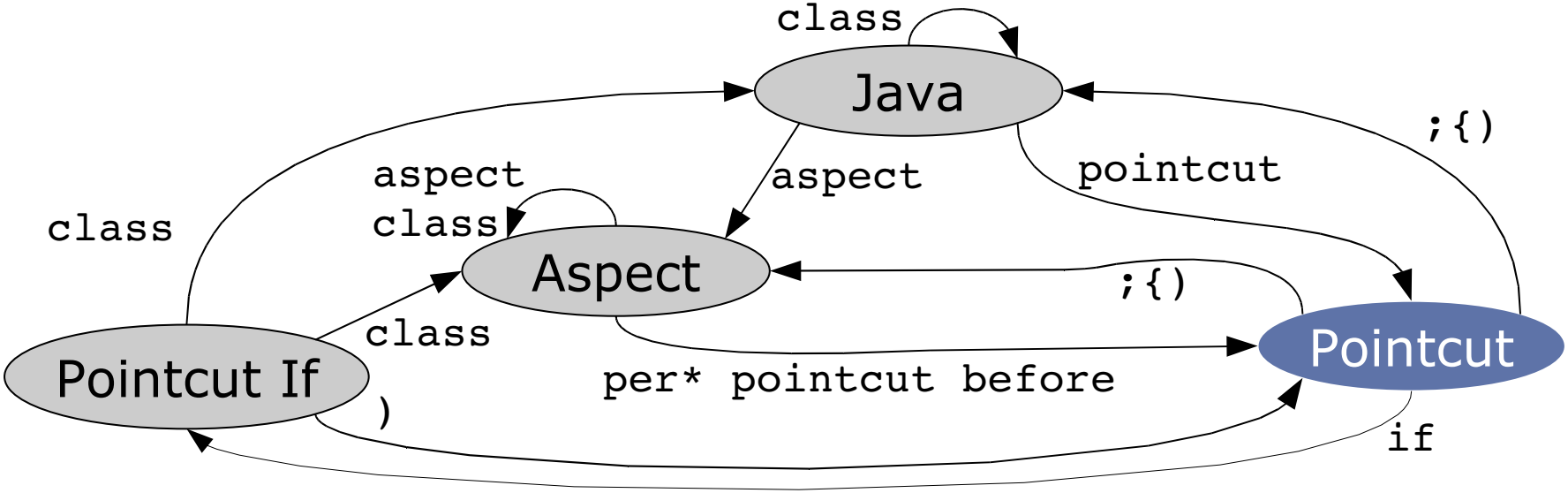

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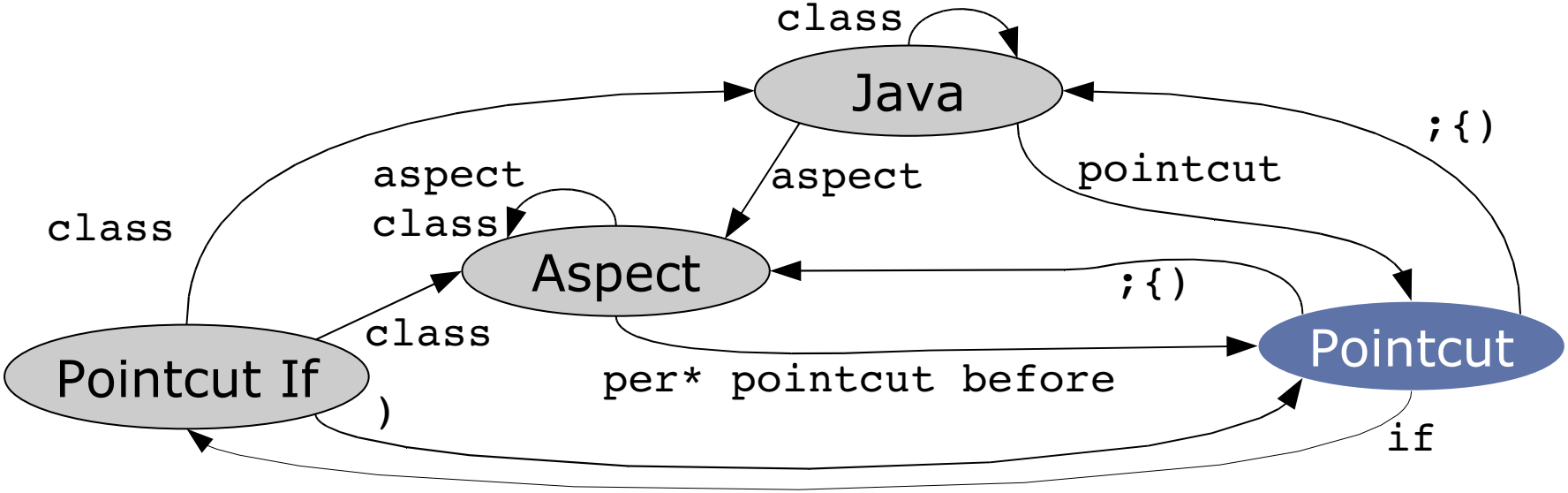

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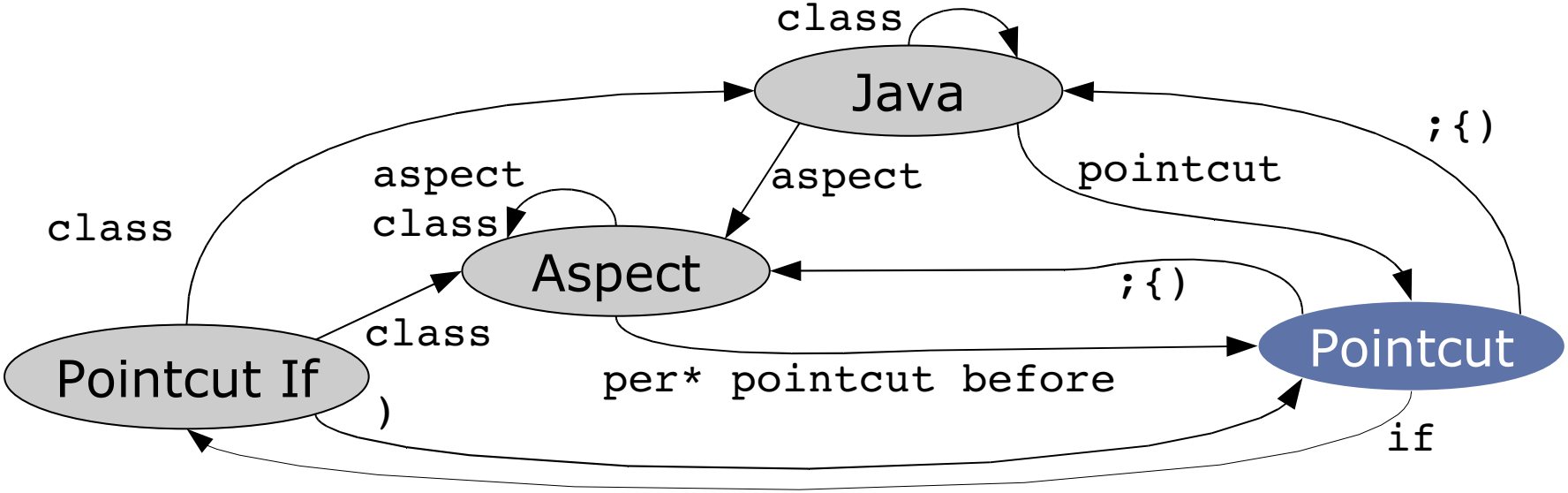

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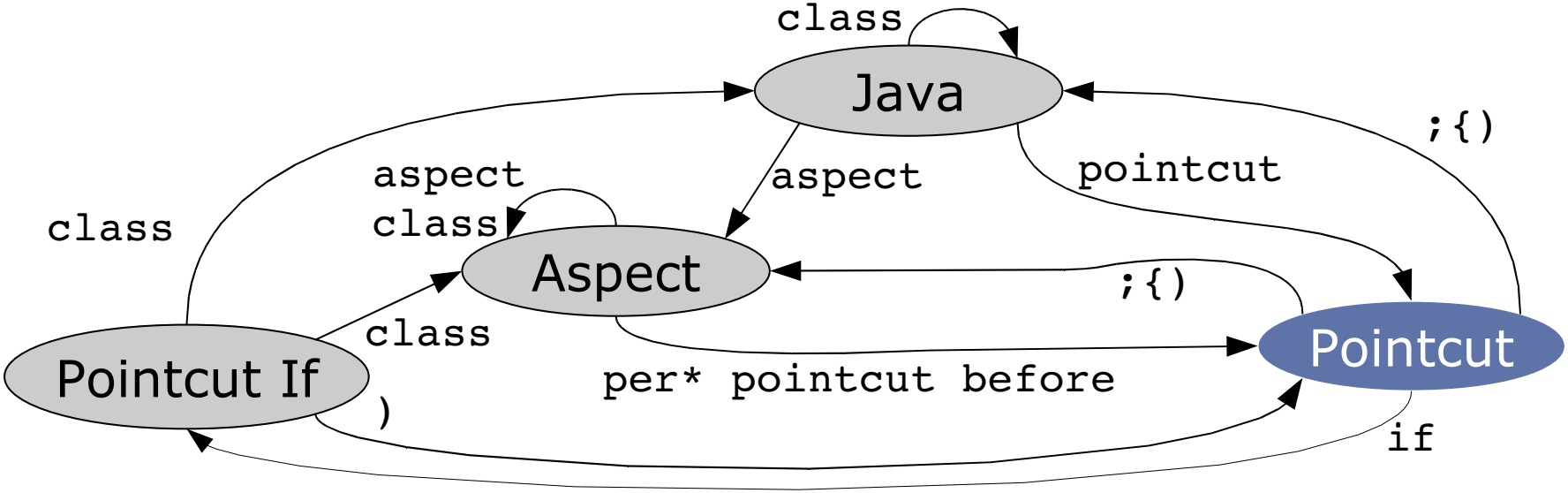

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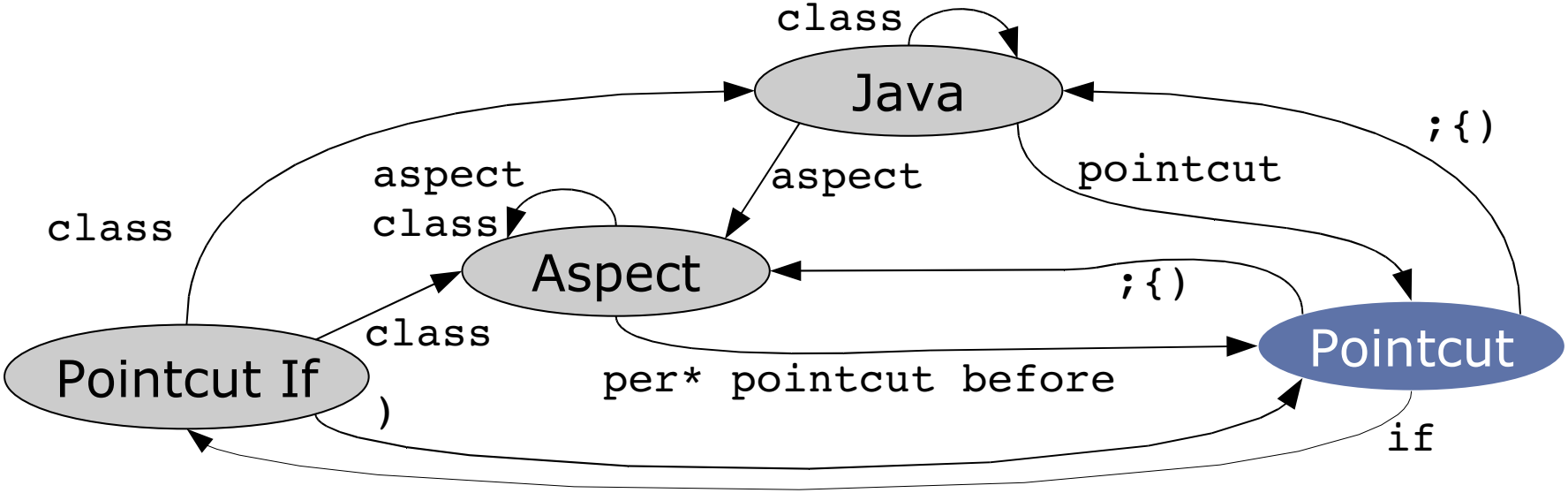

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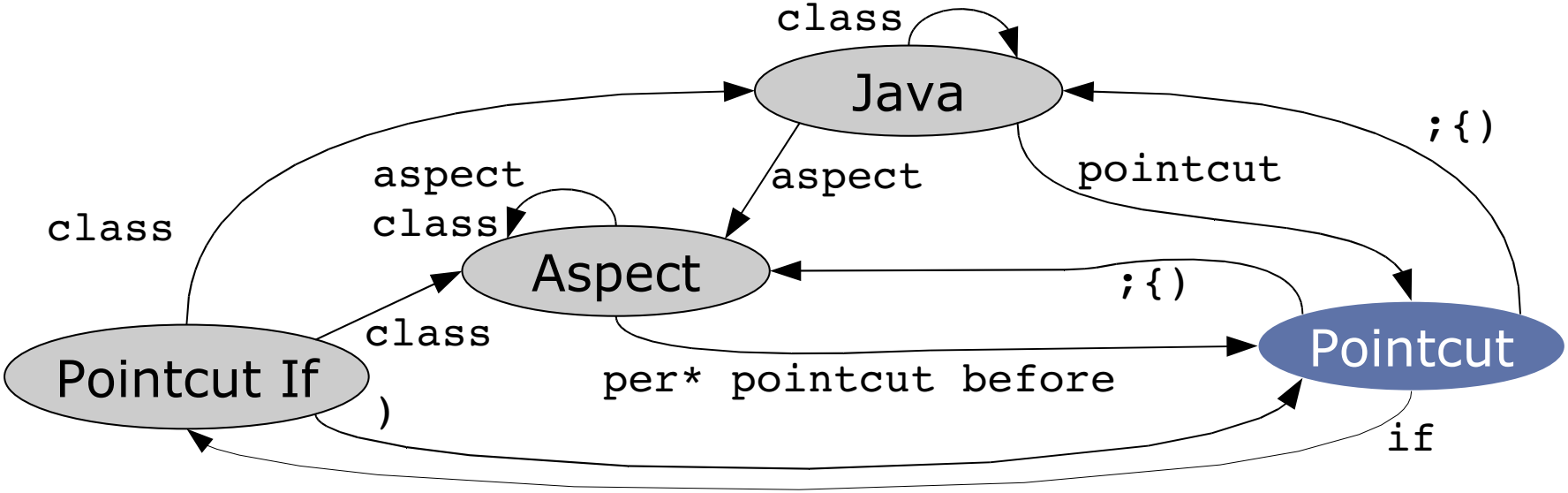

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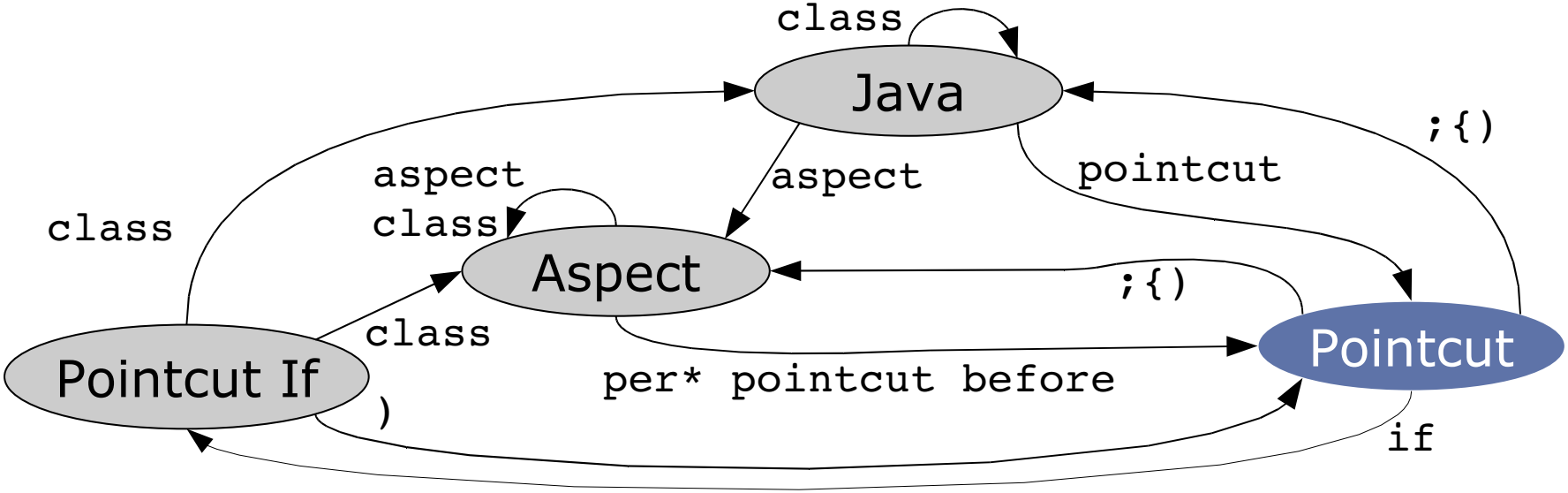

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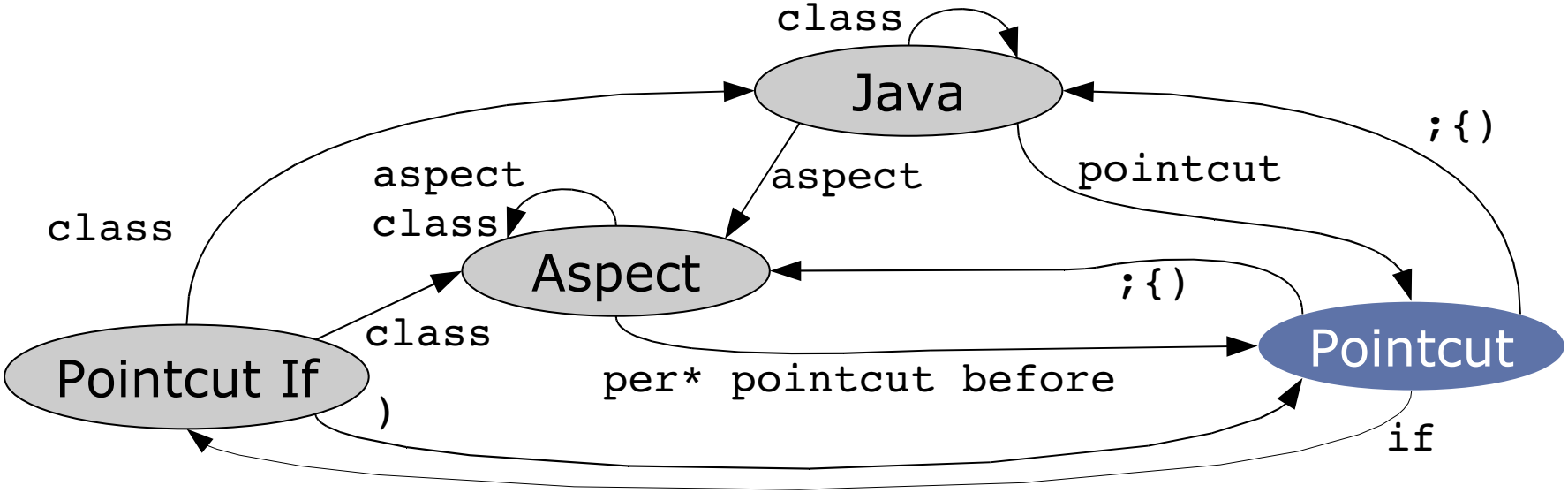

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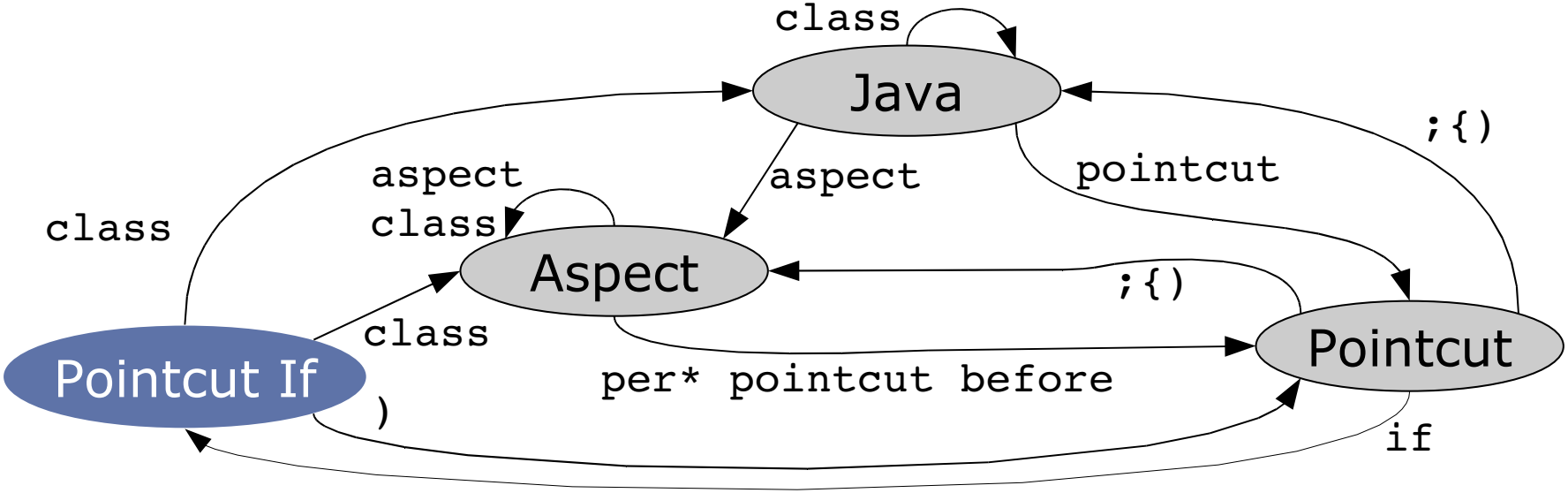

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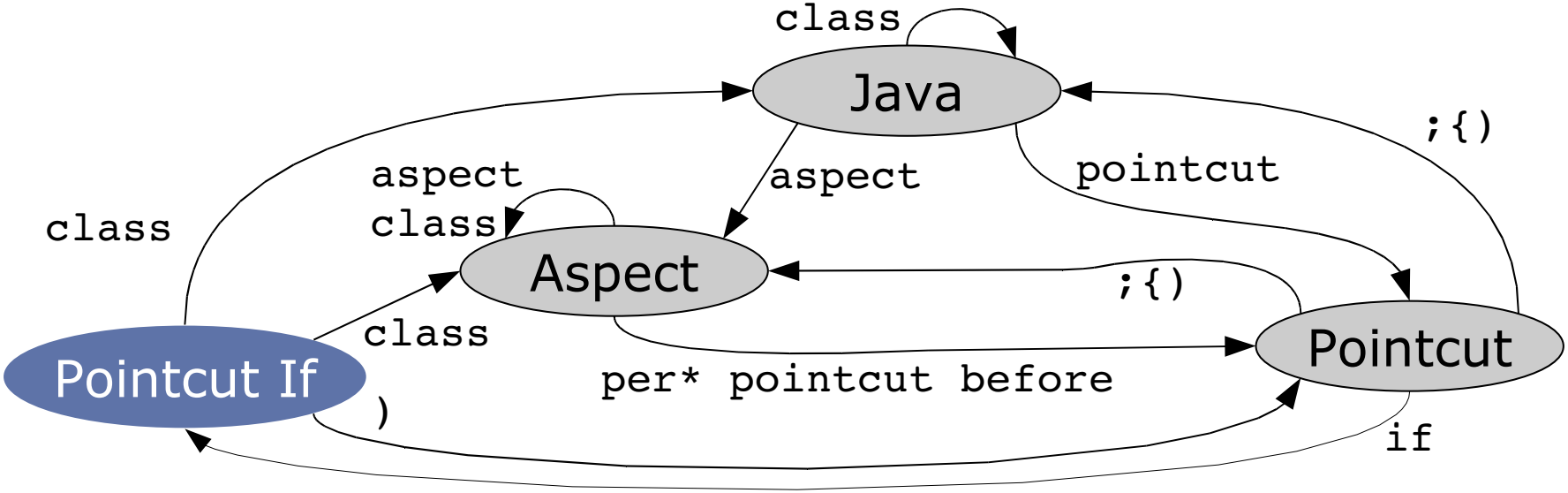

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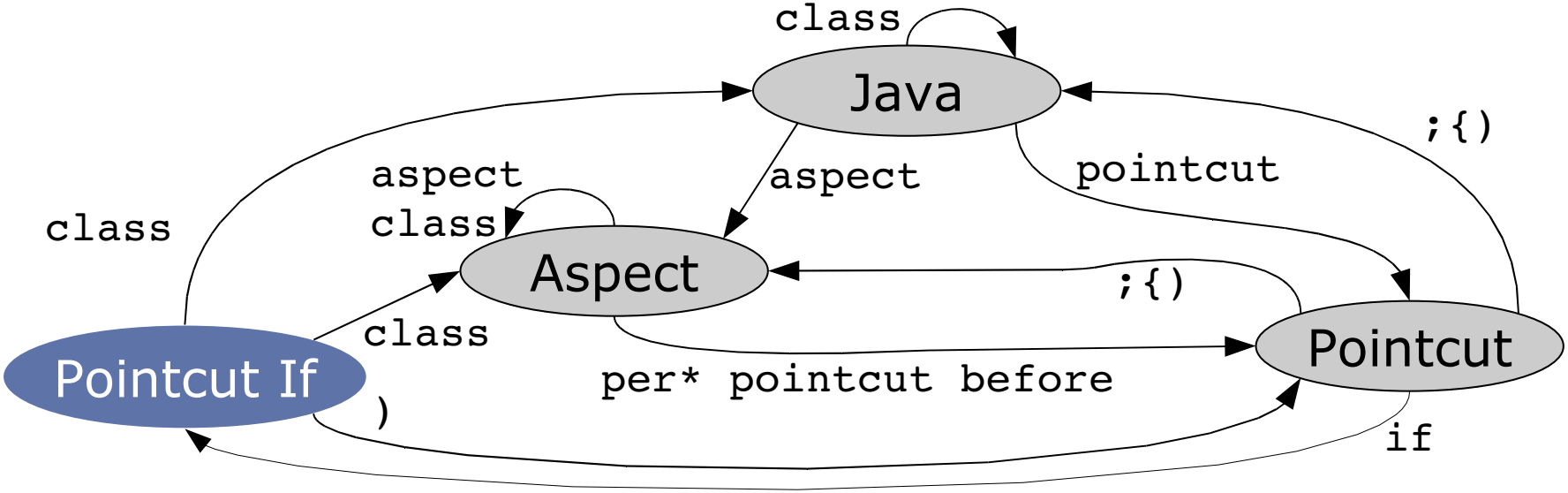

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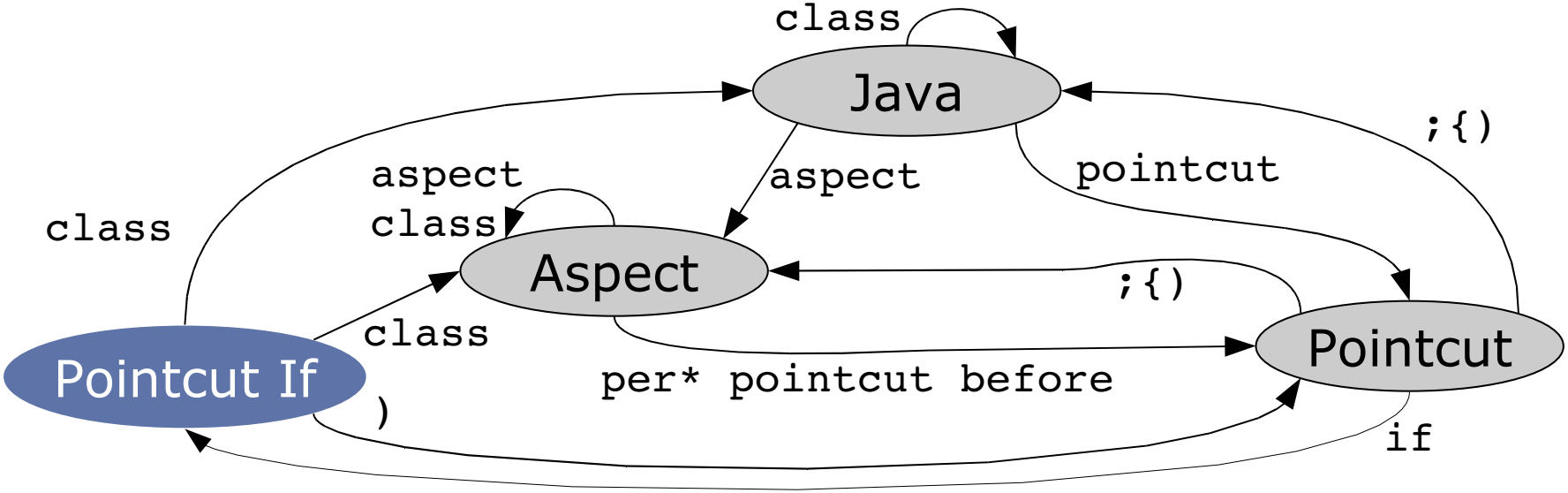

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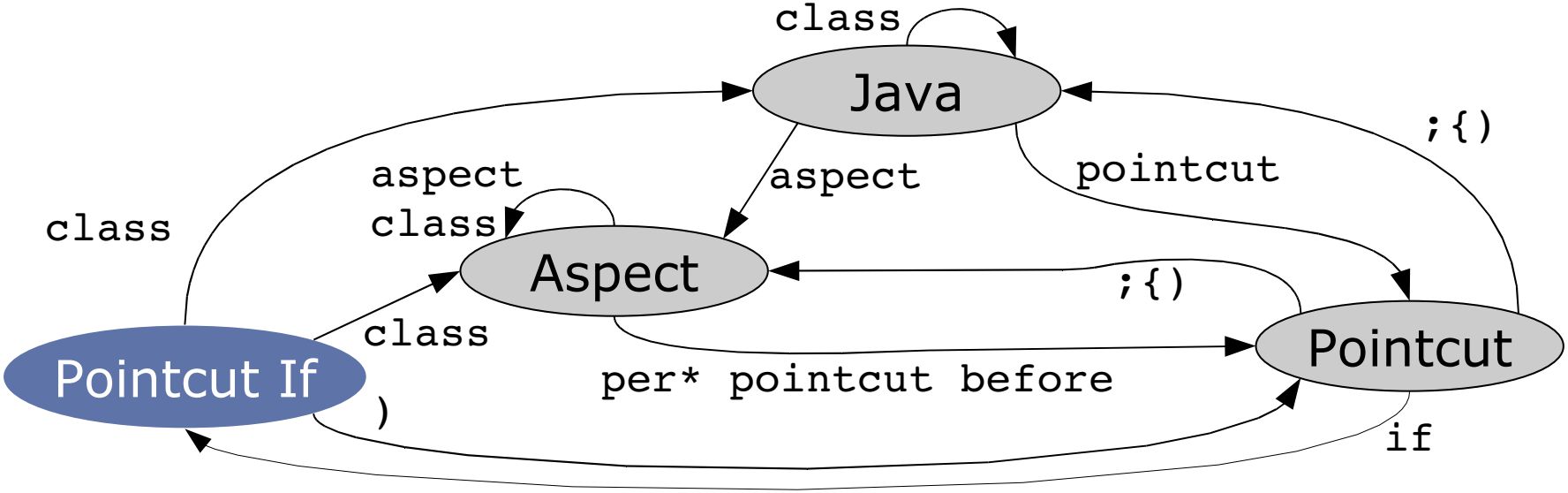

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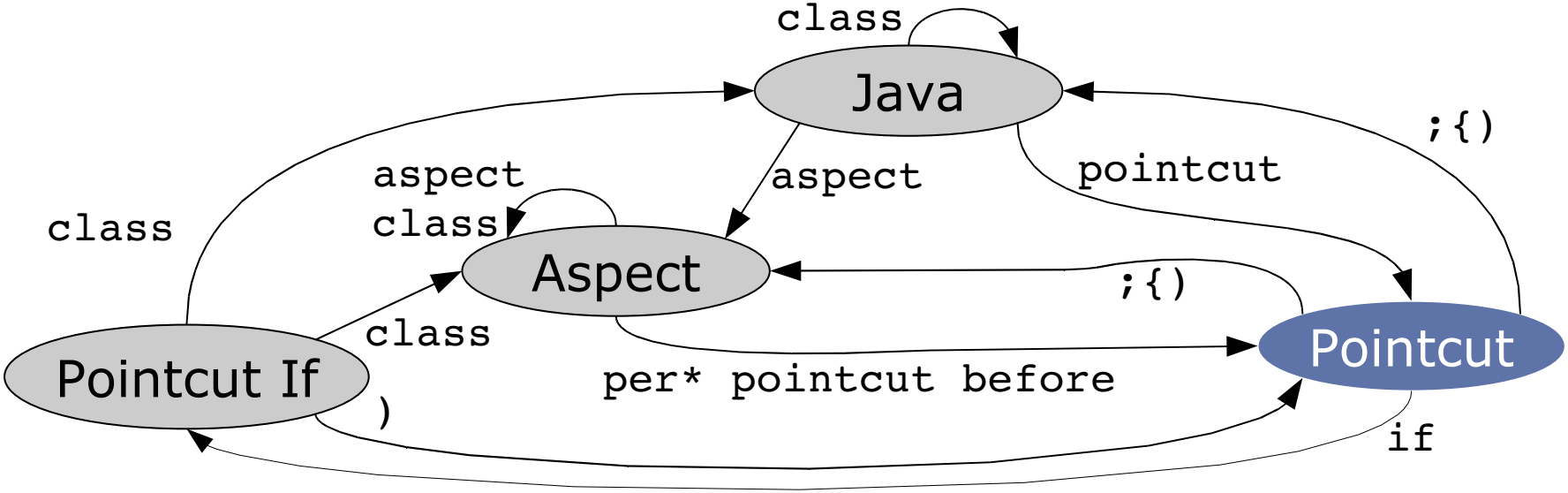

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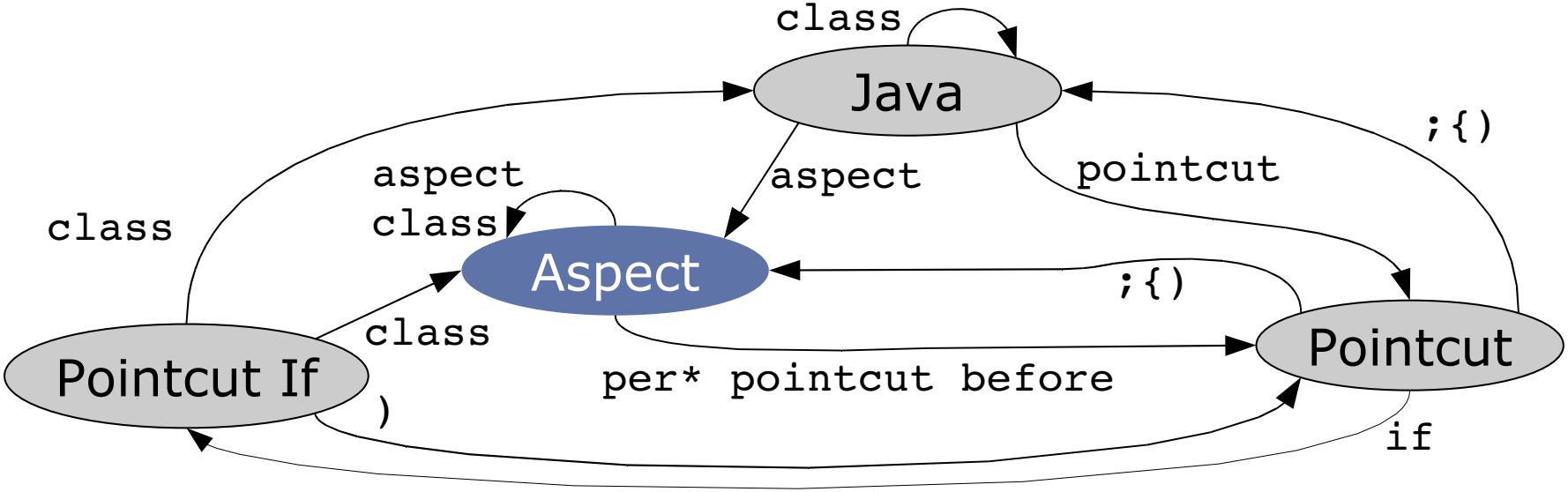

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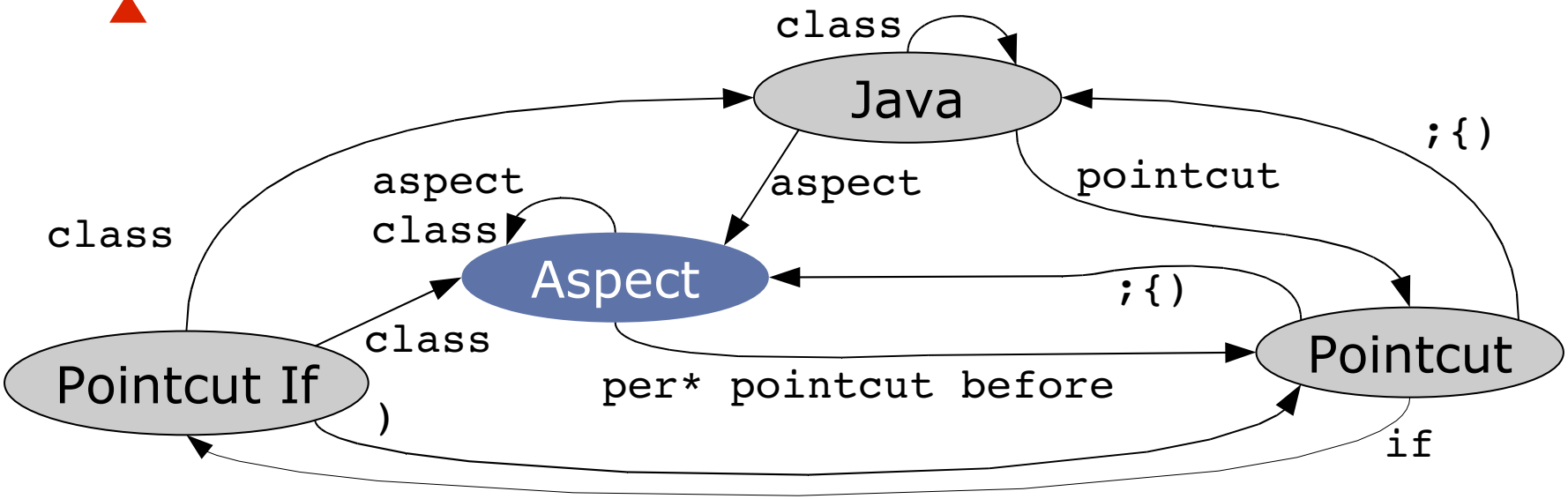

Keywords do not uniquely indicate next state.

- Type declaration: transition to Java or AspectJ

```
public class Foo {}
```

- Class literal: no transition

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Class c = Foo.class;
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Solution

```
lexer.addGlobalKeyword("class",
  new LexerAction_c(new Integer(sym.CLASS)) {
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Managing lexical state in abc: class declarations 6

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Summary of ajc and abc

Approaches

- ajc: multiple parsers, single scanner
- abc: single parser, multiple scanners (stateful)

Issues

- syntax defined operationally in scanner and parser
- no declarative formalization of AspectJ syntax
- various implementation quircks
- correctness of stateful scanner fragile
- context-free parsing in scanner duplicates work
- lexical states influenced by complexity of context-free parsing

Scannerless parsing elegantly deals with these issues

- no separate lexical analysis
- parser operates on individual characters
- scannerless parsing needs generalized-LR parsing

SDF – Syntax Definition Formalism

1. declarative
2. modular
3. context-free and lexical syntax
4. declarative disambiguation
5. all context-free grammars

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pointcut g(): call(* get*(..))
```

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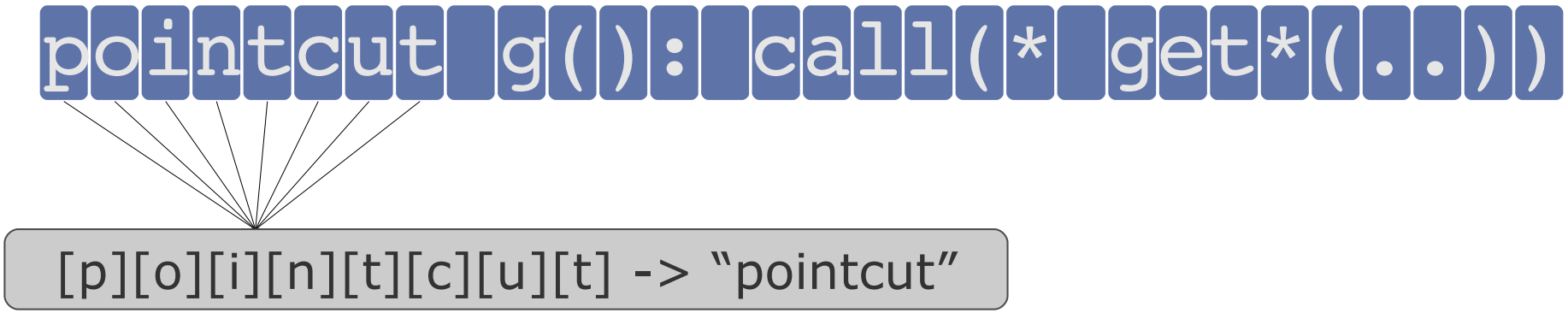
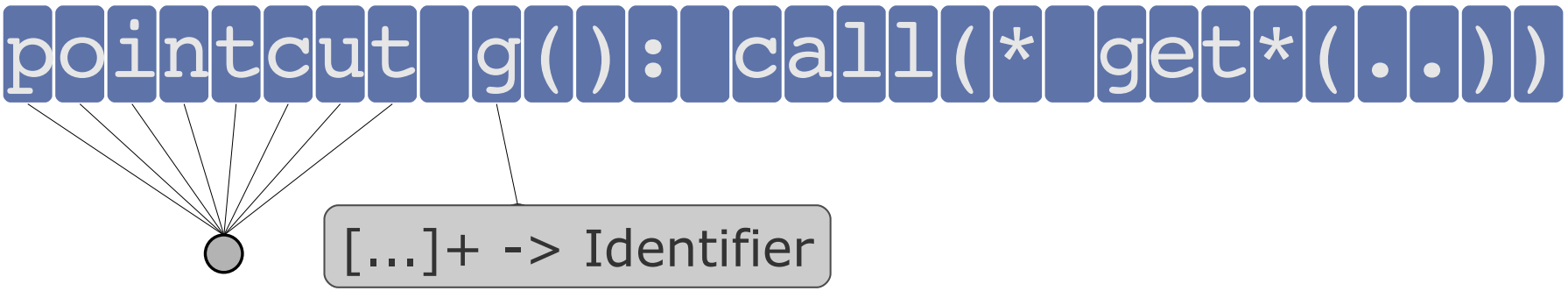
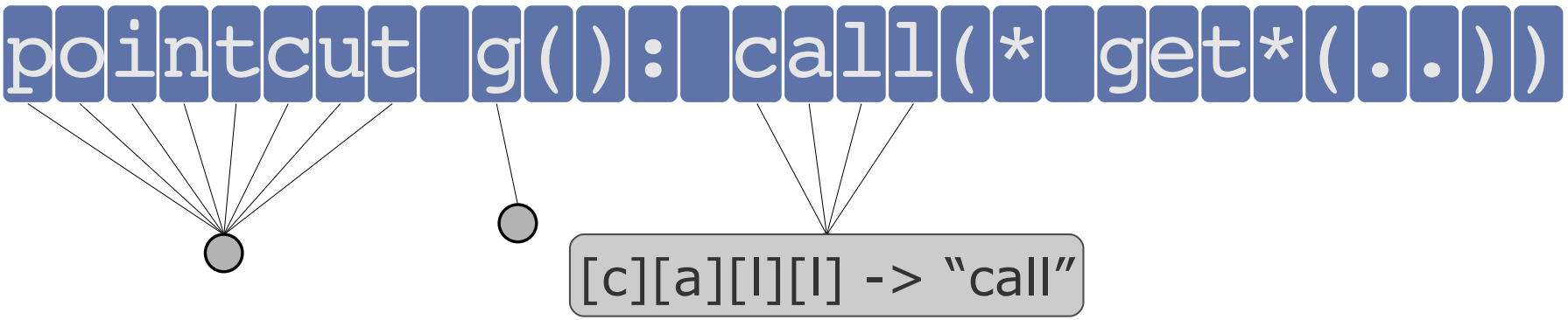
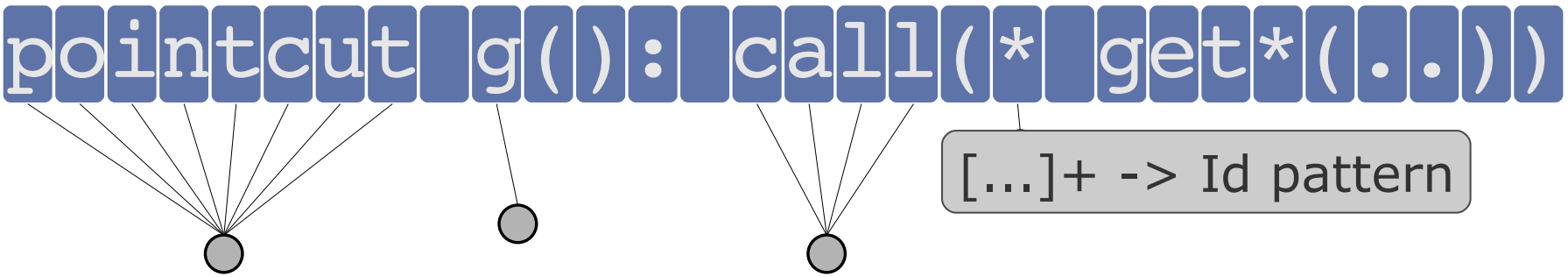

pointcut g(): call(* get*(..))
[p][o][i][n][t][c][u][t] -> “pointcut”


pointcut g(): call(* get*(..))
[...]+ -> Identifier


pointcut g(): call(* get*(..))
[c][a][l][l] -> “call”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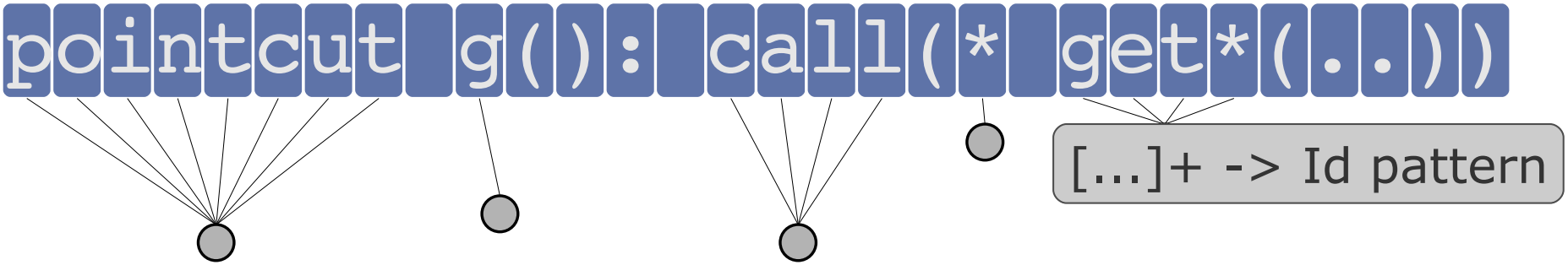
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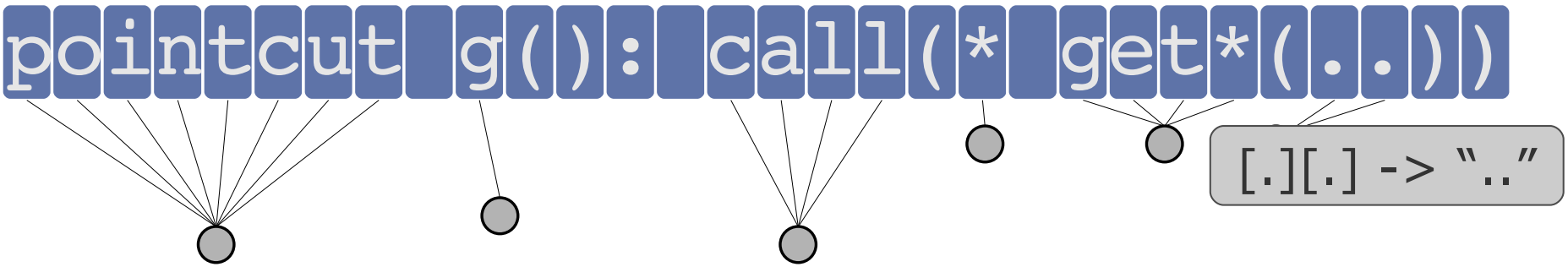
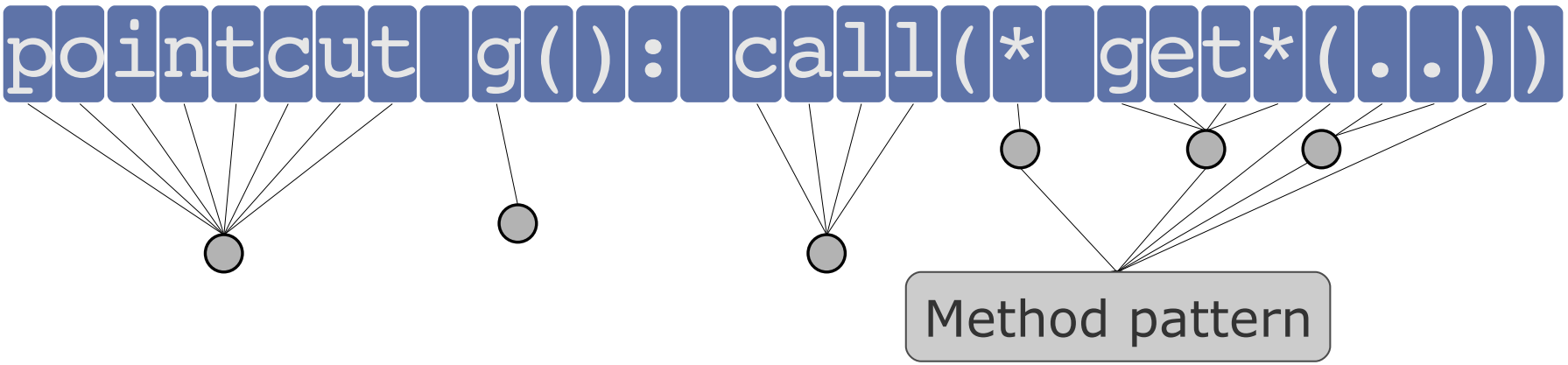
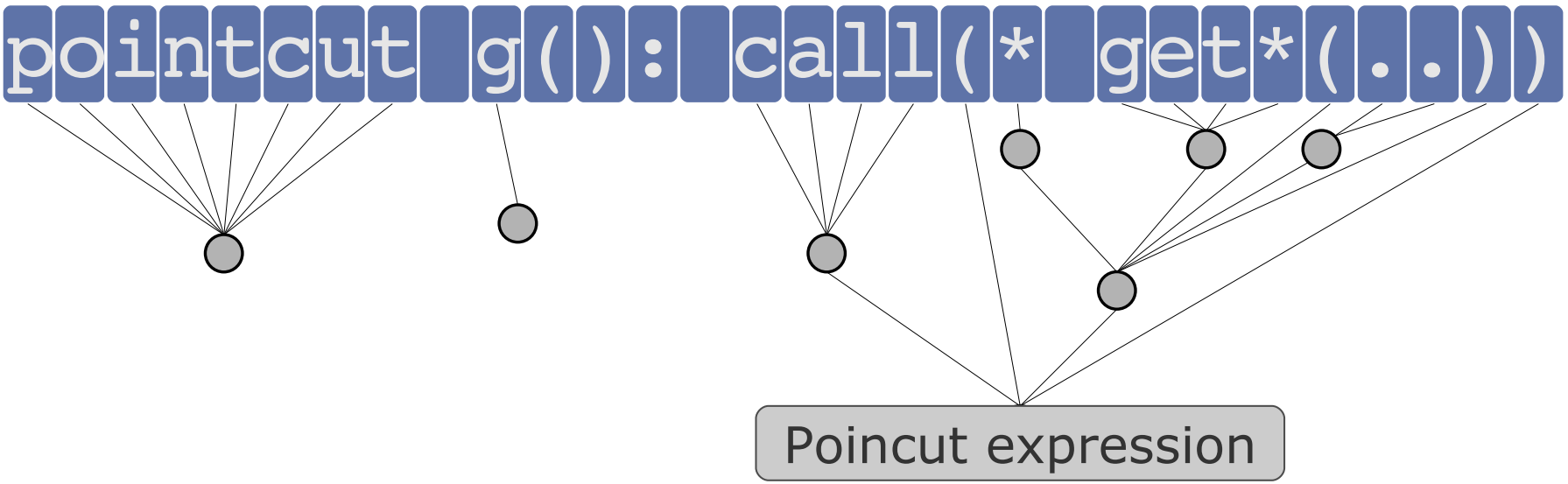

pointcut g(): call(* get*(..))
[.][.] -> ".."


pointcut g(): call(* get*(..))
Method pattern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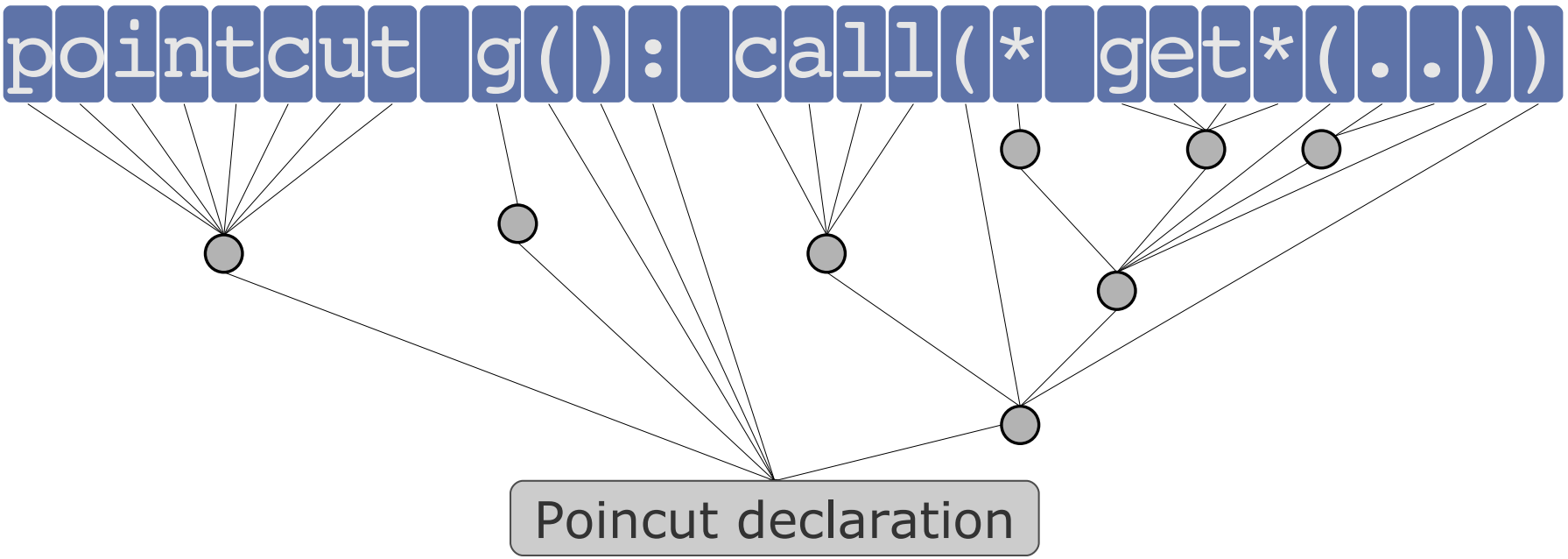
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exports context-free syntax
  PackageDec? ImportDec* TypeDec+ -> CompilationUnit
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  MethodSpec "(" {Expr ","}* ")"    -> Expr
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  AdvMod* AdvSpec Throws? ":" PointcutExpr MethodBody -> AdviceDec
  "before" "(" {Param ","}* ")" -> AdvSpec
  ResultType "around" "(" {Param ","}* ")"  -> AdvSpec
```

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module PointcutExpression exports context-free syntax
  "call"  "(" MethodConstrPattern ")" -> PointcutExpr
  "cflow" "(" PointcutExpr ")"        -> PointcutExpr
  "if"    "(" Expr ")"                -> PointcutExpr
```

```
module Pattern exports
context-free syntax
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- compose the involved languages

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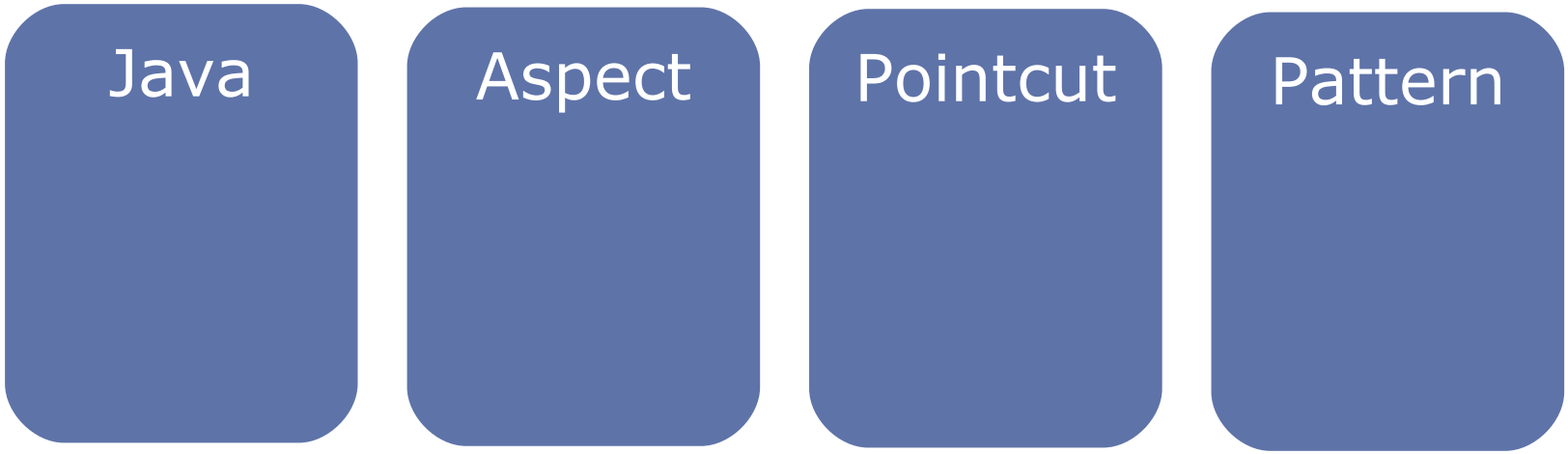
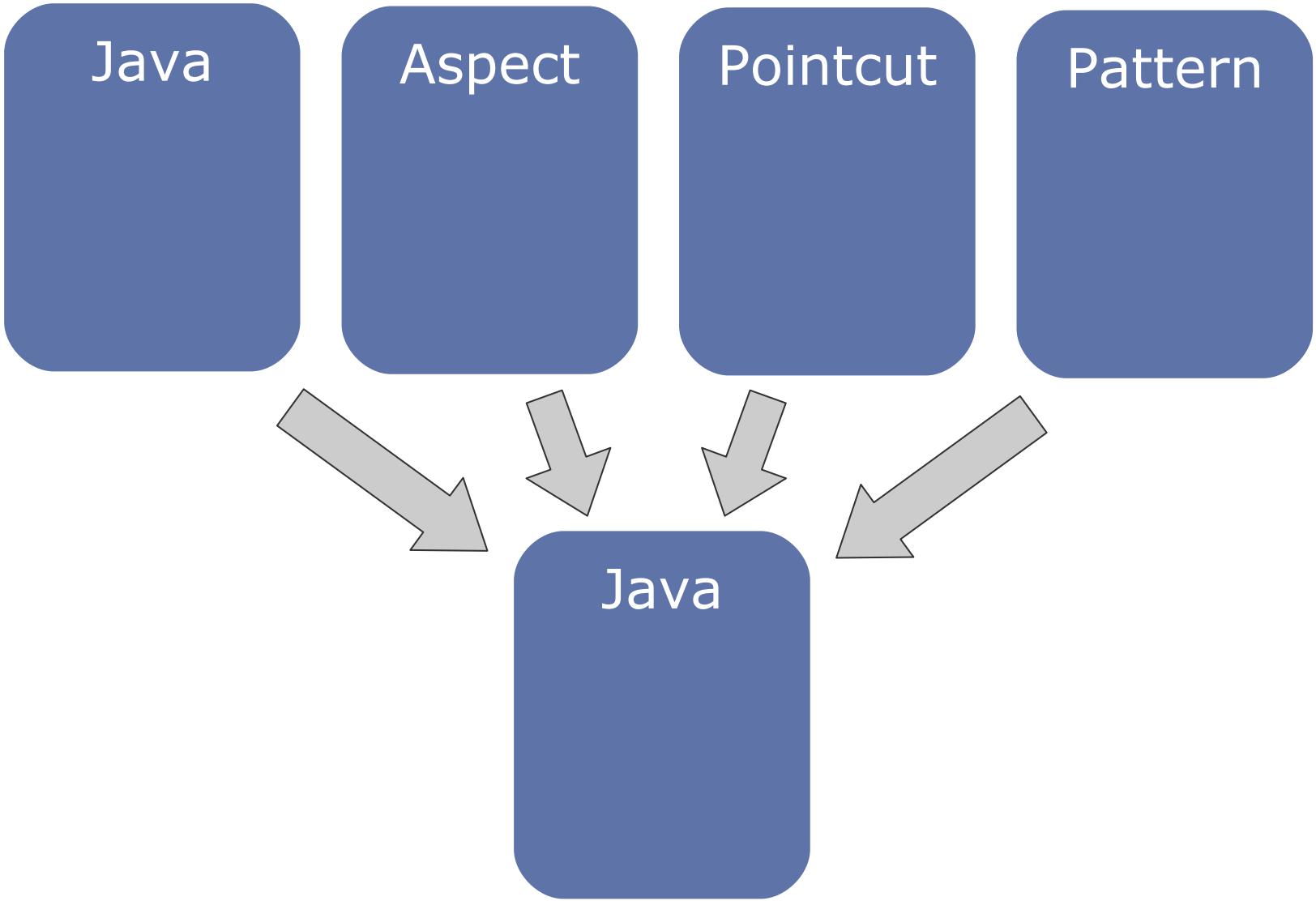
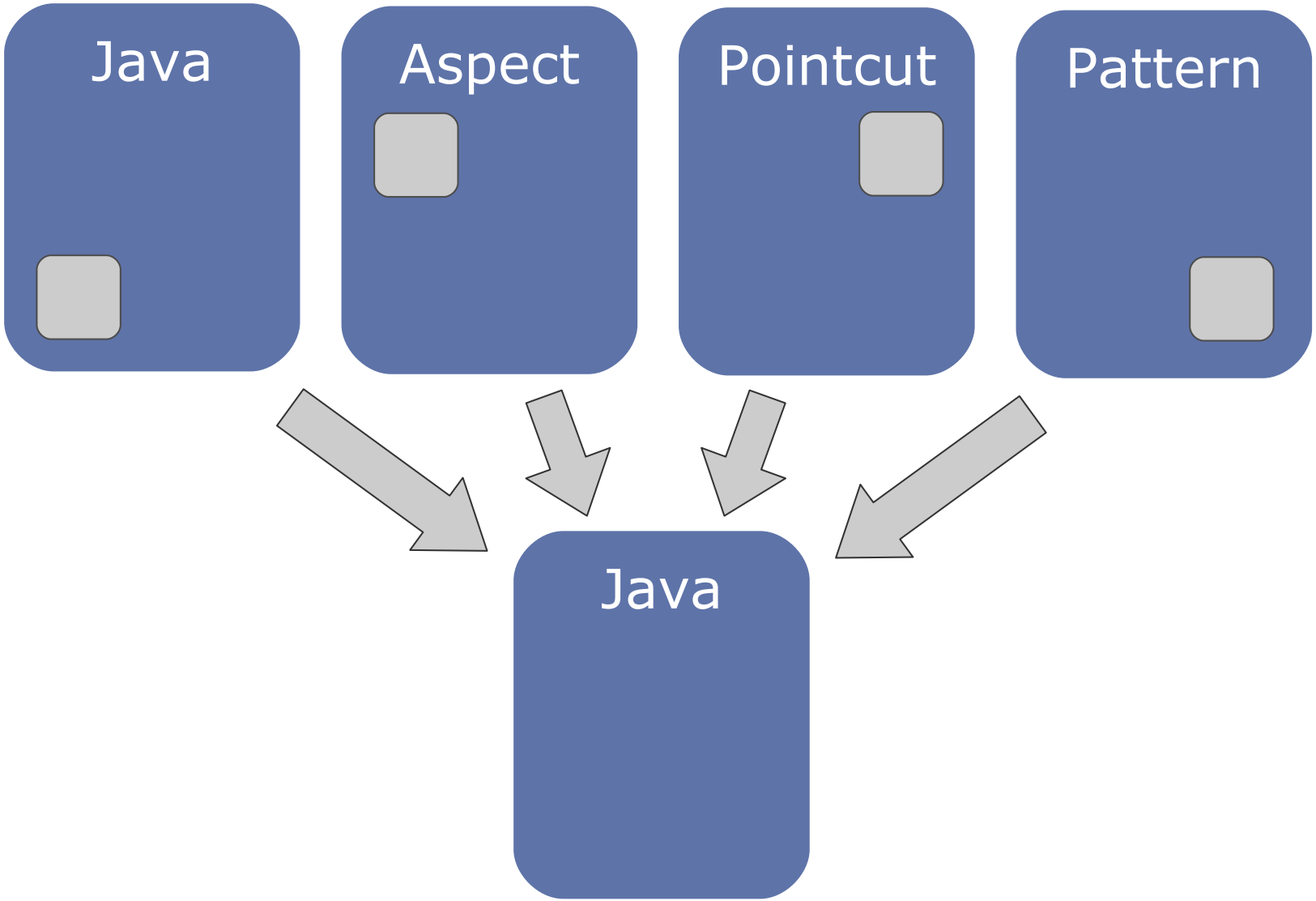

Java
Aspect
Pointcut
Pattern


Java
Aspect
Pointcut
Pattern
Java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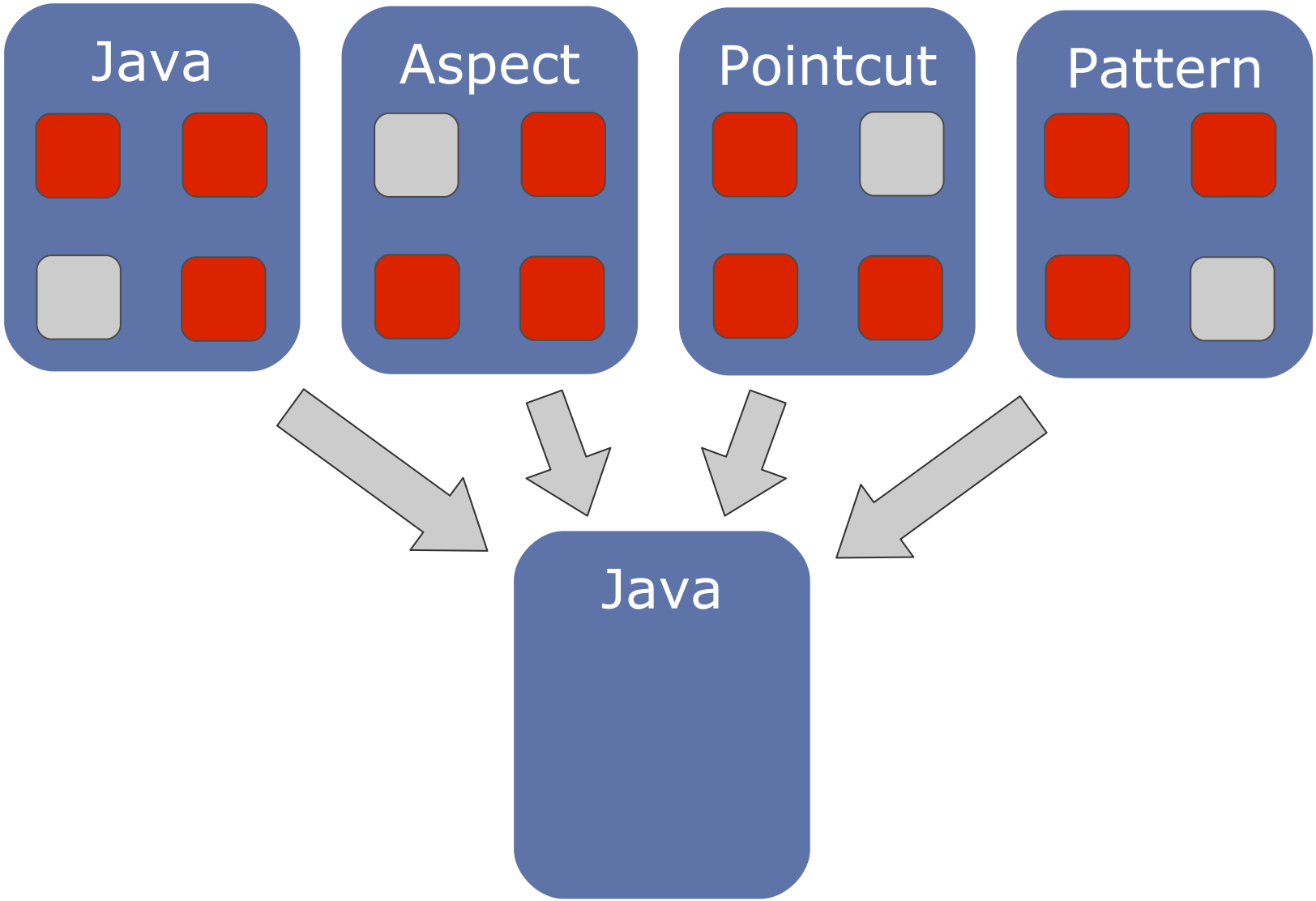
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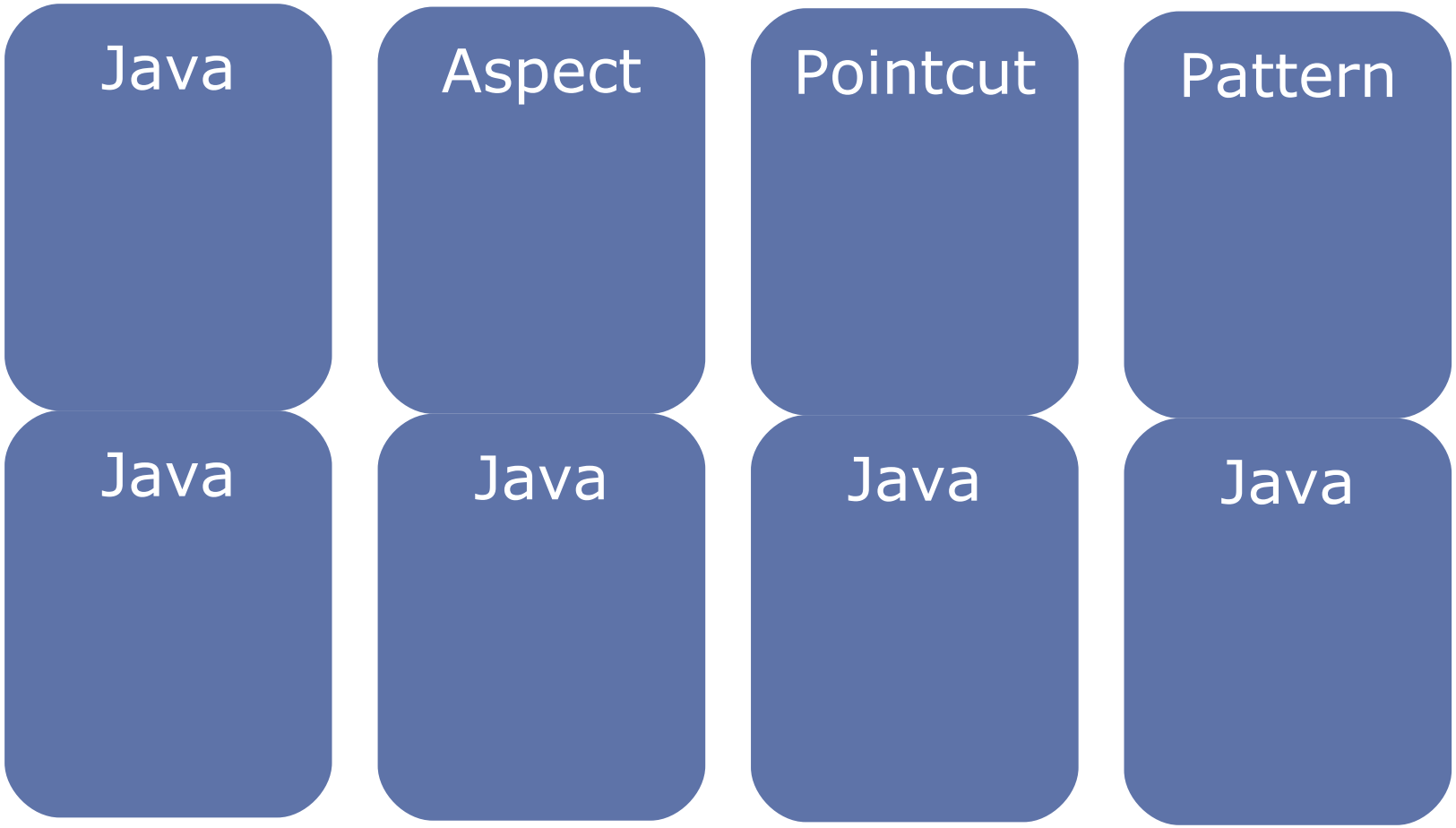
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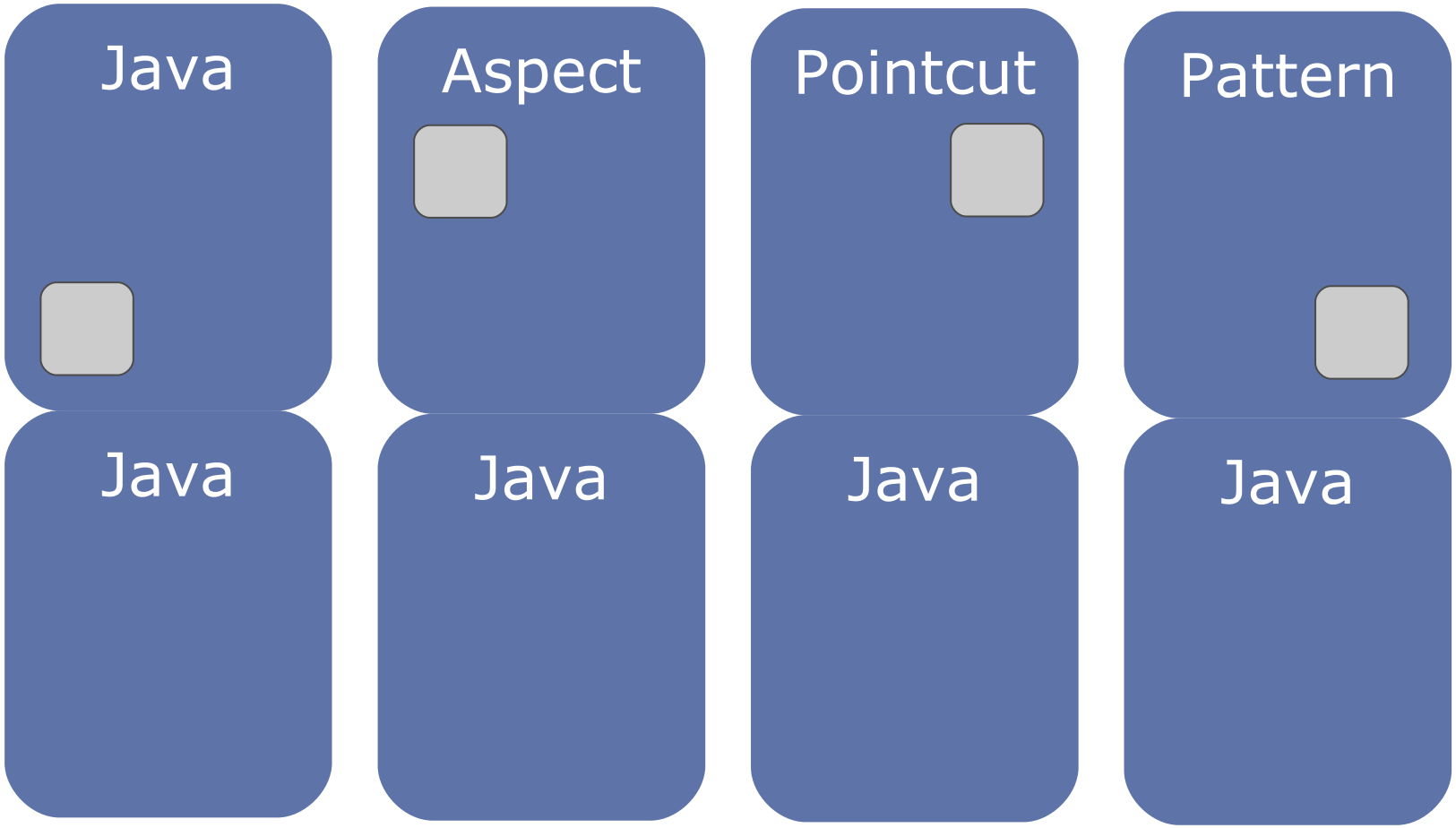
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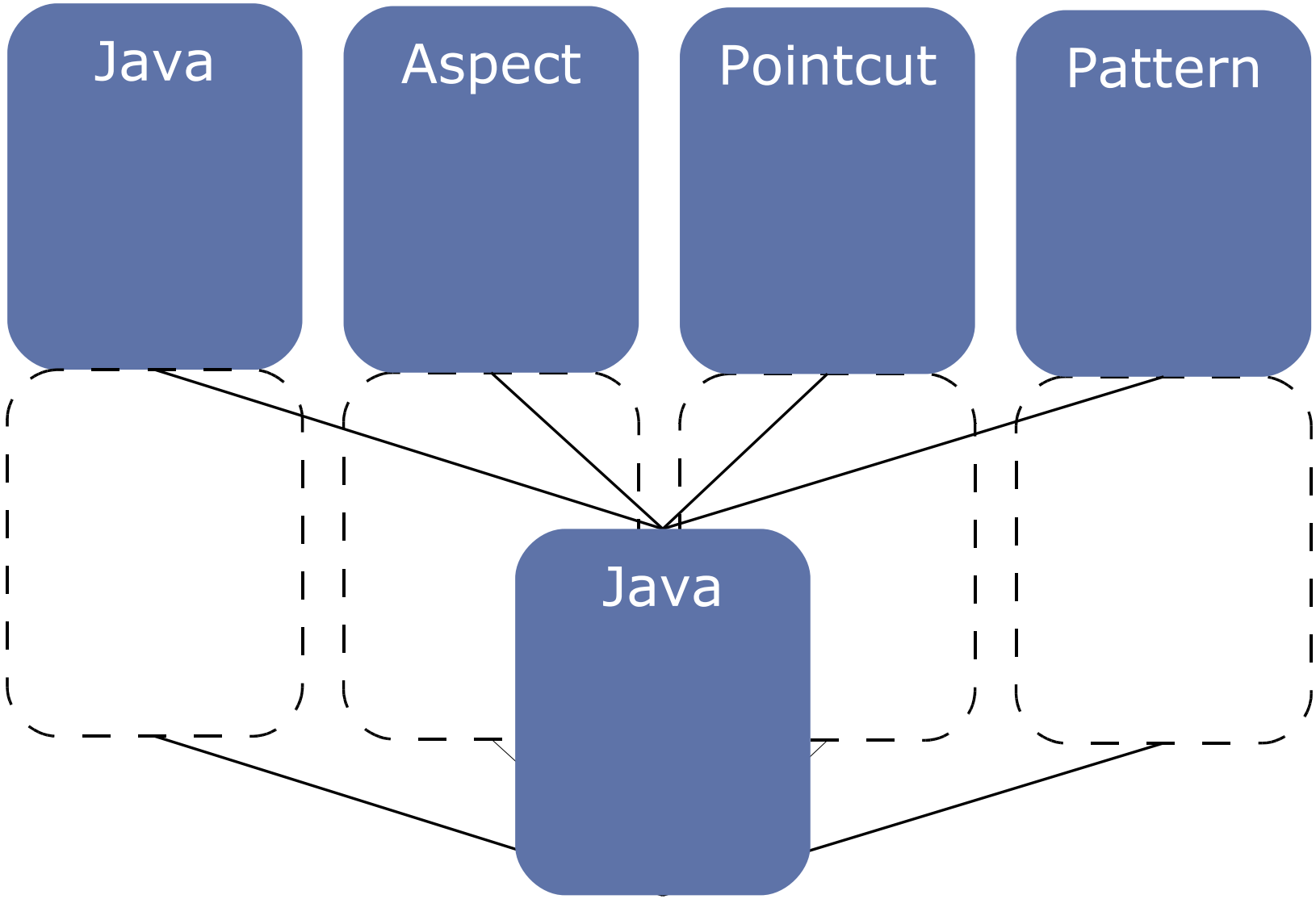
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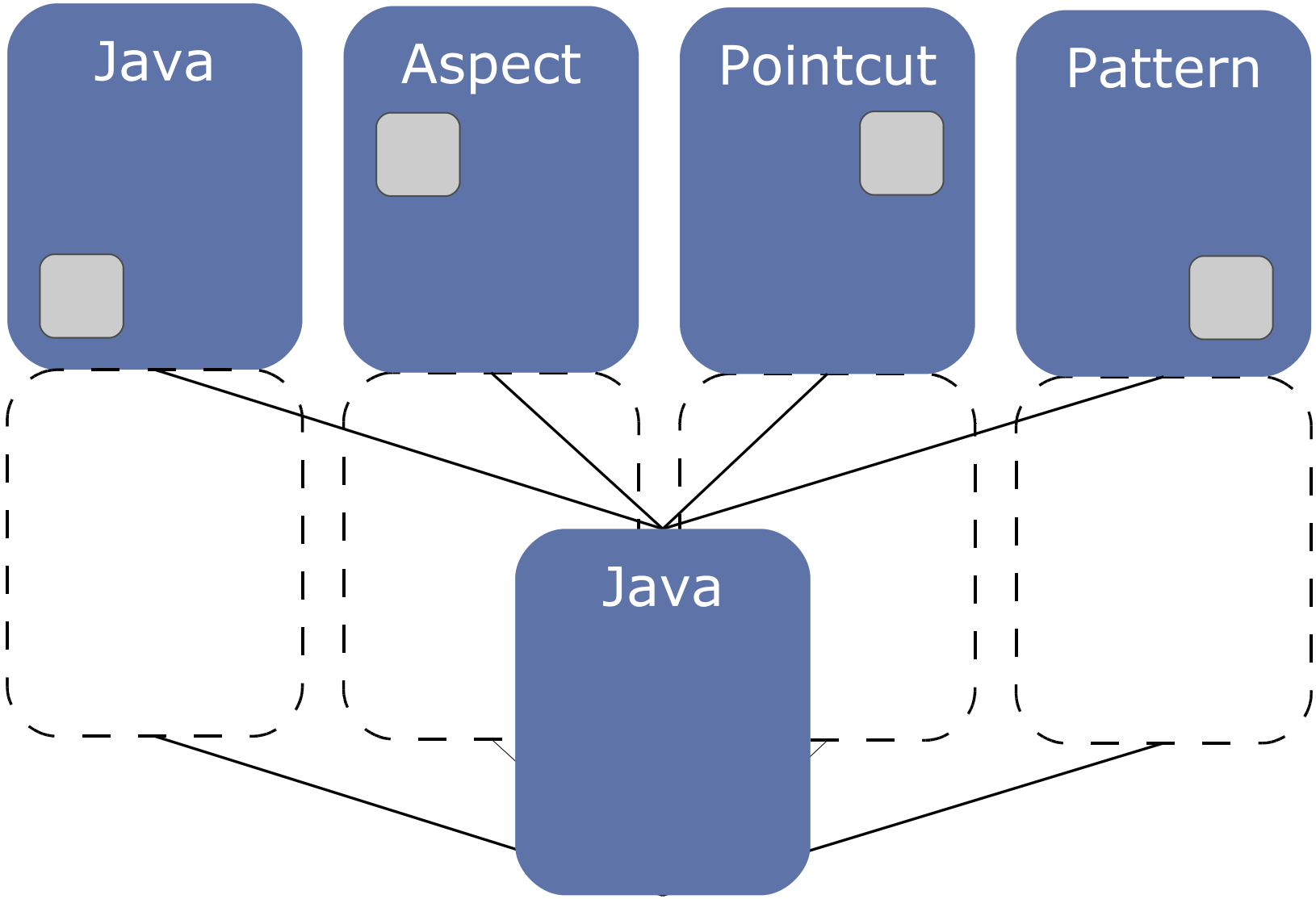
Java
Aspect
Pointcut
Pattern
Java

some production rules using grammar mixins

```
AspectDec                      -> TypeDec⟦JavaCtx⟧
ClassBodyDec⟦AspectCtx⟧ -> AspectBodyDec
AspectDec                      -> ClassMemberDec⟦JavaCtx⟧
PointcutDec                    -> ClassMemberDec⟦JavaCtx⟧

"before" "(" {Param⟦AspectCtx⟧ ","}* ")" -> AdvSpec
"if" "(" Expr⟦JavaCtx⟧ ")" -> PointcutExpr
PrimType⟦PatternCtx⟧       -> TypePattern
```

abc's context-specific keywords

```
"privileged" | "aspect" | "pointcut" -> Keyword⟦JavaCtx⟧
"after" | ... | "proceed" -> Keyword⟦AspectCtx⟧
"error" | ... | "warning" -> Keyword⟦PointcutCtx⟧
PrimPointcutName           -> Keyword⟦PointcutCtx⟧
```

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"error" | ... | "warning" -> Keyword[[PointcutCtx]]
PrimPointcutName           -> Keyword[[PointcutCtx]]
```

The AspectJ syntax definition itself can be extended as well.

```
module HelloWorld[JavaCtx AspectCtx PointcutCtx]
exports context-free syntax
  "cast" "(" TypePattern ")" -> PointcutExpr

  "global" ":" ClassNamePattern ":"
                      PointcutExpr ";" -> PointcutDec

  "cflowlevel" "(" IntLiteral[[JavaCtx]] ","
                      PointcutExpr ")" -> PointcutExpr
lexical syntax
  "cast"       -> Keyword[[PointcutCtx]]
  "cflowlevel" -> Keyword[[PointcutCtx]]
  "global"     -> Keyword[[JavaCtx]]
  "global"     -> Keyword[[AspectCtx]]
```

AspectJ syntax definition

- formal
- extensible
- declarative

Enablers

- scannerless generalized-LR parsing
- modular syntax definition
- grammar mixins

Generalizing

- more languages are mixtures of various sublanguages
- challenging for specification and implementation
- strong motivation for addressing barriers to wider adaption

```
context-free syntax
  PseudoKeyword -> TypeName[[JavaCtx]]              {reject}
  PseudoKeyword -> PackageOrTypeName[[JavaCtx]]     {reject}
  PseudoKeyword -> TypeName[[AspectCtx]]            {reject}
  PseudoKeyword -> PackageOrTypeName[[AspectCtx]]   {reject}
lexical syntax
    "aspect" | "pointcut" | "privileged" | "before"
    | "after" | "around" | "declare" -> PseudoKeyword
```

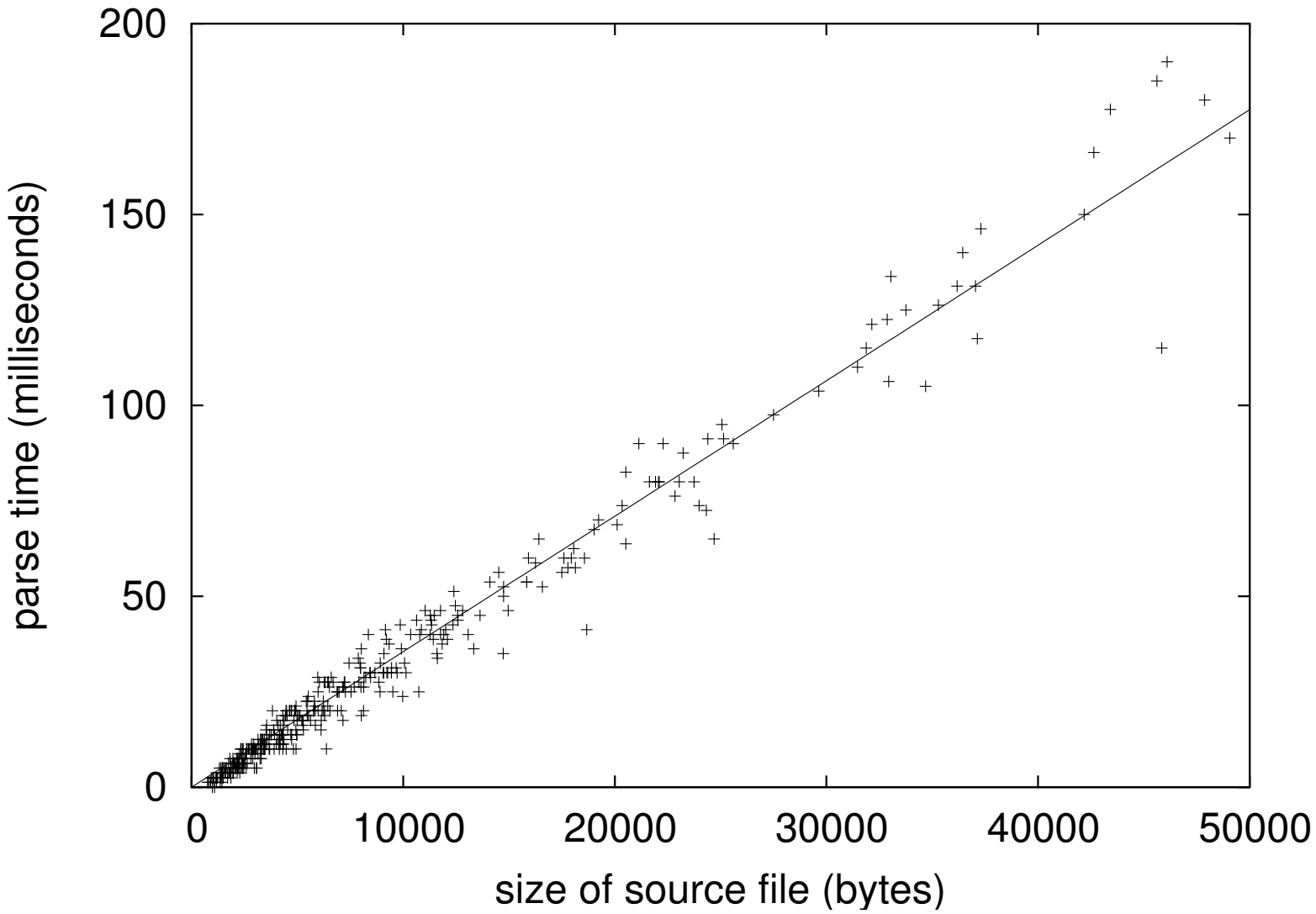
```
lexical syntax
  "privileged" | "aspect" | "pointcut" -> Keyword[[JavaCtx]]
```

```
TypeArgs ::= '<' TypeArgList1
TypeArgList  -> TypeArg
TypeArgList  ::= TypeArgList ',' TypeArg
TypeArgList1 -> TypeArg1
TypeArgList1 ::= TypeArgList ',' TypeArg1
TypeArgList2 -> TypeArg2
TypeArgList2 ::= TypeArgList ',' TypeArg2
TypeArgList3 -> TypeArg3
TypeArgList3 ::= TypeArgList ',' TypeArg3
TypeArg  ::= RefType
TypeArg1 -> RefType1
TypeArg2 -> RefType2
TypeArg3 -> RefType3
RefType1 ::= RefType '>'
RefType1 ::= ClassOrInterface '<' TypeArgList2
RefType2 ::= RefType '>>'
RefType2 ::= ClassOrInterface '<' TypeArgList3
RefType3 ::= RefType '>>>'
```

```
module JavaMix[Ctx]
imports Java
  [ CompilationUnit => CompilationUnit⟦Ctx⟧
    TypeDec         => TypeDec⟦Ctx⟧
    ...
    FieldAccess     => FieldAccess⟦Ctx⟧
    MethodSpec      => MethodSpec⟦Ctx⟧
    Expr            => Expr⟦Ctx⟧  ]
```

```
module AspectJ[JavaCtx AspectCtx PointcutCtx PatternCtx]
imports
  JavaMix[JavaCtx]
  JavaMix[AspectCtx]
  JavaMix[PointcutCtx]
  JavaMix[PatternCtx]
  aspect/Declaration[AspectCtx JavaCtx]
  pattern/Main[PatternCtx]
  pointcut/Expression[PointcutCtx JavaCtx]
```

Performance: Java Benchmark



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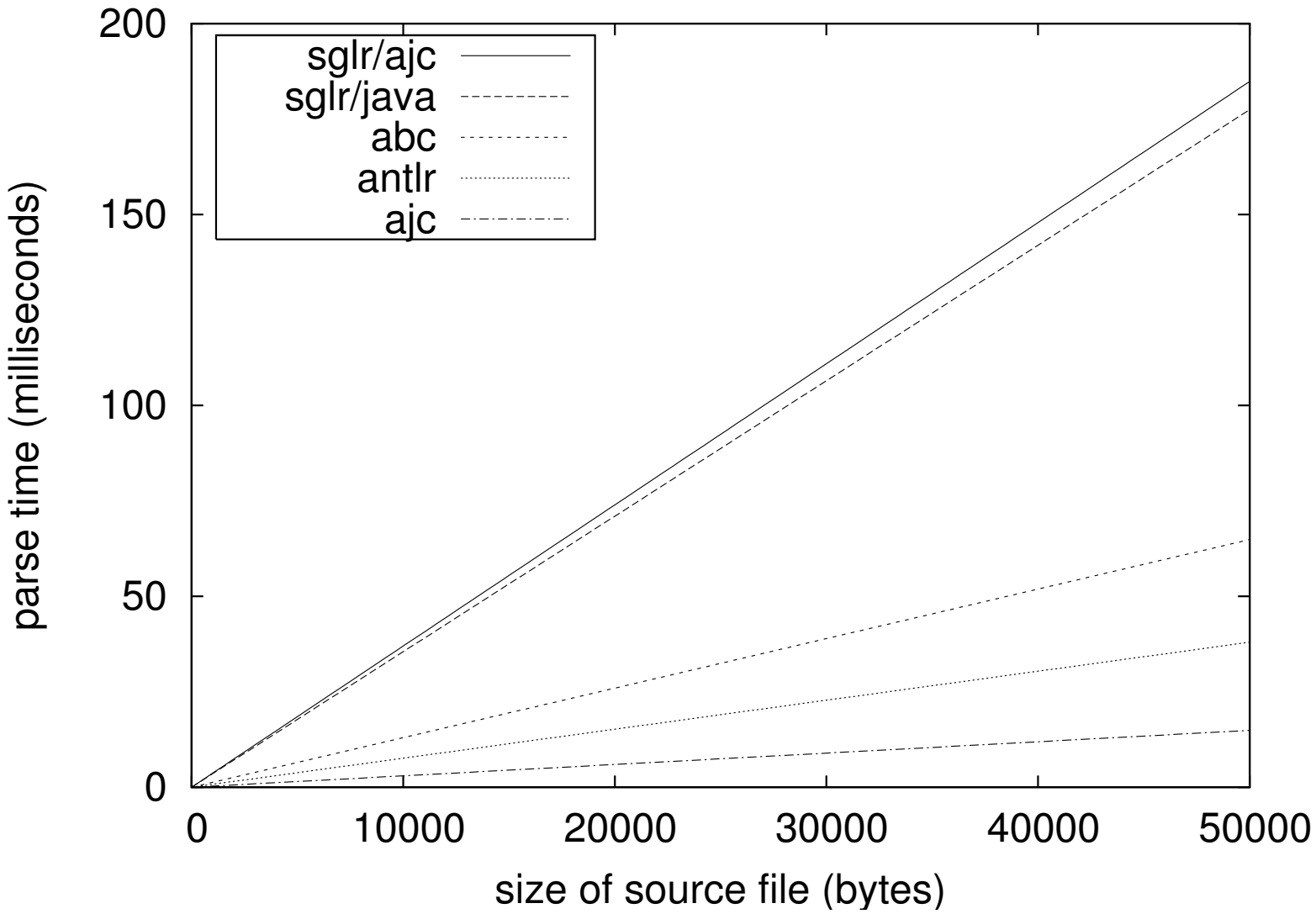
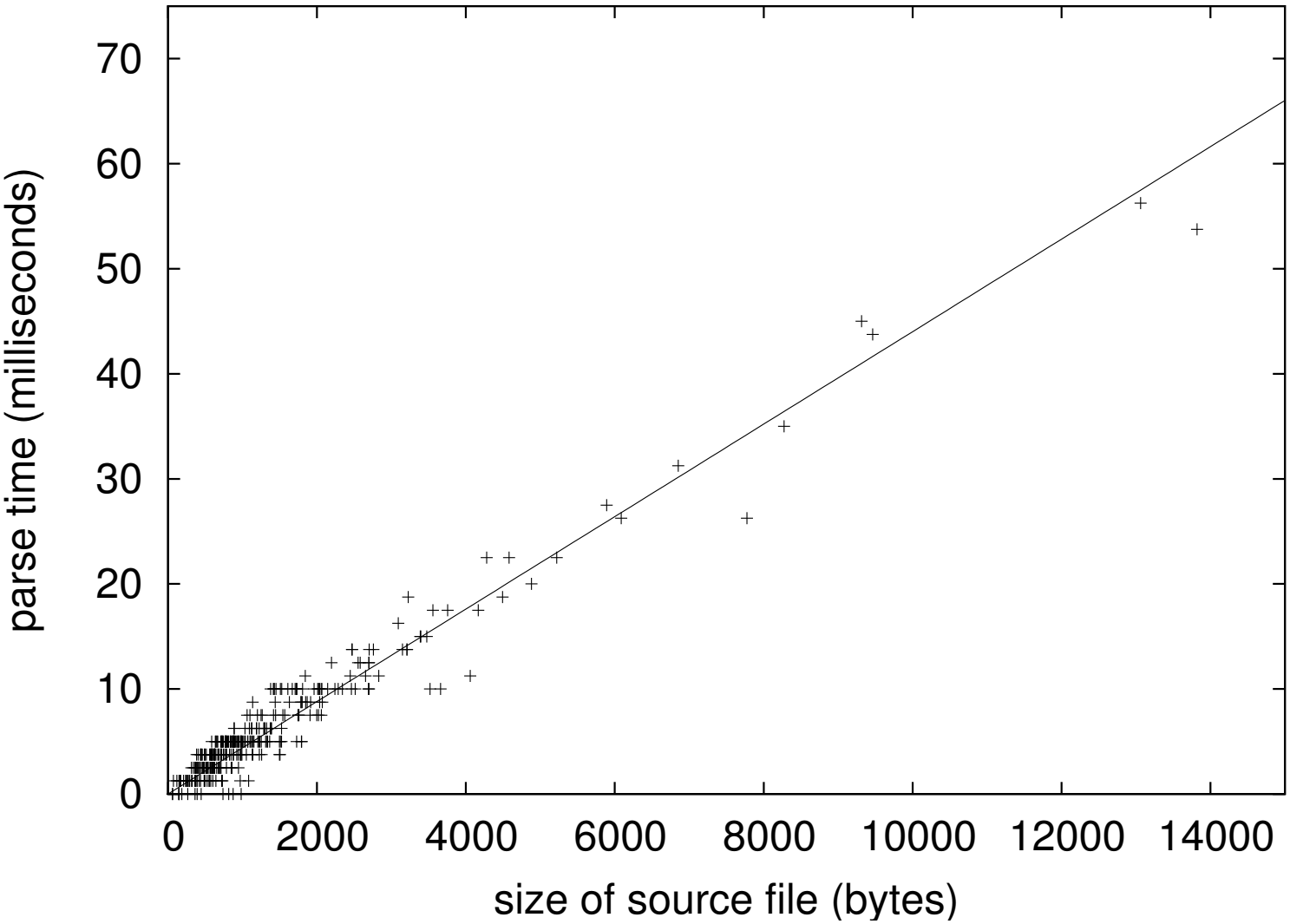


Performance: AspectJ Benchmark



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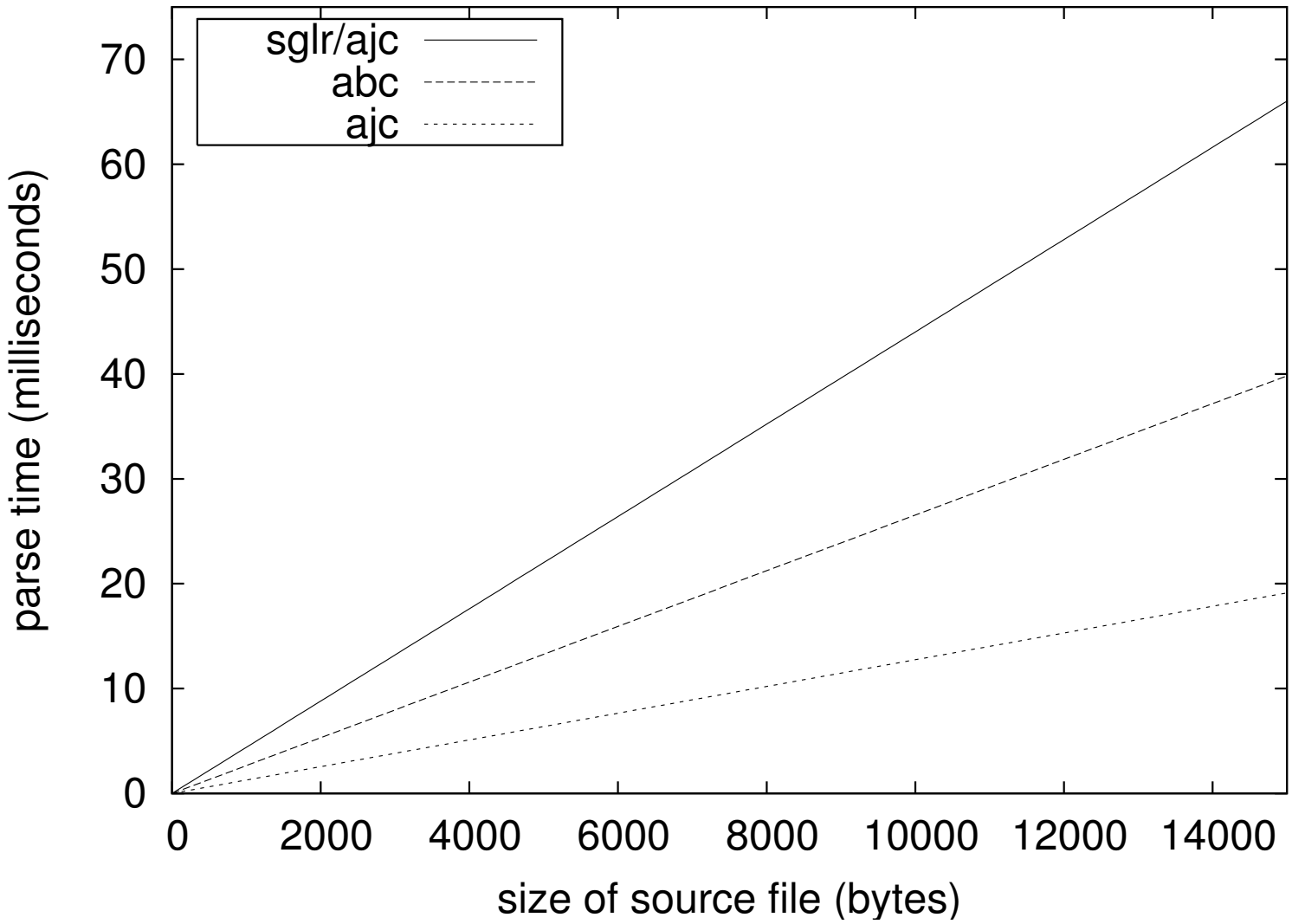

```
PointcutDeclaration ::=
  PcHeader FormalParamListopt ')' ':' PseudoTokens  ';'

DeclareDeclaration ::=
  DeclareAnnoHeader PseudoTokensNoColon ':' Anno ';'

PseudoToken ::=
  '(' | ')' | '.' | '*' | Literal | 'new'
  | JavaIdentifier | 'if' '(' Expression ')' | ...

PseudoTokens ::=
  one or more PseudoToken or ':'
PseudoTokensNoColon ::=
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```

Enter PointcutIf state: keyword lexer action

```
lexer.addPointcutKeyword("if",
  new LexerAction_c(new Integer(sym.PC_IF),
    new Integer(lexer.pointcutifexpr_state())));
```

Leave PointcutIf state: parentheses matching

```
<POINTCUTIFEXPR> {
  "(" { parenLevel++; return op(sym.LPAREN); }
  ")" { parenLevel--;
        if(parenLevel == nestingStack.peek().parenLevel)
          returnToPrevState();
        return op(sym.RPAREN);
      }
}
```

Enter PointcutIf state: keyword lexer action

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      }
}
```

Scanners reserve keywords

- Solution: explicitly allow keywords

```
JavaIdentifier -> 'Identifier'
JavaIdentifier -> AjSimpleName
AjSimpleName -> 'around' or 'aspect' or 'privileged' or
    'pointcut' or 'before' or 'after' or 'declare'
```

- JavaIdentifier used where possible

```
ClassHeaderName1 ::= Modifiersopt 'class' JavaIdentifier
MethodHeaderName ::= Modifiersopt Type JavaIdentifier '('
```

- For LALR reasons not as simple typename

```
import privileged.*;
import org.privileged.*;
```