Cool AST

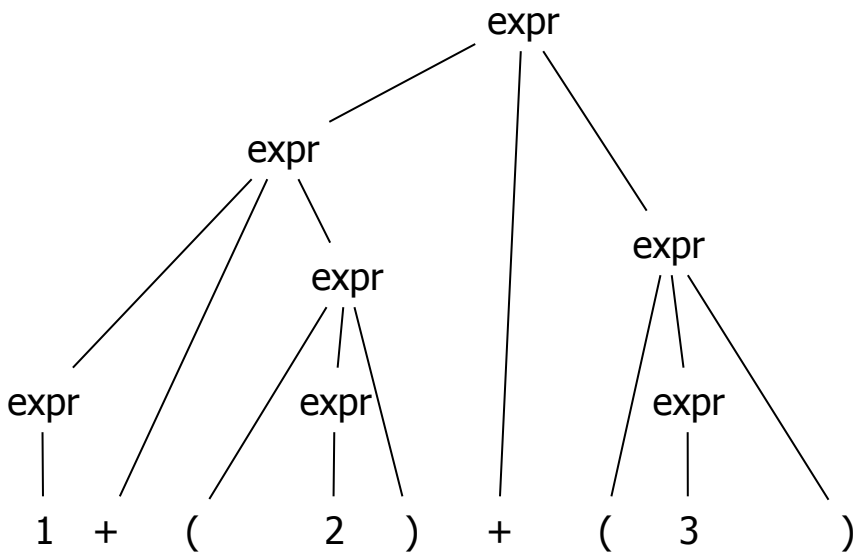
Greta Yorsh

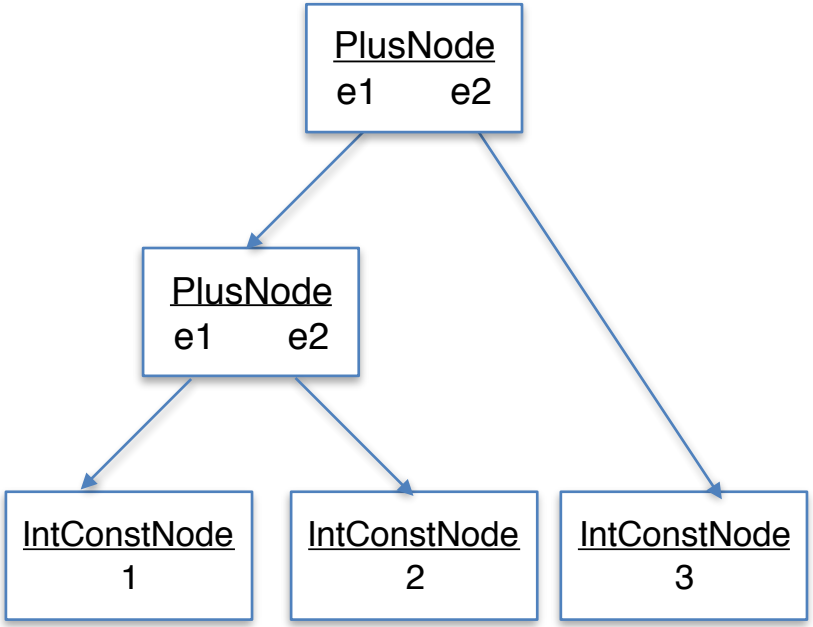
Cool AST

- Design
- Construction
- Traversal

Parse Tree vs Abstract Syntax Tree

```
grammar Example;
expr       : expr + expr | '(' expr ')' | IntConst;
IntConst : ('+'|'-')? [0-9]+ ;
WS          :  (' ' | '\n' |'\r' | '\t')+ -> skip
```





Abstract Syntax Tree (AST)

- A more useful representation of the parse tree
  - less clutter
  - actual level of details depends on your design
- Computation by AST traversal
  - debug printing
  - evaluation of expressions
- Basis for semantic analysis
- Later – annotate AST
  - type information
  - evaluation

(Most of) Cool Syntax

program ::= [*class*;]+

class ::= class TYPE [inherits TYPE] { [*feature*;]* }

feature ::= ID([*formal* [,*formal*]*]) : TYPE { *expr* }

ID : TYPE [<- *expr*]

formal ::= ID : TYPE

expr ::= ID <- *expr*

expr[@TYPE].ID([*expr* [, *expr*]*])

ID([*expr* [, *expr*]*])

if *expr* then *expr* else *expr* fi

while *expr* loop *expr* pool

{ [*expr*;]+ }

let ID : TYPE [<- *expr*] [,ID : TYPE [<- *expr*]]* in *expr*

case *expr* of [ID : TYPE => *expr*;]+ esac

new TYPE

isvoid *expr*

expr + *expr*

expr - *expr*

expr * *expr*

expr / *expr*

~*expr*

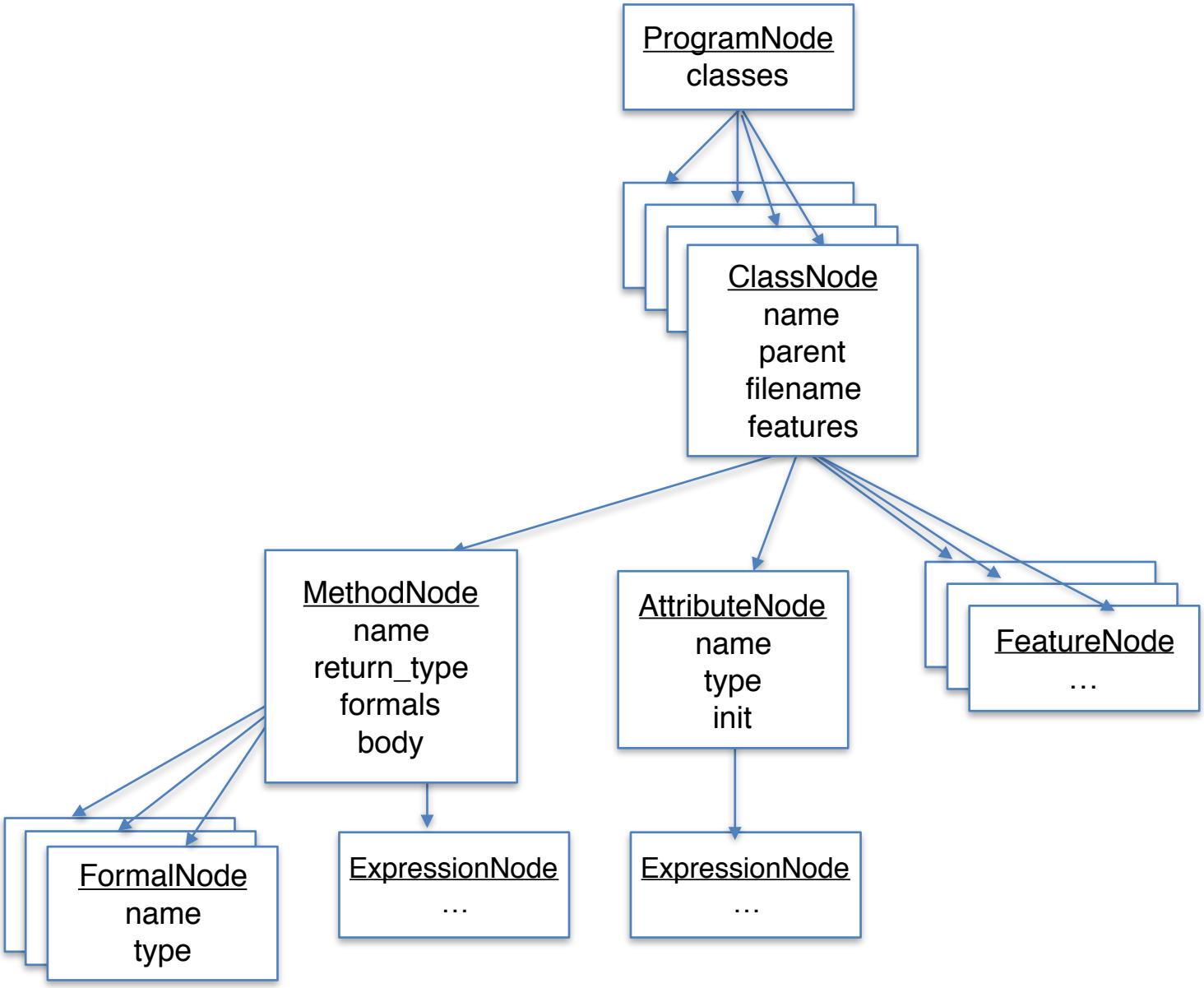
expr < *expr*

expr <= *expr*

expr = *expr*

...

Cool AST


ProgramNode
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ClassNode
name
parent
filename
features
MethodNode
name
return_type
formals
body
AttributeNode
name
type
init
FeatureNode
…
FormalNode
name
type
ExpressionNode
…
ExpressionNode
…

AST design: rules of thumb

- Abstract base class for AST nodes
- Class for the root of AST
- Abstract class for non-terminals with alternatives
- Class for each non-terminal or group of related non-terminals with similar functionality

AST design: rules of thumb

- Abstract base class for AST nodes
  - `abstract class TreeNode {…}`
- Class for the root of AST
  - `class ProgramNode extends TreeNode {…}`

Abstract class for non-terminals with alternative

- **feature : method | attribute;**

- `abstract class FeatureNode extends TreeNode {…}`
- `class MethodNode extends FeatureNode {…}`
- `class AttributeNode extends Feature {…}`

Abstract class for non-terminals with alternative

Abstract class for non-terminals with alternative

- **expr : ID ASSIGN expr l expr PLUS expr**
  …

Abstract class for non-terminals with alternative

- **expr : ID ASSIGN expr | expr PLUS expr ...**

- `abstract class ExpressionNode extends TreeNode`
- `class AssignNode extends ExpressionNode`
- `class PlusNode extends ExpressionNode`

Abstract class for non-terminals with alternative

- `abstract class FeatureNode extends TreeNode`
- `abstract class ExpressionNode extends TreeNode`
- `abstract class ConstNode extends ExpressionNode`
- `abstract class BinopNode extends ExpressionNode`
- `abstract class IntBinopNode extends BinopNode`
- `abstract class BoolBinopNode extends BinopNode`
- `abstract class IntUnopNode extends UnopNode`
- `abstract class BoolUnopNode extends UnopNode`

Class for non-terminals with similar functionality

- **class : CLASS TYPE (INHERITS TYPE)? ‘{‘ feature+ ‘}’;**

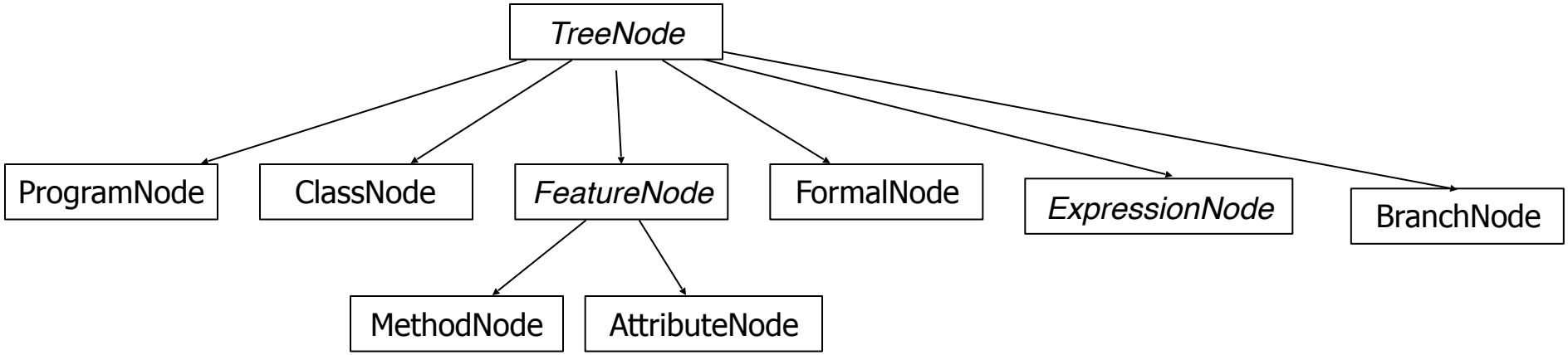
- `class ClassNode extends TreeNode {…}`

Class for non-terminals with similar functionality

- **attr : ID ‘:’ TYPE (‘<-‘ expr)?**

- `class AttributeNode extends FeatureNode`

Class Hierarchy for Cool AST



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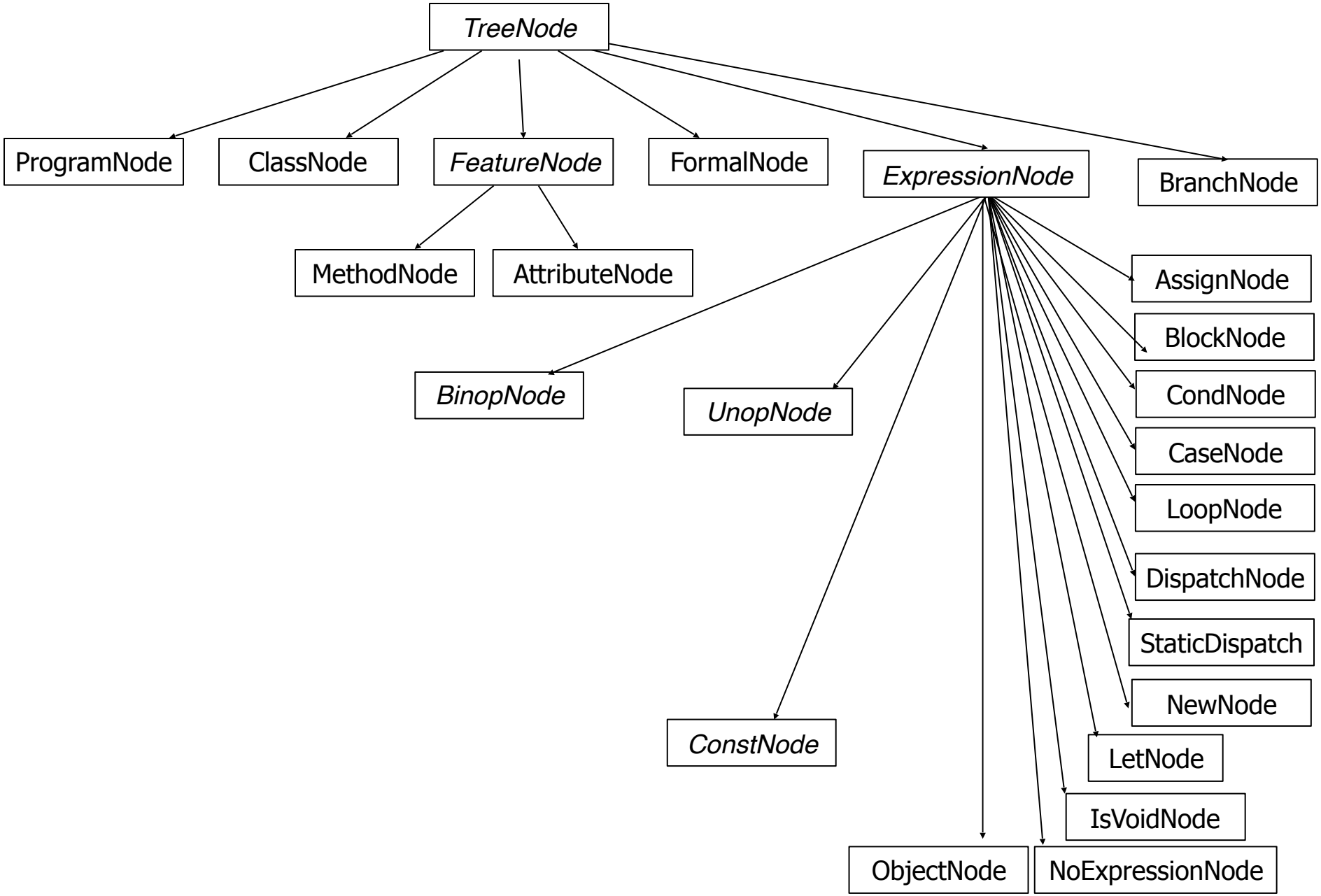

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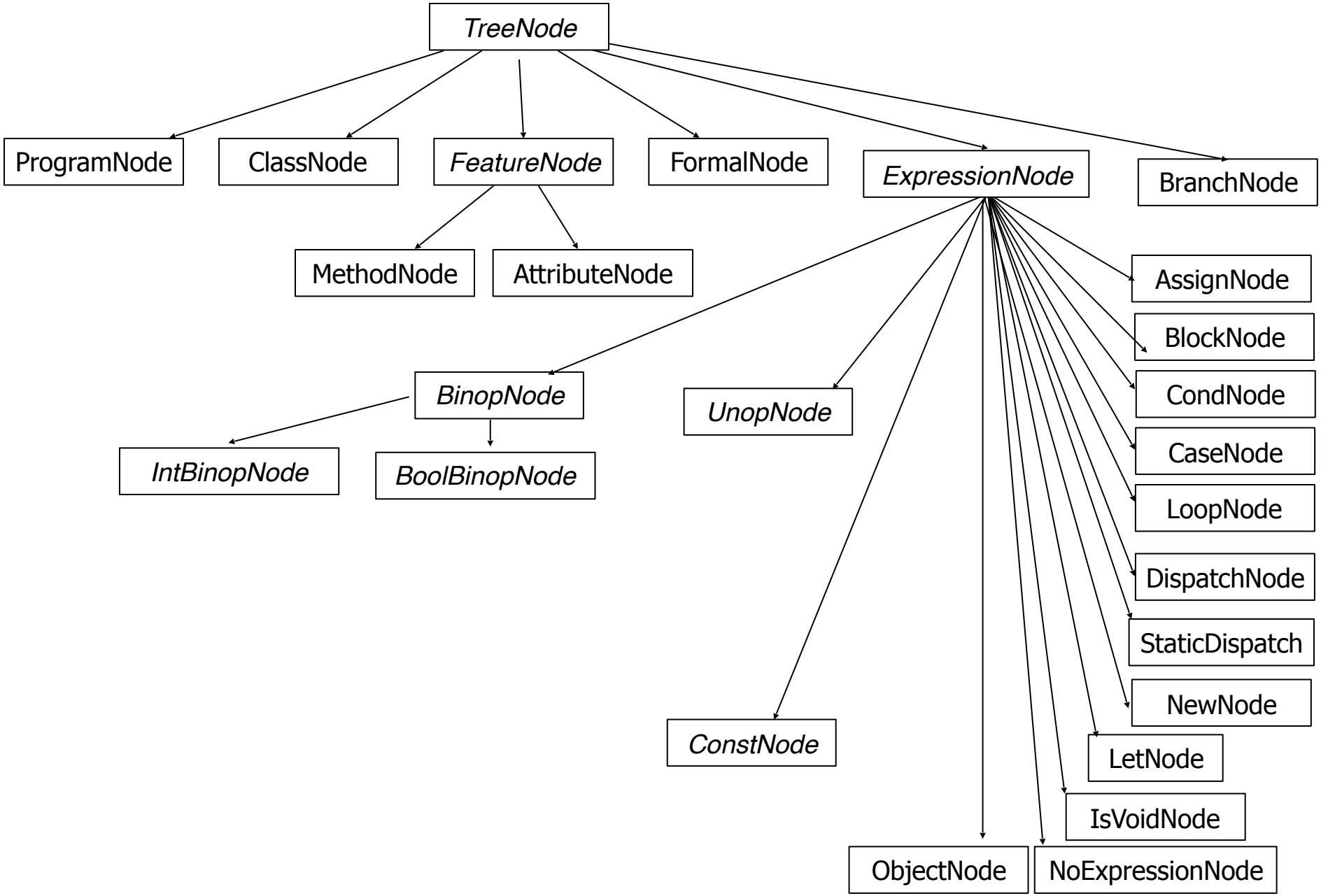

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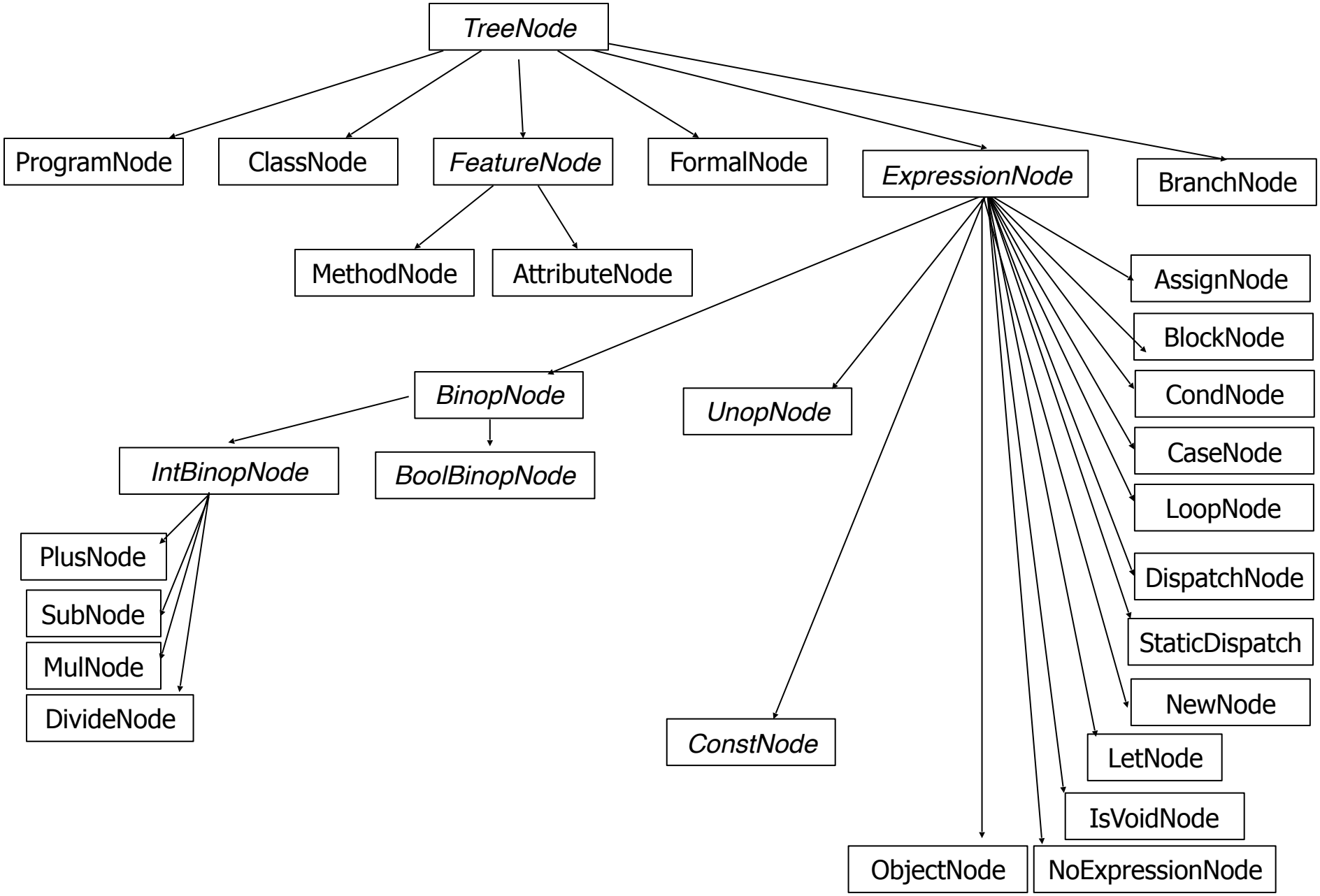

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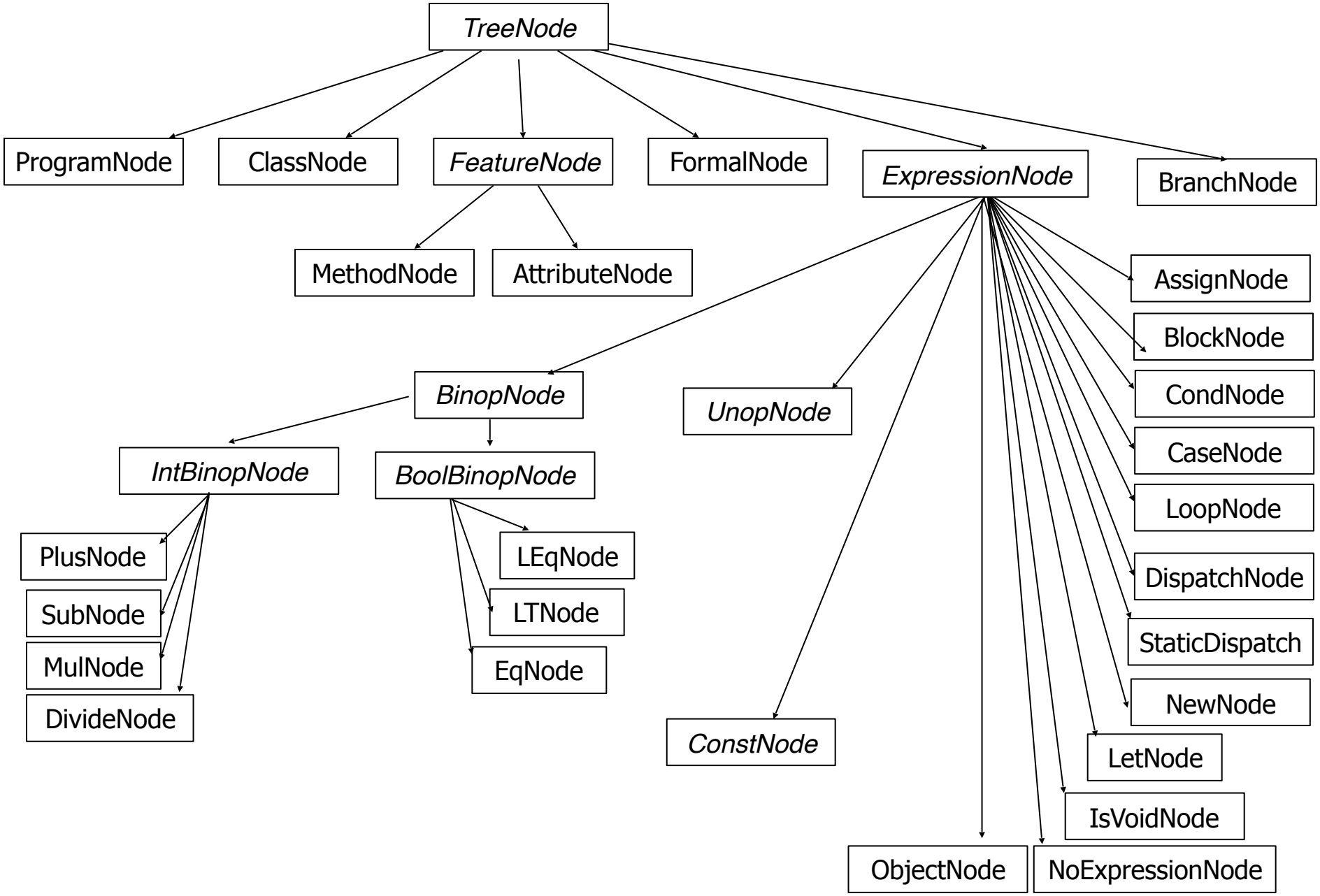

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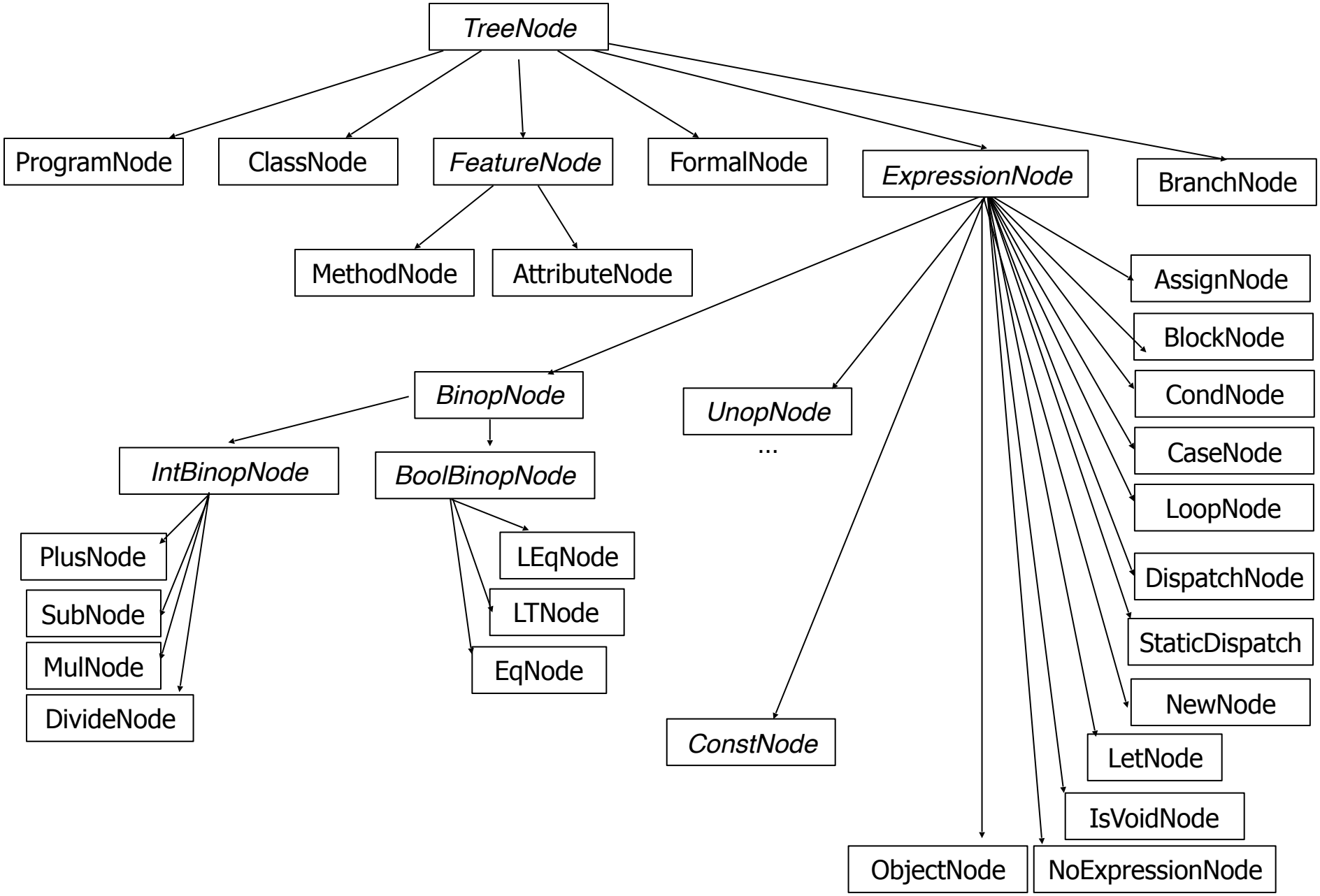

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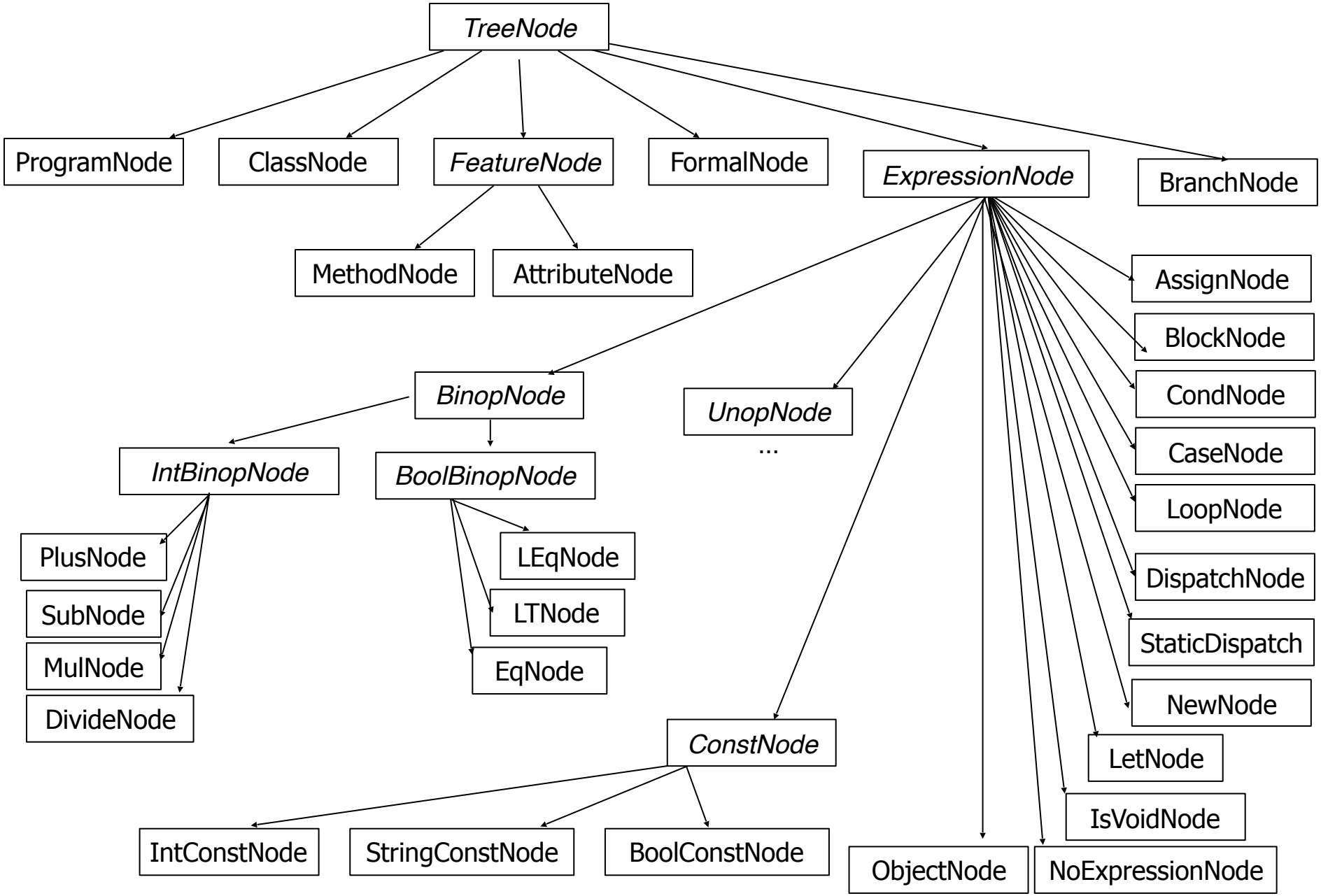

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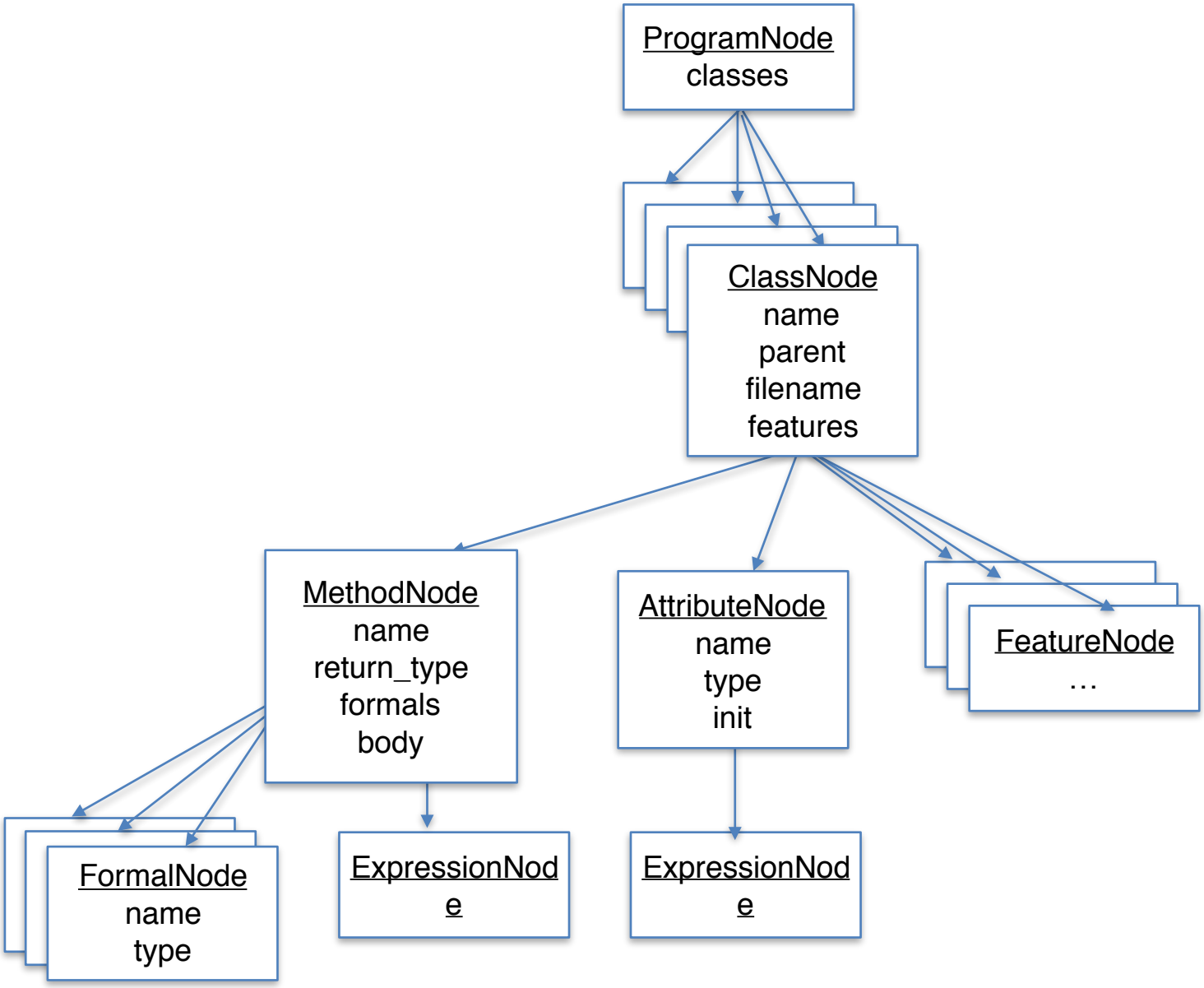
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AST construction: approaches

- When?
  - during parsing (execute on each production)
  - after parsing by traversing the parse tree
- How?
  - actions
    - part of parser generation specification
    - grammar description mixed with code
  - listener or visitor
    - separate grammar from code

AST traversal

- Examples operations
  - pretty printing
  - type checking
  - register allocation
  - code generation
- How?
  - naive: a method per operation in each node class
  - visitor design pattern

Visitor Design Pattern

- Separate object **representation** from **operations** on objects of a data structure
- Each operation implemented as separate visitor

- Java: visitor implements double dispatch

- works well when representation is fixed

AST Visitor

AST Visitor

```
interface TreeVisitor {
  void visit(Tree n);
  void visit(TreeNode n);
  void visit(ProgramNode n);
  void visit(ClassNode n);
  void visit(MethodNode n);
  void visit(BlockNode n);
  void visit(AssignNode n);
  …
}
```

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  …
}
```

```
interface Tree {
   void accept(TreeVisitor visitor);
}
```

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  …
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interface Tree {
   void accept(TreeVisitor visitor);
}
```

```
abstract class TreeNode implements Tree {
   void accept(TreeVisitor visitor){
      v.visit(this);
   }
}
```

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  void visit(AssignNode n);
  …
}
```

```
class BaseVisitor implements TreeVisitor {
  void visit(Tree n){…}
  void visit(TreeNode n) {…}
  void visit(ProgramNode n) {
    foreach (ClassNode c : n.getClasses()
      c.accept(v);
  }
  void visit(BinopNode n) {
     n.getE1().accept(v);
     n.getE2().accept(v);
  }…
}
```

```
interface Tree {
   void accept(TreeVisitor visitor);
}
```

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abstract class TreeNode implements Tree {
   void accept(TreeVisitor visitor){
      v.visit(this);
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  }…
}
```

```
interface Tree {
   void accept(TreeVisitor visitor);
}
```

```
abstract class TreeNode implements Tree {
   void accept(TreeVisitor visitor){
      v.visit(this);
   }
}
```

```
class DumpVisitor
   extends BaseVisitor {
  void visit(ClassNode n){
     out.println("_class");
     super.visit(n);
  } …
  void visit(ConstNode n){
     out.print(n.getVal());
  }
  …
}
```

AST Visitor

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interface TreeVisitor {
  void visit(Tree n);
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  }…
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```
interface Tree {
   void accept(TreeVisitor visitor);
}
```

```
abstract class TreeNode implements Tree {
   void accept(TreeVisitor visitor){
      v.visit(this);
   }
}
```

```
void main() {
   Tree root; …
   TreeVisitor v = new DumpVisitor ();
   root.accept(v); …
```

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class DumpVisitor
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```

Visitor with return value

Visitor with return value

```
class EvalVisitor implements BaseVisitor {
  Object visit(PlusNode n){
    Integer v1 = (Integer) n.getE1().accept();
    Integer v2 = (Integer) n.getE2().accept();
    return v1 + v2;
  }
  Object visit(IntConstNode n){
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void main() {
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   Integer result = (Integer) root.accept(v);
   …
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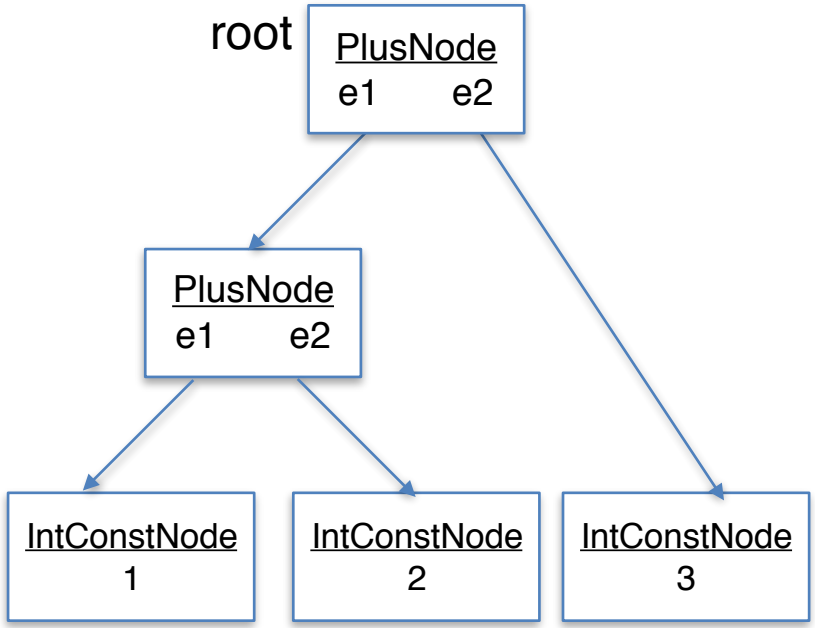

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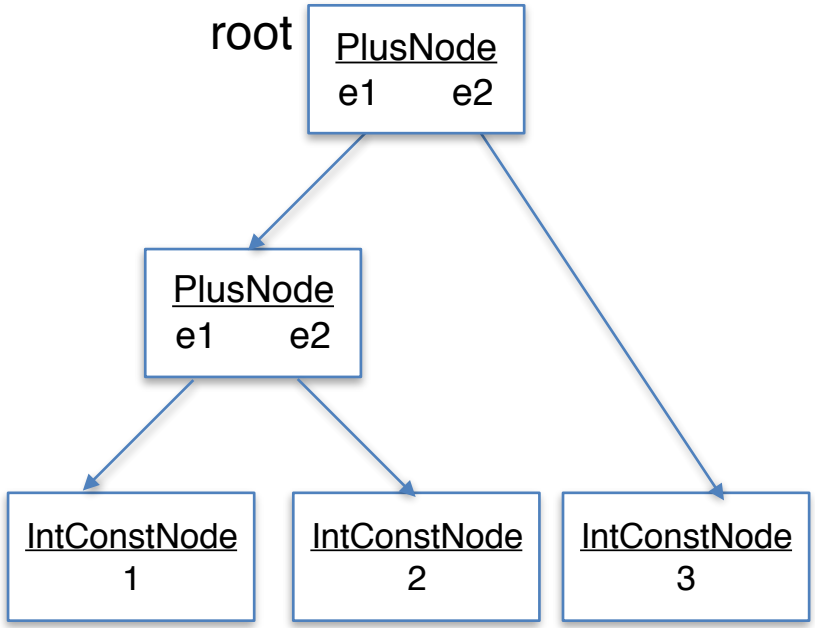

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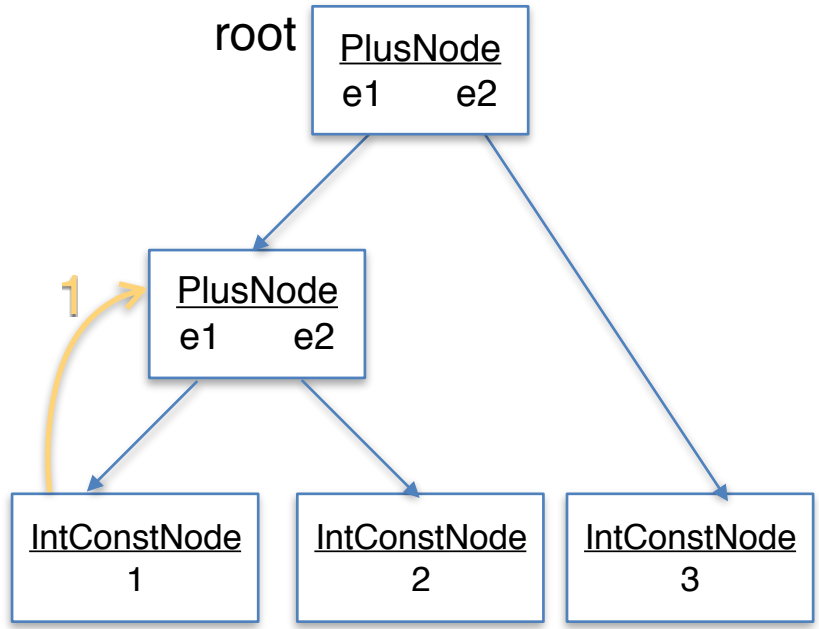

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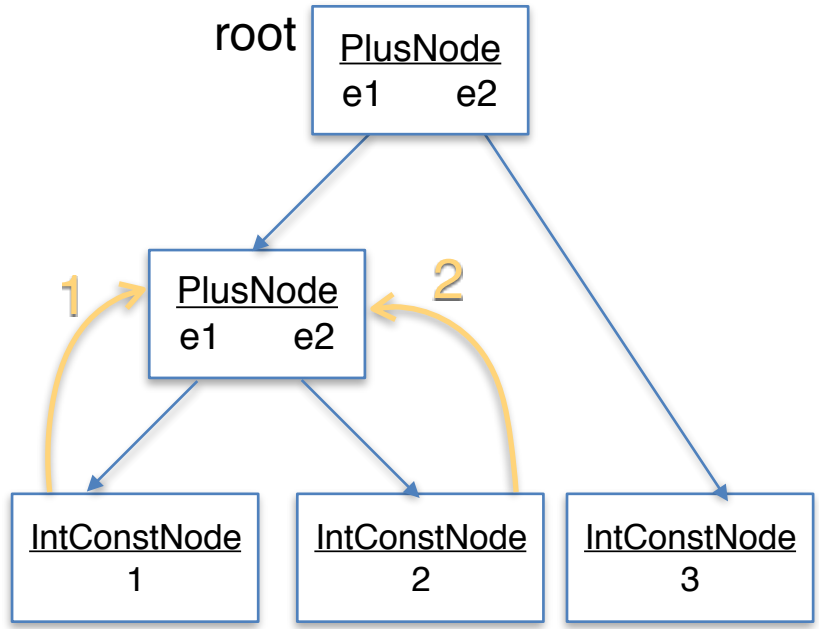

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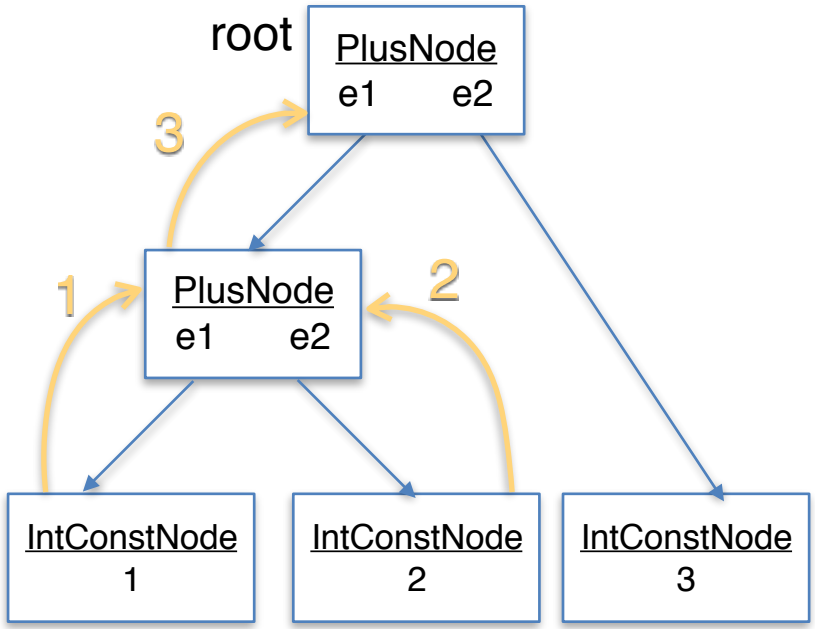

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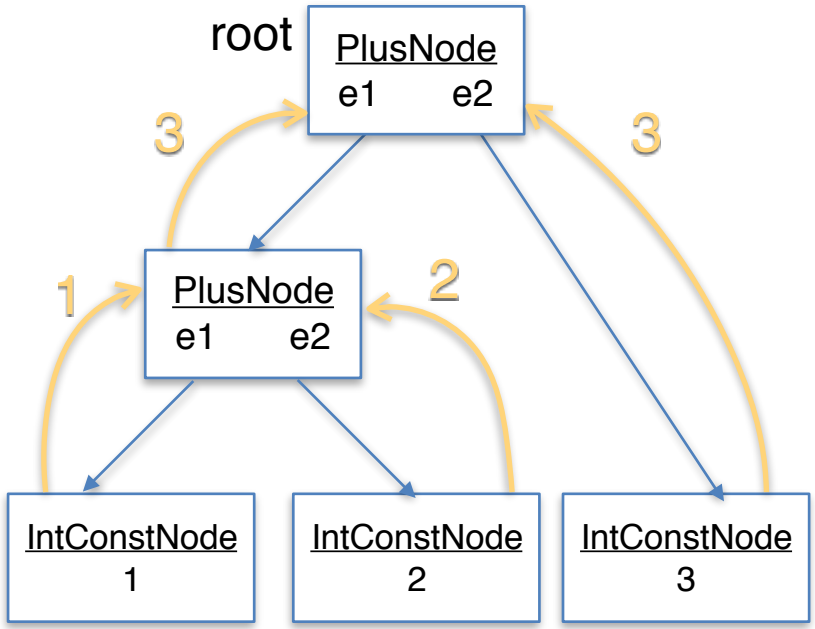

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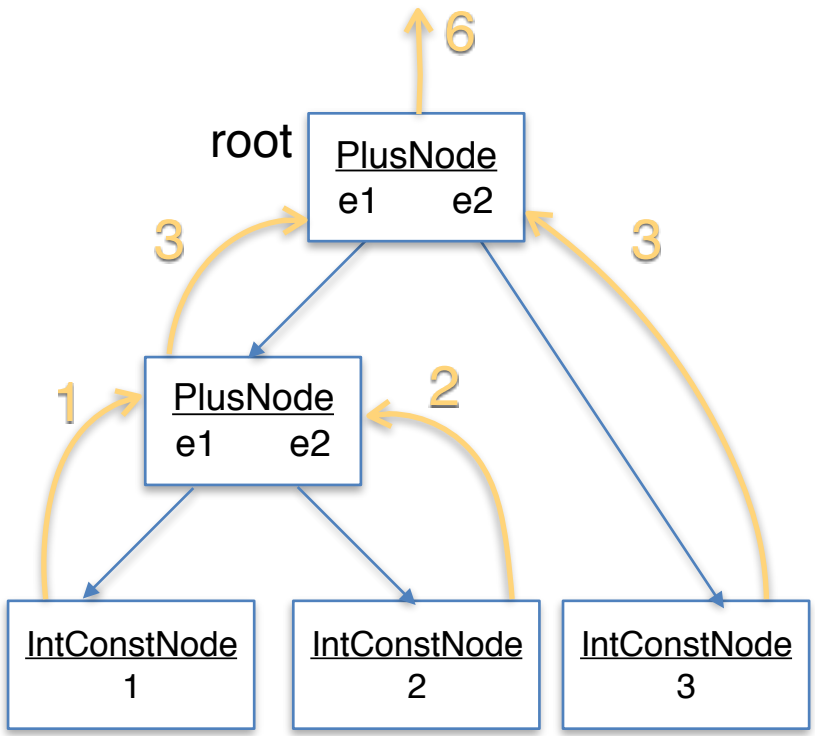

Visitor variations

```
public class IntConstNode extends ConstNode {
   public Object accept(TreeVisitor visitor, Object data){
      return v.visit(this);
   }
}
```

```
public class PlusNode extends IntBinopNode {
   public Object accept(TreeVisitor visitor, Object data){
      return v.visit(this);
   }
}
```

```
class EvalVisitor implements TreeVisitor{
public:
    Object visit(ClassNode e, Object o);
    Object visit(MethodNode e , Object o);
    Object visit(BlockNode e , Object o);
    Object visit(AssignNode e , Object o);
    ...
}
```

```
void main() {
   Tree root; …
   TreeVisitor v = new EvalVisitor ();
   Integer result = (Integer) root.accept(v,data);
   …
}
```

Propagate values
down the AST and back

Visitor variations

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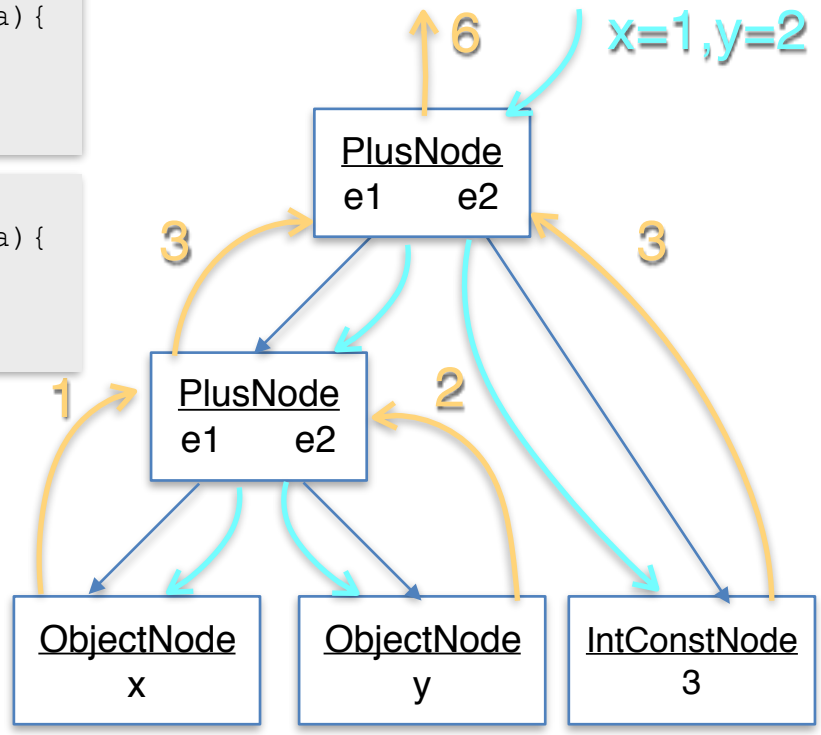
}
```



Propagate values
down the AST and back

Visitors: which method is called?

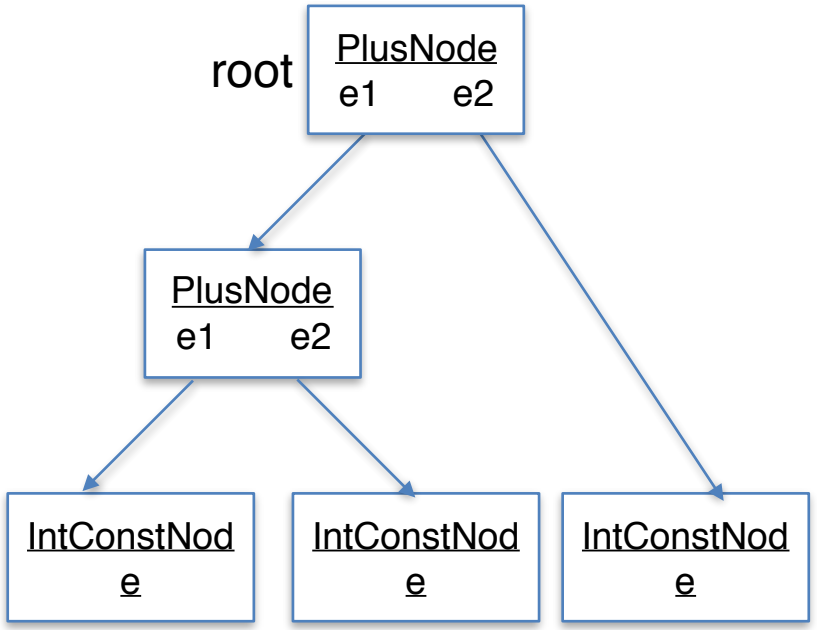
- static dispatch
- dynamic dispatch
  - single
  - multiple

- method overloading
- method overriding

Single dispatch

```
class EvalVisitor implements BaseVisitor {
  public Object visit(PlusNode n){
    Integer v1 = (Integer) visit(n.getE1());
    Integer v2 = (Integer) visit(n.getE2());
    return v1 + v2;
  }
  public Object visit(IntConstNode n){
    return (Integer) n.getVal();
  }
  public Object visit(ExpressionNode n){
    return 0;
  }
  …
}
```

```
void main() {
   PlusNode root; …
   TreeVisitor v = new EvalVisitor ();
   Integer result = (Integer) v.visit(root);
   …
}
```



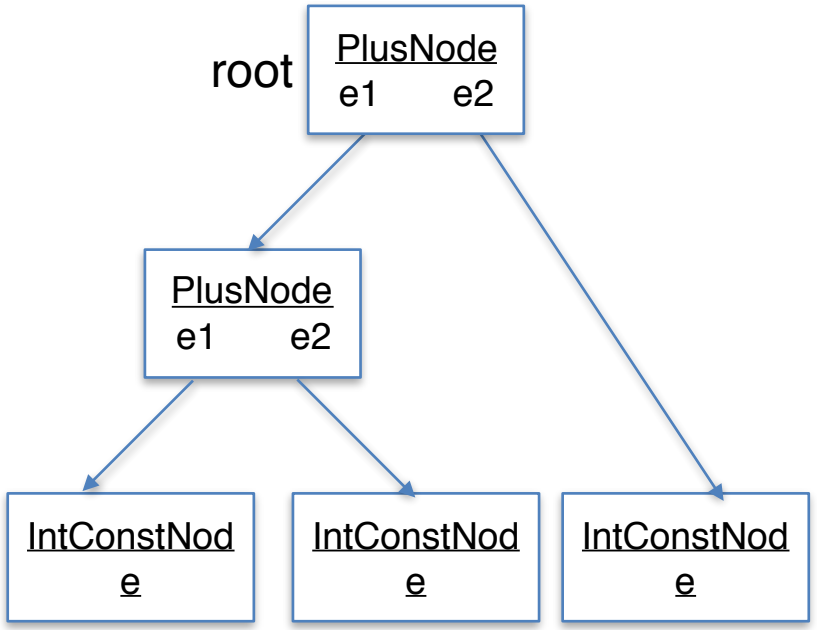
Double dispatch

```
class EvalVisitor implements BaseVisitor {
  public Object visit(PlusNode n){
    Integer v1 = (Integer) n.getE1().accept();
    Integer v2 = (Integer) n.getE2().accept();
    return v1 + v2;
  }
  public Object visit(IntConstNode n){
    return (Integer) n.getVal();
  }
  public Object visit(ExpressionNode n){
    return 0;
  }
  …
}
```

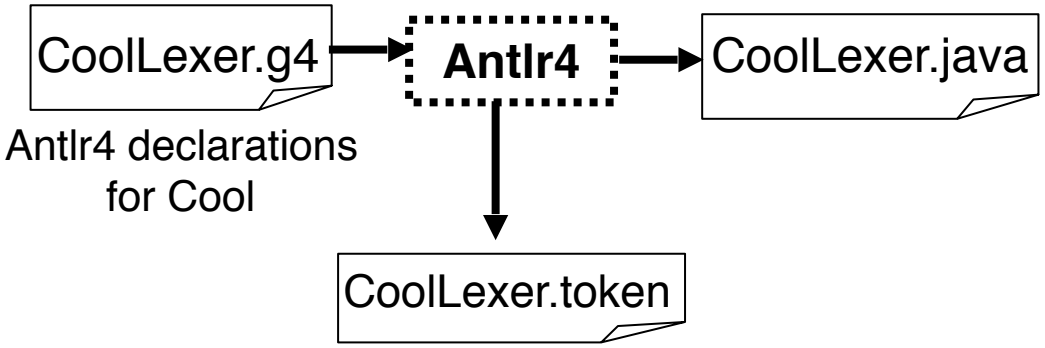
```
class PlusNode extends IntBinopNode {
   Object accept(TreeVisitor visitor){
      return v.visit(this);
   }…
}
```

```
class IntConstNode extends ConstNode {
   Object accept(TreeVisitor visitor){
      return v.visit(this);
   }…
}
```

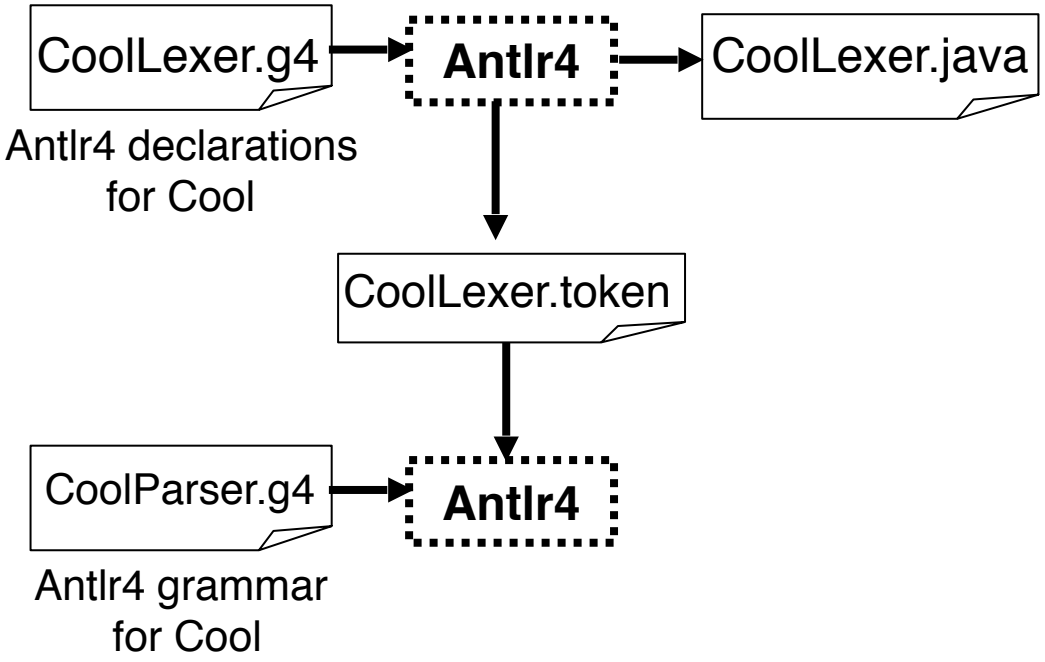
```
void main() {
   Tree root; …
   TreeVisitor v = new EvalVisitor ();
   Integer result = (Integer) root.accept(v);
   …
}
```



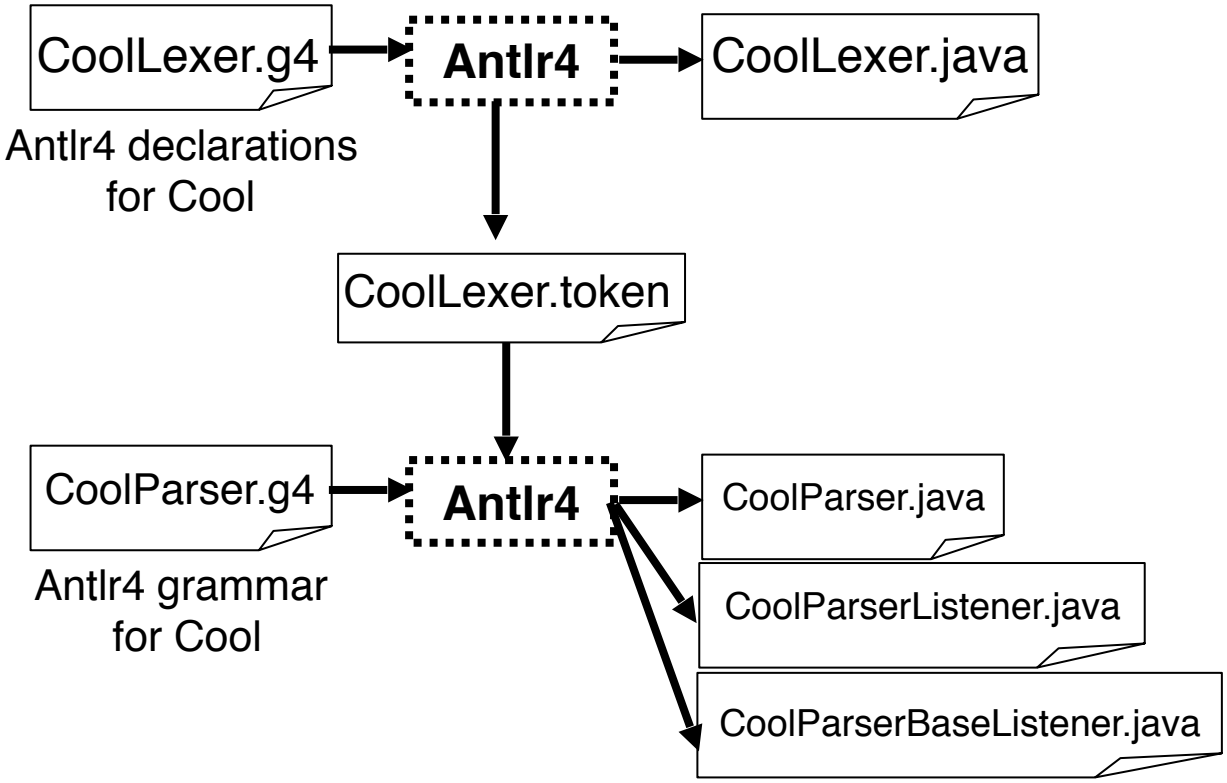
Antlr: build and run a parser



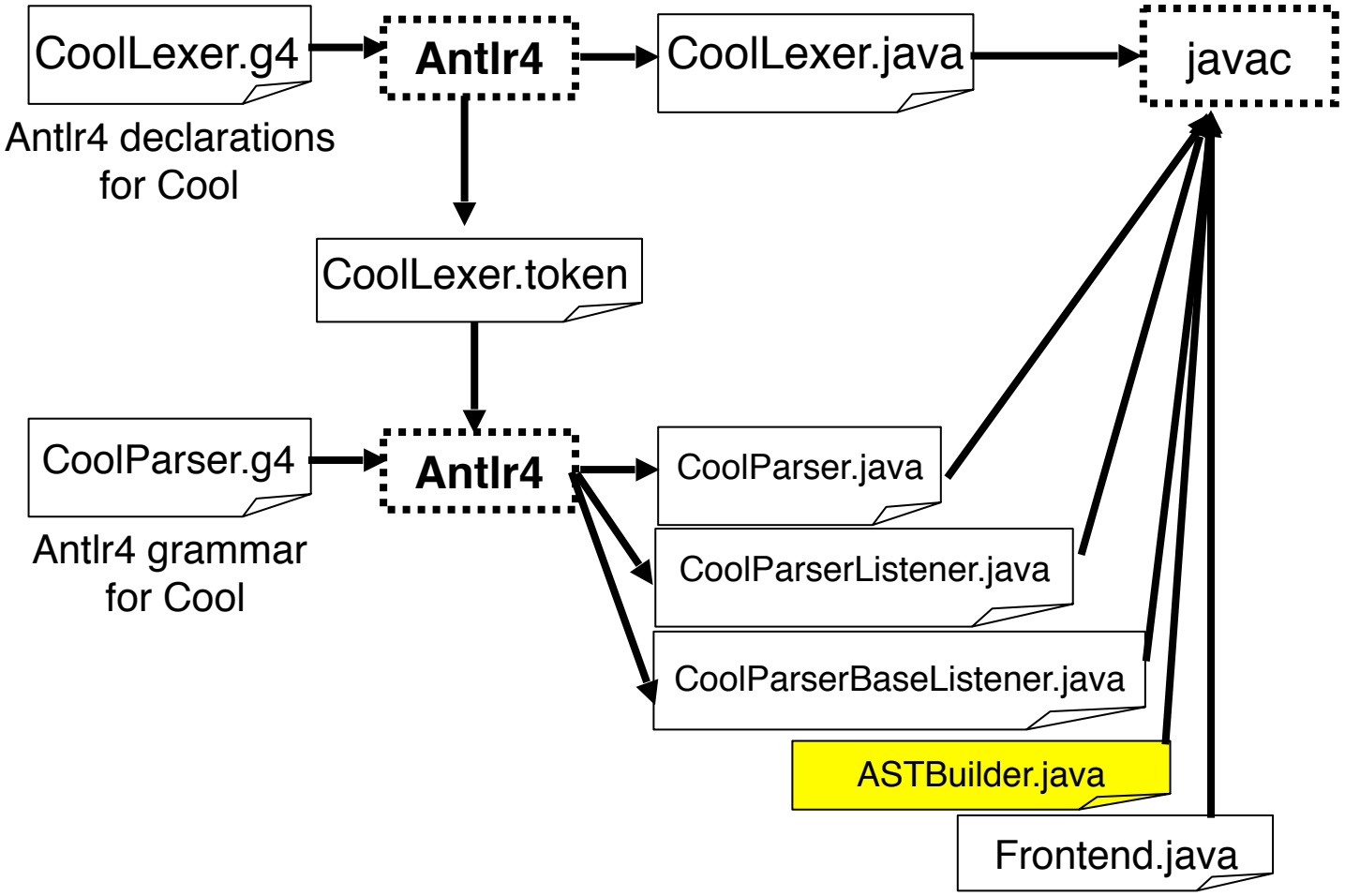
Antlr: build and run a parser



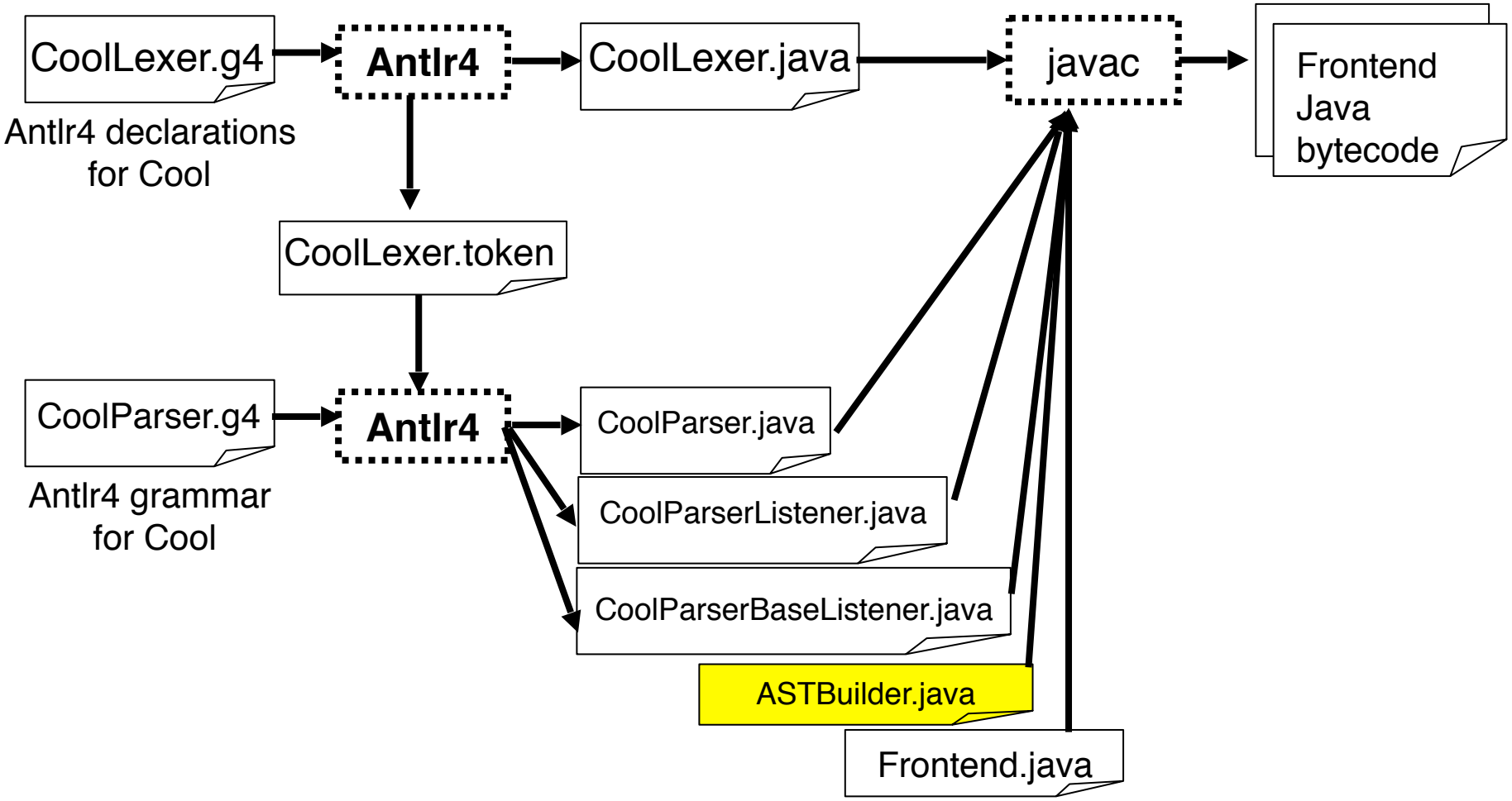
Antlr: build and run a parser



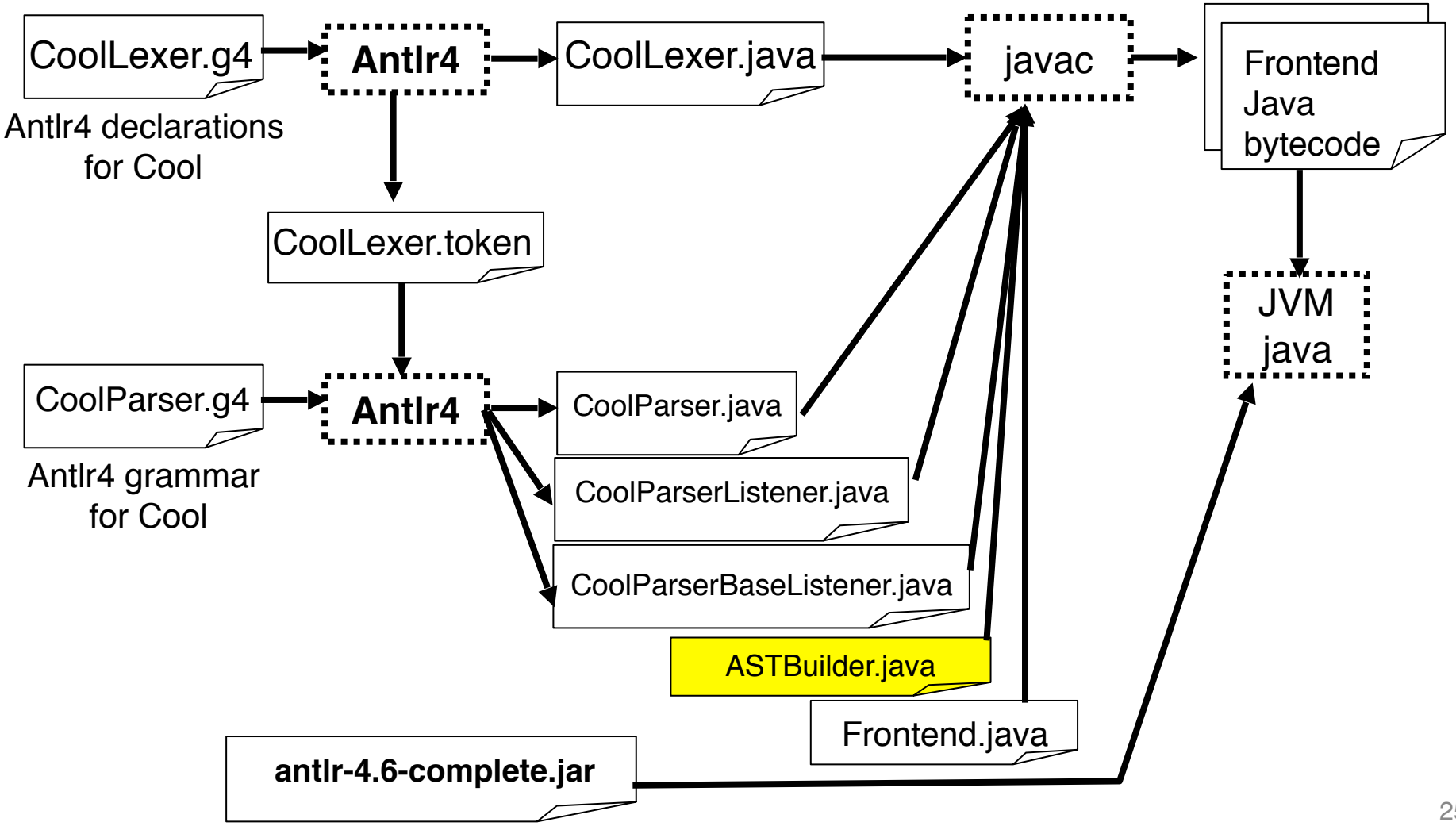
Antlr: build and run a parser



Antlr: build and run a parser



Antlr: build and run a parser



Antlr: build and run a parser