Check-In

Scope Review

Consider the following program in Levi

Is this program well-named in a static scoping scheme? In a dynamic scoping scheme?

What is the output for each scheme in which it compiles?

```
a : int;
v : () void {
    a = a + 1;
    out << a;
}
w : () void {
    a = 7;
    v();
    out << a;
}
main : () void {
    a : int = 1;
    w();
    out <<  a;
}
```

University of Kansas | Drew Davidson

Semantic Analysis

Housekeeping

Administrivia + Announcements

P3 due Wednesday

due Friday 2 penalties

Last Lecture

Lecture Review – Scope

Issues of Scope

- Scheme
- Shadowing
- Overloading

You Should Know

- Scope properties
- How scope affects semantics
- High-level scope rules for our language

Semantics

Lecture Outline

Lecture Overview – Semantic Analysis

Name Analysis

- Enforcing scope

Symbol Table

- What it is
- What it does

Semantics

Name Analysis

Semantic Analysis

Idea:

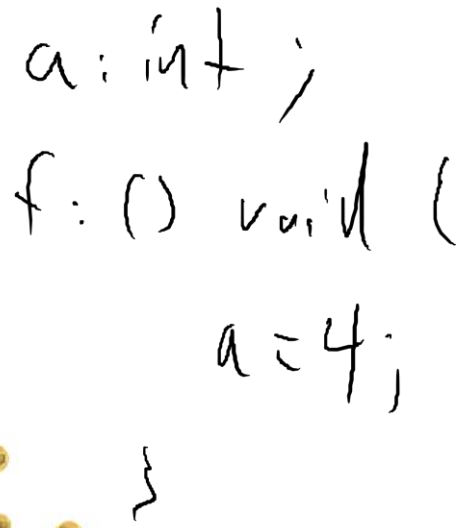
- Associates IDs with their uses in the program
  - i.e. Emplace symbol table entries
- Implemented as an AST pass

Purpose:

- Needed for code generation
- Catch some obvious errors
  - (undeclared IDs)

Recognizing Identifier Context

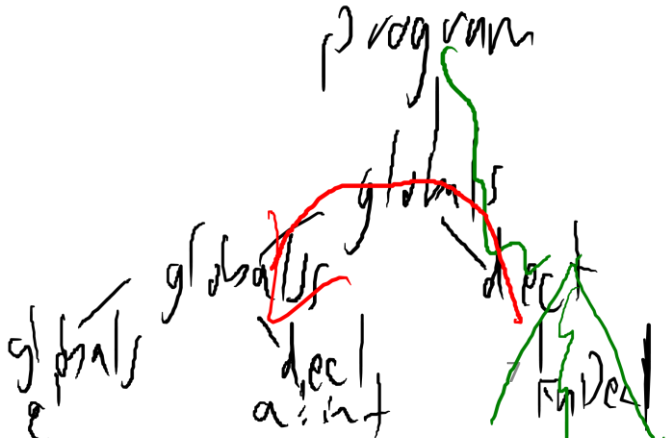
Semantic Analysis



A Context-Free Grammar is… context free

- A node needs information from outside of its subtree
- The definition of a identifiers needs to be connected to its occurrences
- We need a data structure to propagate such context

There's lots of ways to do this!
We'll just cover 1 way



The Compiler's Symbol Table

Semantic Analysis

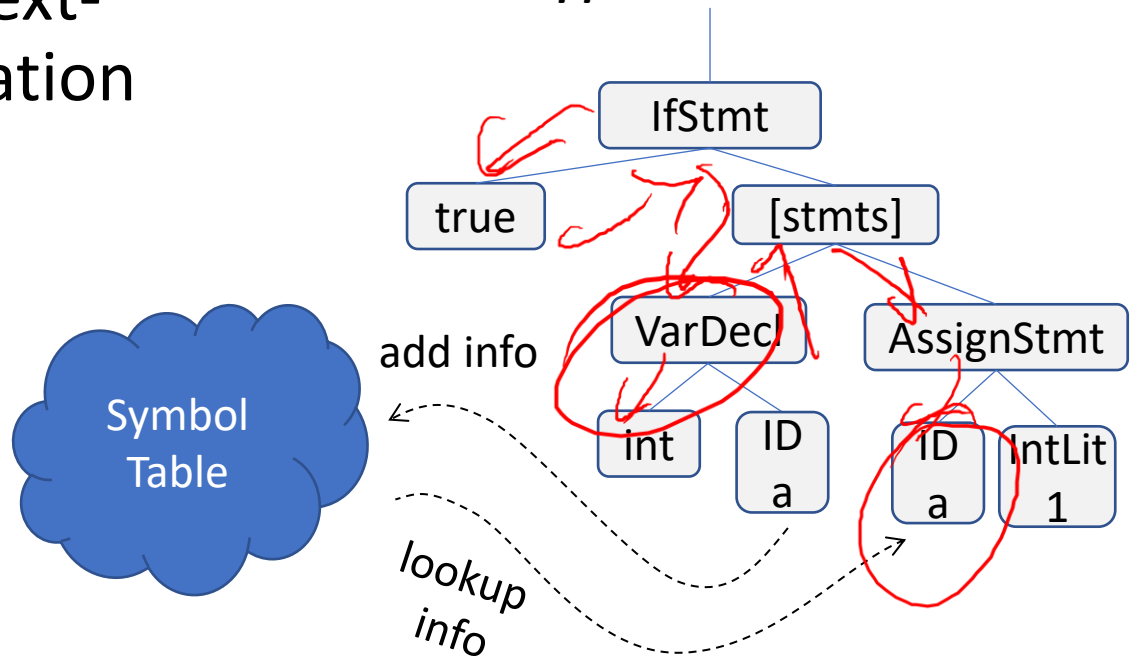
Repository of semantic symbol information

- Populated during a walk of the AST
- Propagates context-sensitive information

Program Snippet

```
if(true){
  int a;
  a = 1;
}
```

AST Snippet



The Compiler's Symbol Table

Semantic Analysis

What's in the symbol table:

- Depends on the language

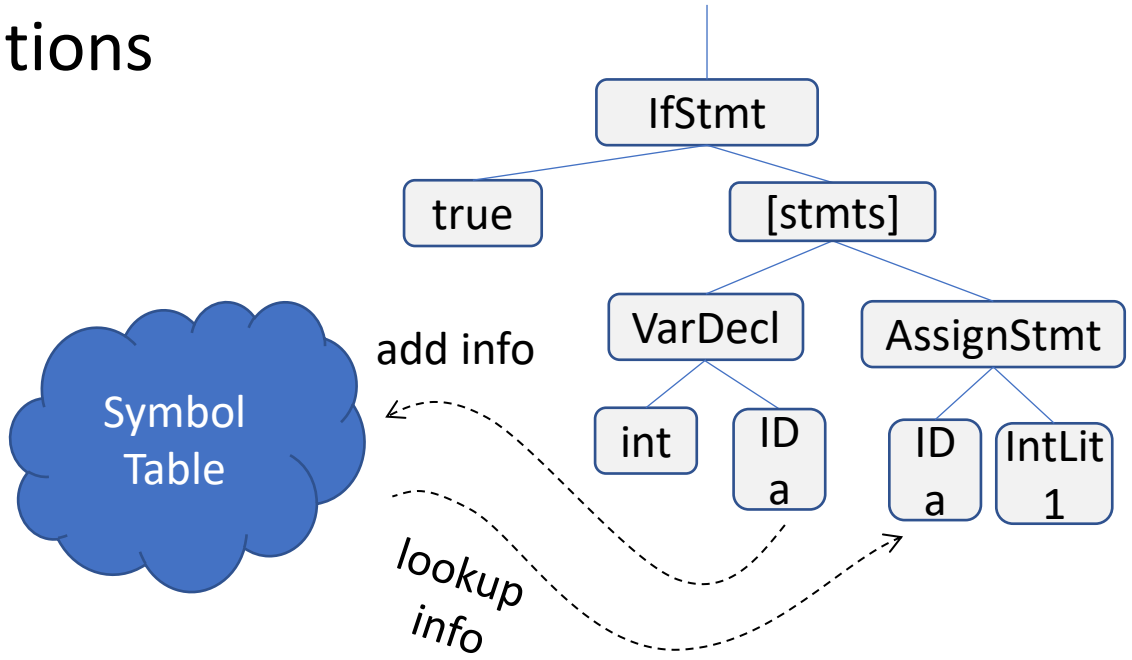
Kinds of entries we need:

- Variable Declarations
- Function Declarations

Program Snippet

```
if(true){
  int a;
  a = 1;
}
```

AST Snippet



The Compiler's Symbol Table

Semantic Analysis

What's in the symbol table:

- Depends on the language

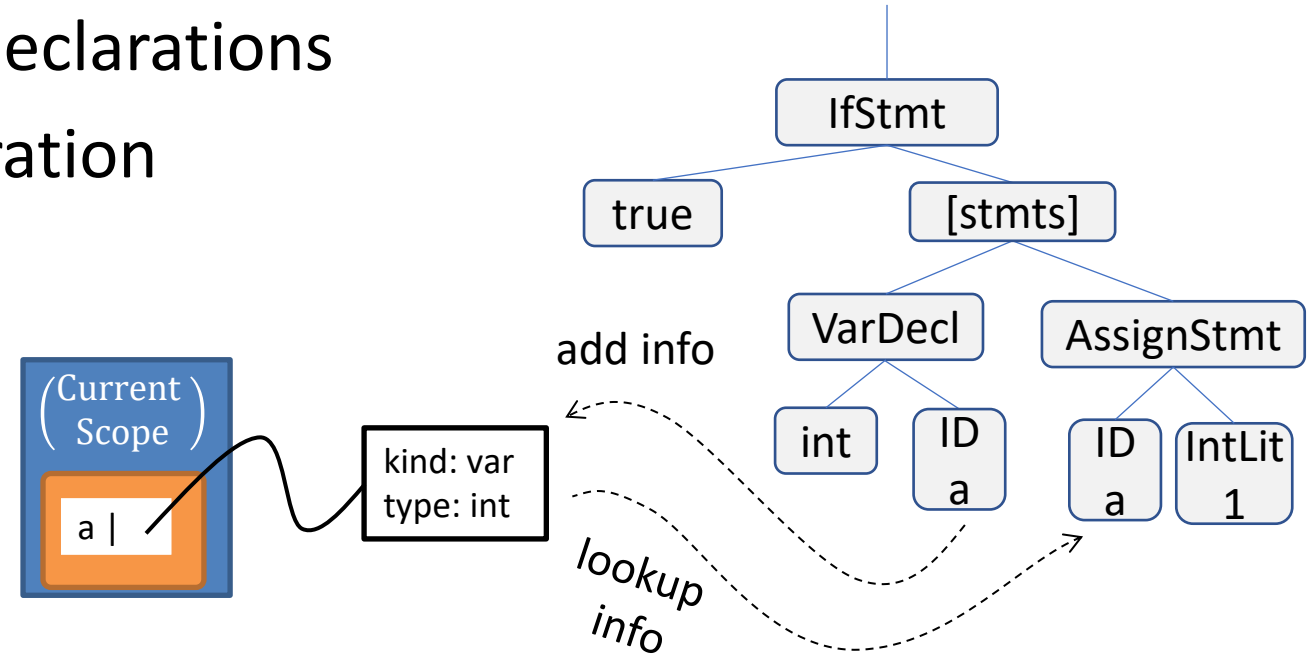
Kinds of entries we need:

- Variable Declarations
- Function Declarations
- Sink declaration

Program Snippet

```
if(true){
  int a;
  a = 1;
}
```

AST Snippet



Symbol Table: A "Snapshot" of Scope

At any (static) program point

- Symbol table shows *what's* in scope
- Symbol table shows which scope contains the entry

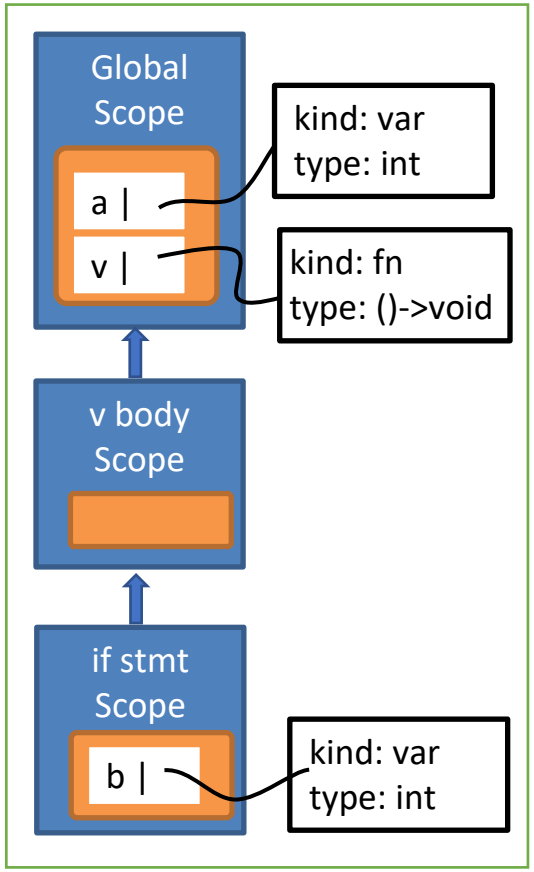
Implementation:

- A list of hashmaps (1 map per scope)

```
1. int a;
2. void v(){
3.    if (a){
4.       int b;
5.    }
6. }
```

Here →

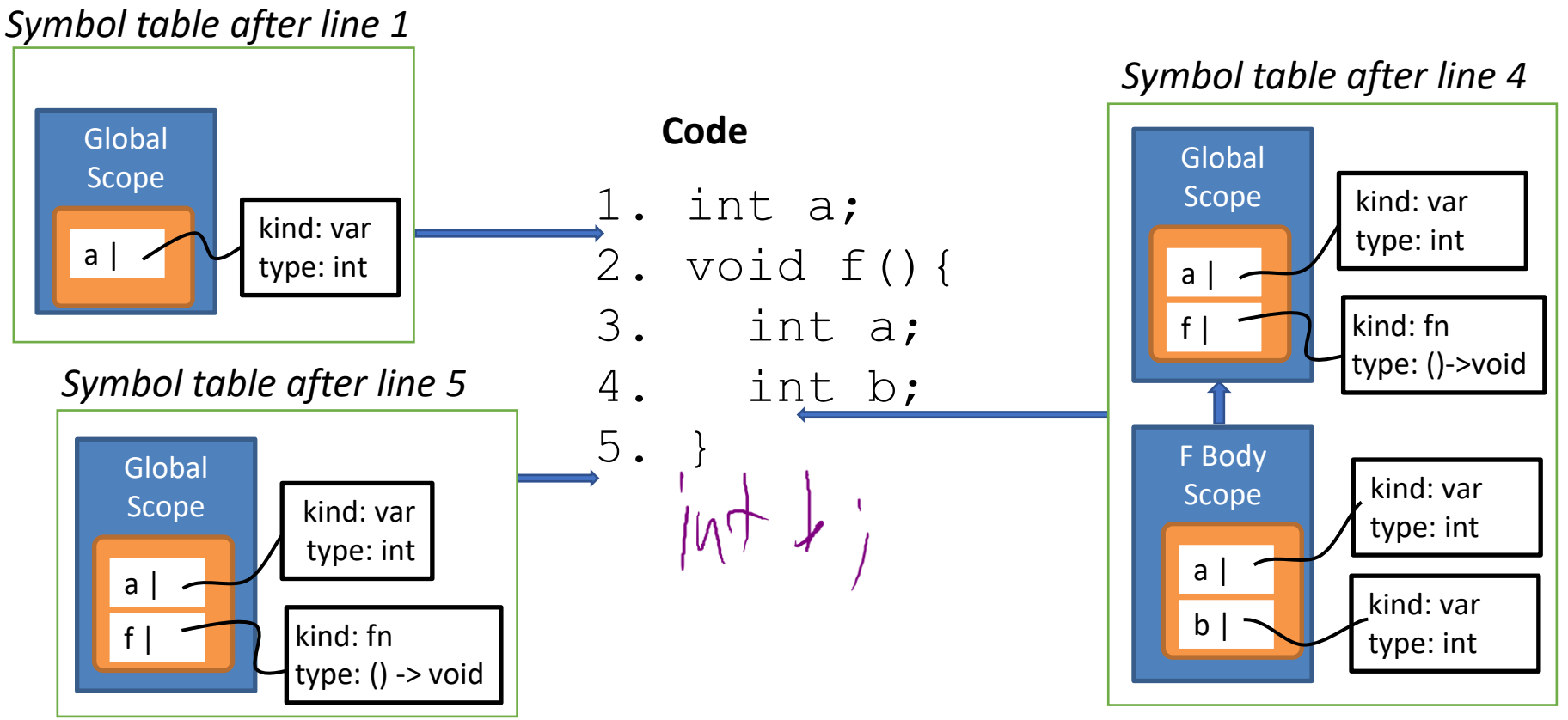
Symbol table after line 4



Symbol Table: Scopes "Sub-tables"

Semantic Analysis - Name Analysis

Create one hashmap per scope



Implementation

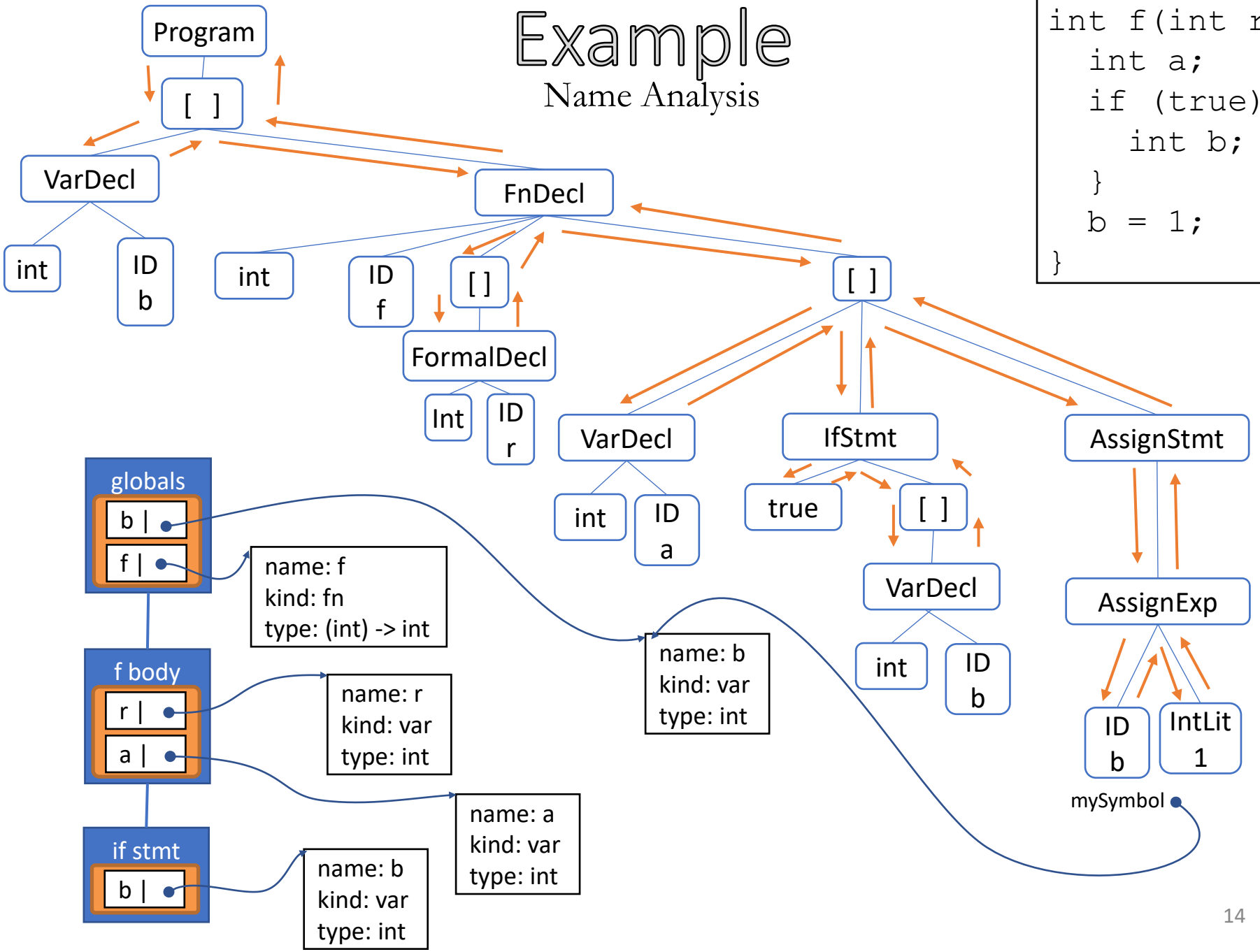
Semantic Analysis - Name Analysis

- Walk the AST, much like the unparse() method
  - Augment AST nodes with a link to the relevant name in the symbol table
  - Build new entries into the symbol table when a declaration is encountered
  - Connect AST nodes to the entry they add or reference in the symbol table

Example

Name Analysis

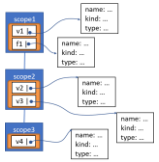
```
int b;
int f(int r){
  int a;
  if (true){
    int b;
  }
  b = 1;
}
```



(My) Terminology

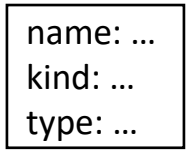
Name Analysis - Implementation

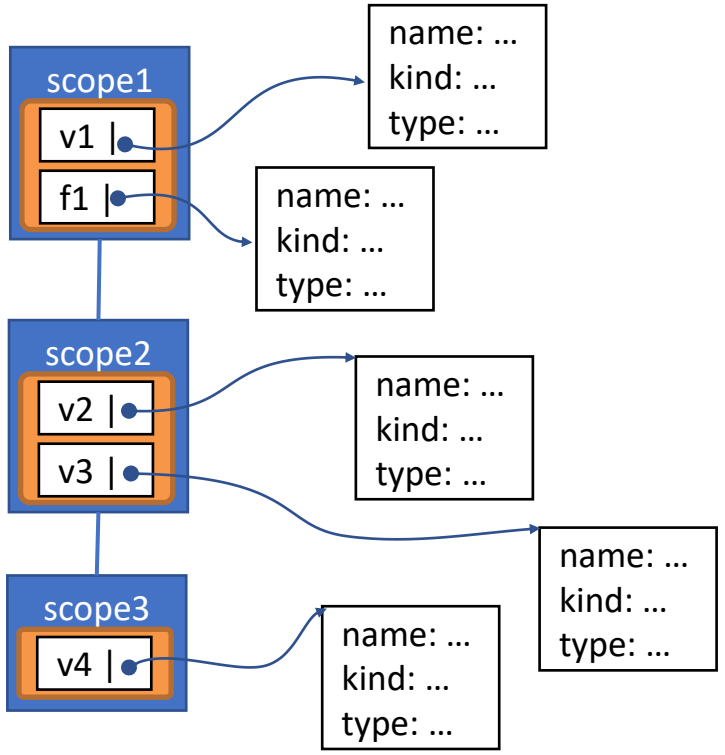
- Symbol Table – the whole structure



- Scope Table – A single map

- Symbol Table Entry (AKA “Semantic Symbol”)





Implementation Suggestions

Name Analysis - Implementation

Two approaches

- A nameAnalysis method for each ASTNode subclass
  - Override as appropriate
- The use of the visitor pattern

The Visitor Pattern

Name Analysis - Implementation

```
class ASTNode {
  public void unparse(…) = 0;
  public bool nameAnalysis(…) = 0;
  public void typeAnalysis(…) = 0;
};
class PlusNode : public ExpNode {
  public void unparse(…){ … }
  public bool nameAnalysis(…){ … }
  public void typeAnalysis(…){ … }
};
class FnDeclNode : public ASTNode {
 public void unparse(…){ … }
  public bool nameAnalysis(…){ … }
  public void typeAnalysis(…){ … }
};
```

```
class ASTNode {
  public void visit(Visitor * v){ … }
};
class PlusNode : public ASTNode {
  public void visit(Visitor * v){ … }
};
class FnDeclNode : public ASTNode {
  public void visit(Visitor * v){ … }
};
```

The Visitor Pattern

Name Analysis - Implementation

```
class PlusNode : public ExpNode {
  public void unparse (…){
    myLHS->unparse();
    out << "+";
    myRHS->unparse();
  }
};
```

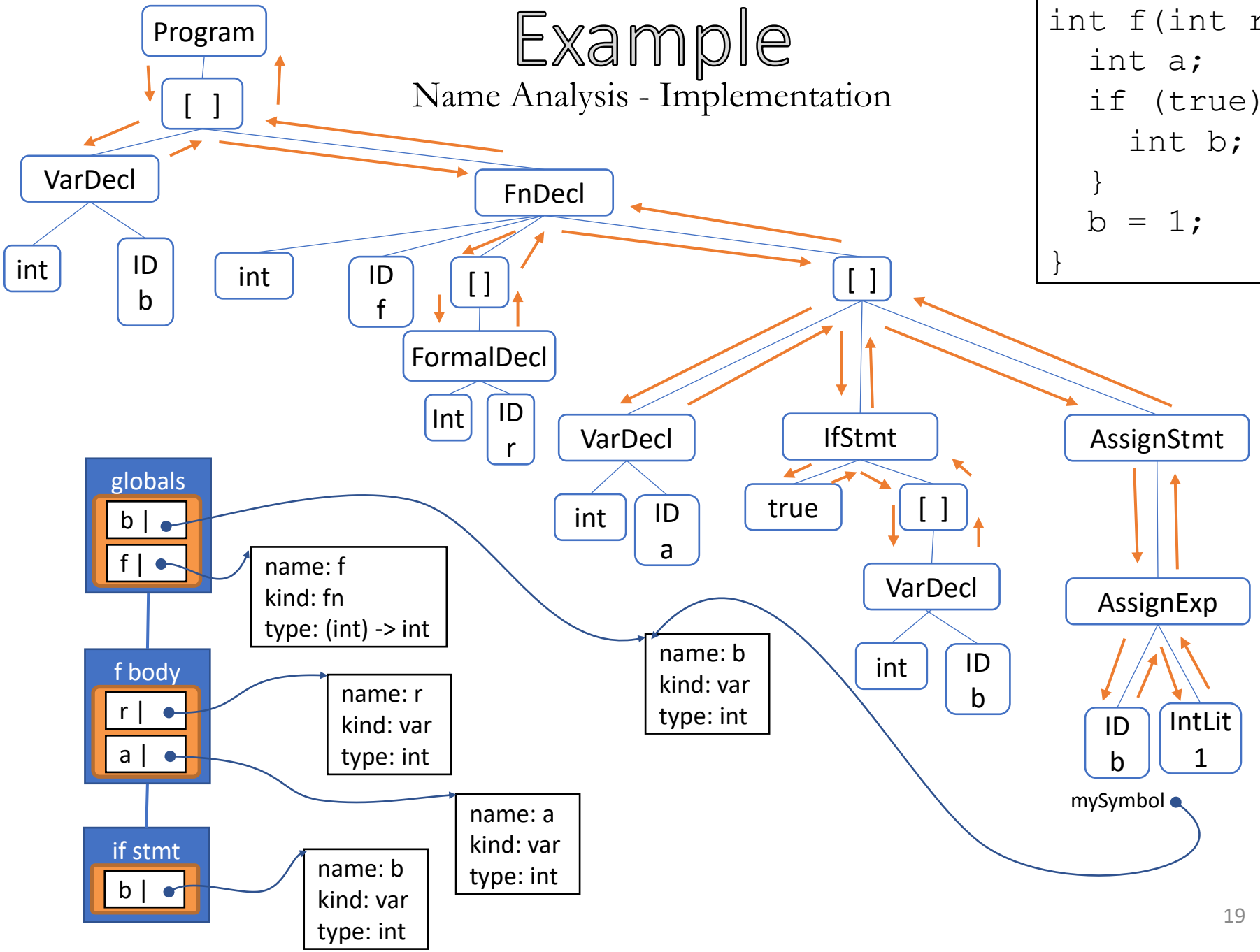
```
class PlusNode {
  void visit(Visitor * v) {
    myLHS->visit(v);
    v->visitPlus(this);
    myRHS->visit(v);
  }
}

class UnparseVisitor {
  void visitPlus(PlusNode * n) {
    out << "+";
  }
}
```

Example

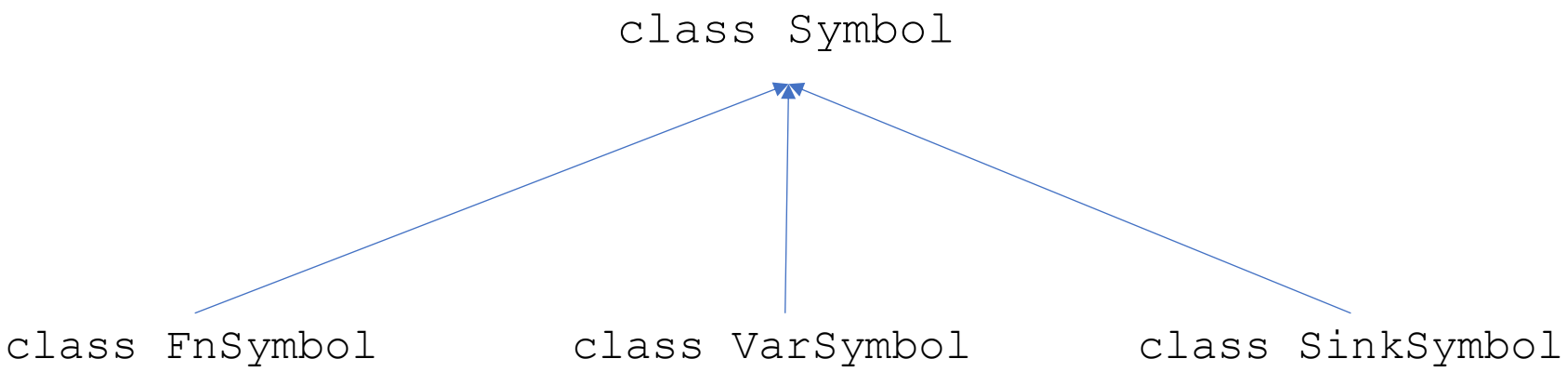
Name Analysis - Implementation

```
int b;
int f(int r){
  int a;
  if (true){
    int b;
  }
  b = 1;
}
```



The Symbol Class Hierarchy (Drew's Version)

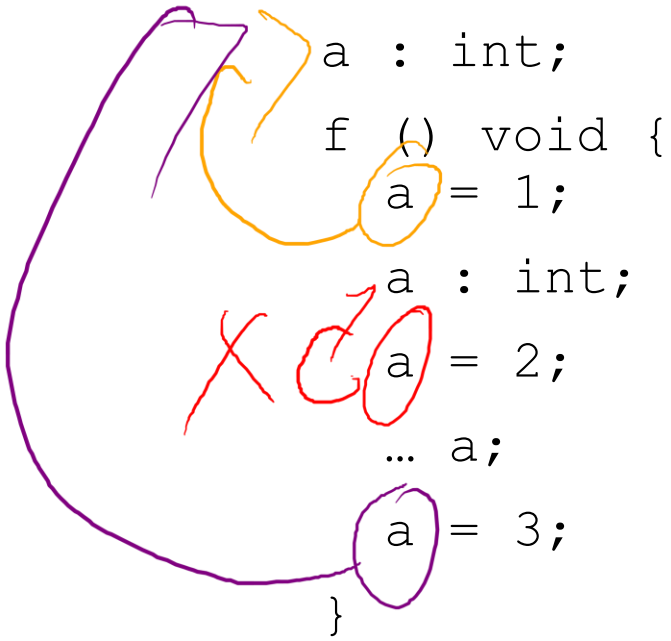
Name Analysis – Implementation

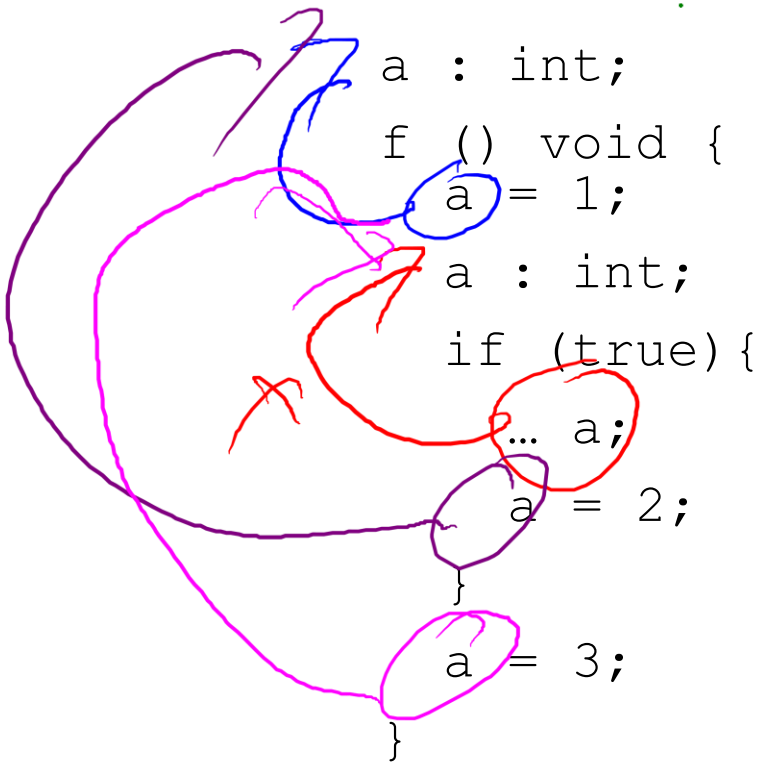


The Sink Statement

Name Analysis – Implementation

- A sort-of-unique situation

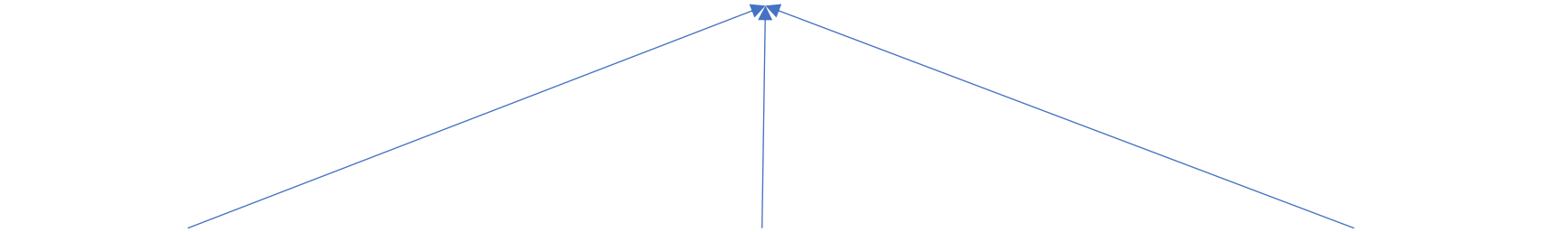




Accommodating Sink (Drew's Version)

Name Analysis – Implementation

```
class Symbol {
  SinkSymbol * sunkBy;
};
```



```
class FnSymbol
```

```
class VarSymbol
```

```
class SinkSymbol {
  Symbol * sinks;
};
```

The Sink Statement: Suggestion

Name Analysis – Implementation

```
a : int;
f () void {
  a = 1;
  a : int;
  if (true){
    … a;
    a = 2;
  }
  a = 3;
}
```

Summary

Name Analysis – Wrap-Up

- Described an analysis for enforcing static scoping
- Demonstrated a way to implement the analysis as a walk over the AST

Next Time

Name Analysis – Wrap-Up

Type Systems

- What type systems are
- Why we use them
- The type system for our language