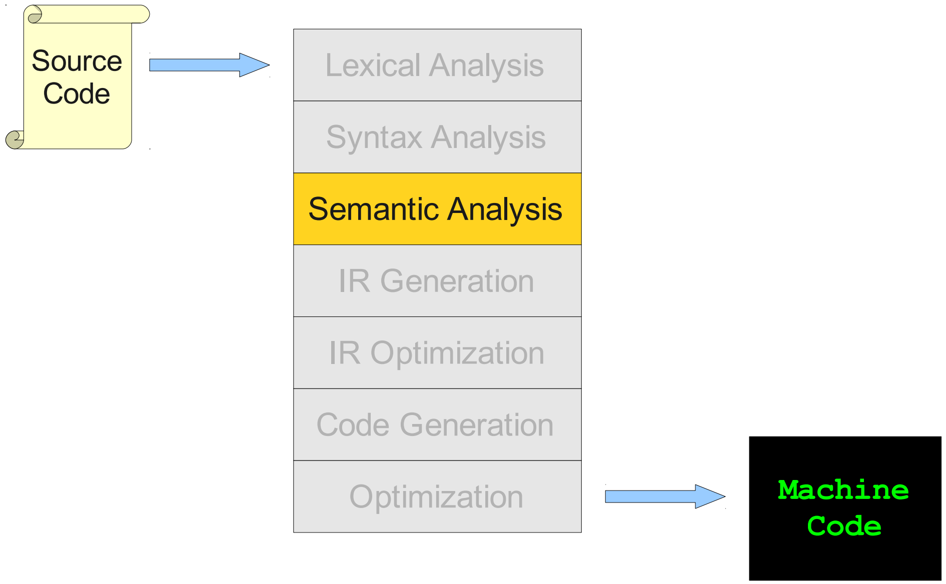
Symbol Tables and Scope Checking

Where We Are



Where We Are

- Program is **lexically** well-formed:
  - Identifiers have valid names.
  - Strings are properly terminated.
  - No stray characters.
- Program is **syntactically** well-formed:
  - Class declarations have the correct structure.
  - Expressions are syntactically valid.
- Does this mean that the program is **legal**?

Beyond Syntax Errors

- What's wrong with this C code? (Note: it parses correctly)

- Undeclared identifier
- Multiply declared identifier
- Index out of bounds
- Wrong number or types of arguments to function call
- Incompatible types for operation
- break statement outside switch/loop
- goto with no label

```
foo(int a, char * s){...}

int bar() {
  int f[3];
  int i, j, k;
  char q, *p;
  float k;
  foo(f[6], 10, j);
  break;
  i->val = 42;
  j = m + k;
  printf("%s,%s.\n",p,q);
  goto label42;
}
```

Semantic Analysis

- Ensure that the program has a well-defined meaning.
- Verify properties of the program that aren't caught during the earlier phases:
  - Variables are declared before they're used.
  - Expressions have the right types.
  - …
- Once we finish semantic analysis, we know that the user's input program is legal.

Challenges in Semantic Analysis

- Reject the largest number of incorrect programs.
- Accept the largest number of correct programs.
- Do so quickly.

Other Goals of Semantic Analysis

- Gather useful information about program for later phases:
  - Determine what variables are meant by each identifier.
  - Build an internal representation of inheritance hierarchies.
  - Count how many variables are in scope at each point.

Scope Checking

What's in a Name?

- The same name in a program may refer to fundamentally different things:
- This is **perfectly legal** Java code:

```
public class Name {
    int Name;
    Name Name(Name Name) {
        Name.Name = 137;
        return Name((Name) Name);
    }
}
```

What's in a Name?

- The same name in a program may refer to fundamentally different things:
- This is **perfectly legal** Java code:

```
public class Name {
    int Name;
    Name Name(Name Name) {
        Name.Name = 137;
        return Name((Name) Name);
    }
}
```

What's in a Name?

- The same name in a program may refer to completely different objects:
- This is **perfectly legal** C++ code:

```
int Awful() {
   int x = 137;
   {
      string x = "Scope!"
      if (float x = 0)
         double x = x;
   }
   if (x == 137) cout << "Y";
}
```

What's in a Name?

- The same name in a program may refer to completely different objects:
- This is **perfectly legal** C++ code:

```
int Awful() {
   int x = 137;
   {
      string x = "Scope!"
      if (float x = 0)
         double x = x;
   }
   if (x == 137) cout << "Y";
}
```

Scope

- The **scope** of an entity is the set of locations in a program where its name refers to itself.
- The introduction of new variables into scope may hide older variables.
- How do we keep track of what's visible?

Symbol Tables

- A **symbol table** is a mapping from a name to the thing that name refers to.
- As we run our semantic analysis, continuously update the symbol table with information about what is in scope.
- Questions:
  - What does this look like in practice?
  - What operations need to be defined on it?
  - How do we implement it?

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Tables: The Intuition

Symbol Table

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Tables: The Intuition

```
int x = 137;
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int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Table

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Table	
x	0

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Table	
x	0

Symbol Tables: The Intuition

```
int x = 137;
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int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Table	
x	0
z	1

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Table	
x	0
z	1

Symbol Tables: The Intuition

```
int x = 137;
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int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Table	
x	0
z	1

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Table	
x	0
z	1
x	2
y	2

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
  }
}
```

Symbol Table	
x	0
z	1
x	2
y	2

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
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}
```

Symbol Table	
x	0
z	1
x	2
y	2

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x, y, z);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
    printf("%d,%d,%d\n", x, y, z);
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```

Symbol Table	
x	0
z	1
x	2
y	2

Symbol Tables: The Intuition

```
int x = 137;
int z = 42;
int MyFunction(int x, int y) {
  printf("%d,%d,%d\n", x @2, y@2, z@1);
  {
    int x, z;
    z = y;
    x = z;
    {
      int y = x;
      {
        printf("%d,%d,%d\n", x, y, z);
      }
      printf("%d,%d,%d\n", x, y, z);
    }
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Symbol Table	
x	0
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x	2
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Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5

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    z = y;
    x = z;
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      int y = x;
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Symbol Table	
x	0
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x	2
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x	0
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x	0
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Symbol Tables: The Intuition

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 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
 3:   printf("%d,%d,%d\n", x@2, y@2, z@1);
 4:   {
 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x;
10:       {
11:         printf("%d,%d,%d\n", x, y, z);
12:       }
13:       printf("%d,%d,%d\n", x, y, z);
14:     }
15:     printf("%d,%d,%d\n", x, y, z);
16:   }
17: }
```

Symbol Table	
x	0
z	1
x	2
y	2
x	5
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Symbol Tables: The Intuition

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 0: int x = 137;
 1: int z = 42;
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 6:     z = y@2;
 7:     x = z@5;
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Symbol Table	
x	0
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```

Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5
y	9

Symbol Tables: The Intuition

```
 0: int x = 137;
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 3:   printf("%d,%d,%d\n", x@2, y@2, z@1);
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 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x@5;
10:       {
11:         printf("%d,%d,%d\n", x, y, z);
12:       }
13:       printf("%d,%d,%d\n", x, y, z);
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Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5
y	9

Symbol Tables: The Intuition

```
 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
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 4:   {
 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x@5;
10:       {
11:         printf("%d,%d,%d\n", x, y, z);
12:       }
13:       printf("%d,%d,%d\n", x, y, z);
14:     }
15:     printf("%d,%d,%d\n", x, y, z);
16:   }
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Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5
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Symbol Tables: The Intuition

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 0: int x = 137;
 1: int z = 42;
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 4:   {
 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x@5;
10:       {
11:         printf("%d,%d,%d\n", x, y, z);
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Symbol Table	
x	0
z	1
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Symbol Tables: The Intuition

```
 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
 3:   printf("%d,%d,%d\n", x@2, y@2, z@1);
 4:   {
 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x@5;
10:       {
11:         printf("%d,%d,%d\n", x, y, z);
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14:     }
15:     printf("%d,%d,%d\n", x, y, z);
16:   }
17: }
```

Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5
y	9

Symbol Tables: The Intuition

```
 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
 3:   printf("%d,%d,%d\n", x@2, y@2, z@1);
 4:   {
 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x@5;
10:       {
11:         printf("%d,%d,%d\n", x@5, y@9, z@5);
12:       }
13:       printf("%d,%d,%d\n", x, y, z);
14:     }
15:     printf("%d,%d,%d\n", x, y, z);
16:   }
17: }
```

Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5
y	9

Symbol Tables: The Intuition

```
 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
 3:   printf("%d,%d,%d\n", x@2, y@2, z@1);
 4:   {
 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x@5;
10:       {
11:         printf("%d,%d,%d\n", x@5, y@9, z@5);
12:       }
13:       printf("%d,%d,%d\n", x, y, z);
14:     }
15:     printf("%d,%d,%d\n", x, y, z);
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```

Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5
y	9

Symbol Tables: The Intuition

```
 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
 3:   printf("%d,%d,%d\n", x@2, y@2, z@1);
 4:   {
 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x@5;
10:       {
11:         printf("%d,%d,%d\n", x@5, y@9, z@5);
12:       }
13:       printf("%d,%d,%d\n", x, y, z);
14:     }
15:     printf("%d,%d,%d\n", x, y, z);
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```

Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5
y	9

Symbol Tables: The Intuition

```
 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
 3:   printf("%d,%d,%d\n", x@2, y@2, z@1);
 4:   {
 5:     int x, z;
 6:     z = y@2;
 7:     x = z@5;
 8:     {
 9:       int y = x@5;
10:       {
11:         printf("%d,%d,%d\n", x@5, y@9, z@5);
12:       }
13:       printf("%d,%d,%d\n", x, y, z);
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15:     printf("%d,%d,%d\n", x, y, z);
16:   }
17: }
```

Symbol Table	
x	0
z	1
x	2
y	2
x	5
z	5
y	9

Symbol Tables: The Intuition

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Symbol Table	
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y	2
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Symbol Table	
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x	5
z	5

Symbol Tables: The Intuition

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Symbol Table	
x	0
z	1
x	2
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Symbol Table	
x	0
z	1
x	2
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Symbol Tables: The Intuition

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15:     printf("%d,%d,%d\n", x@5, y@2, z@5);
16:   }
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```

Symbol Table	
x	0
z	1
x	2
y	2

Symbol Tables: The Intuition

```
 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
 3:   printf("%d,%d,%d\n", x@2, y@2, z@1);
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17: }
```

Symbol Table	
x	0
z	1

Symbol Tables: The Intuition

```
 0: int x = 137;
 1: int z = 42;
 2: int MyFunction(int x, int y) {
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14:     }
15:     printf("%d,%d,%d\n", x@5, y@2, z@5);
16:   }
17: }
```

Symbol Table	
x	0
z	1

Symbol Table Operations

- Typically implemented as a **stack of tables**.
- Each table corresponds to a particular scope.
- Stack allows for easy “enter” and “exit” operations.
- Symbol table operations are
  - **Push scope**: Enter a new scope.
  - **Pop scope**: Leave a scope, discarding all declarations in it.
  - **Insert symbol**: Add a new entry to the current scope.
  - **Lookup symbol**: Find what a name corresponds to.

Using a Symbol Table

- To process a portion of the program that creates a scope (block statements, function calls, classes, etc.)
  - Enter a new scope.
  - Add all variable declarations to the symbol table.
  - Process the body of the block/function/class.
  - Exit the scope.
- Much of semantic analysis is defined in terms of recursive AST traversals like this.

Another View of Symbol Tables

Another View of Symbol Tables

```
int x;
int y;
int MyFunction(int x, int y)
{
  int w, z;
  {
    int y;
  }
  {
    int w;
  }
}
```

Another View of Symbol Tables

Root Scope

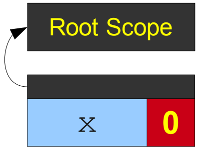
```
int x;
int y;
int MyFunction(int x, int y)
{
  int w, z;
  {
    int y;
  }
  {
    int w;
  }
}
```

Another View of Symbol Tables

Root Scope

```
int x;
int y;
int MyFunction(int x, int y)
{
  int w, z;
  {
    int y;
  }
  {
    int w;
  }
}
```

Another View of Symbol Tables

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int x;
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    int w;
  }
}
```

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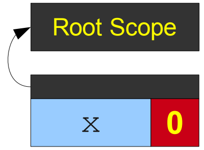


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```

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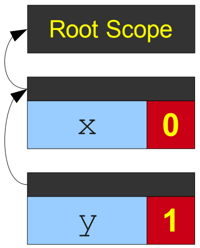


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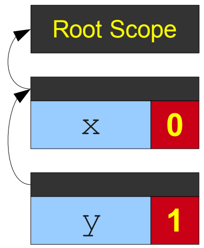


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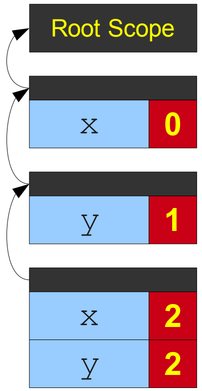

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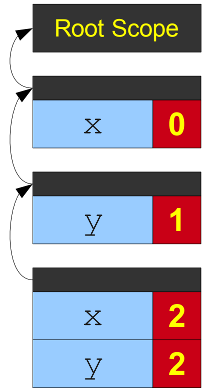

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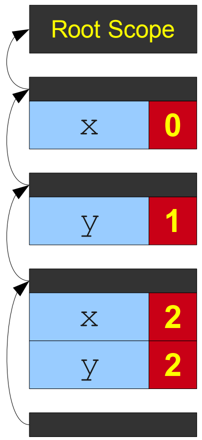

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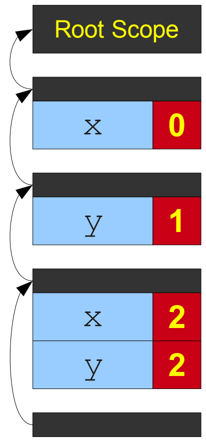

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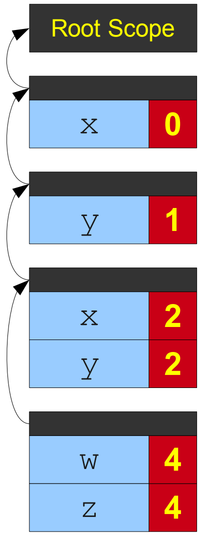

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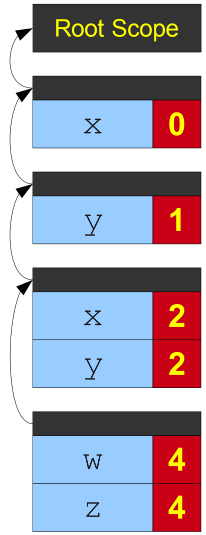

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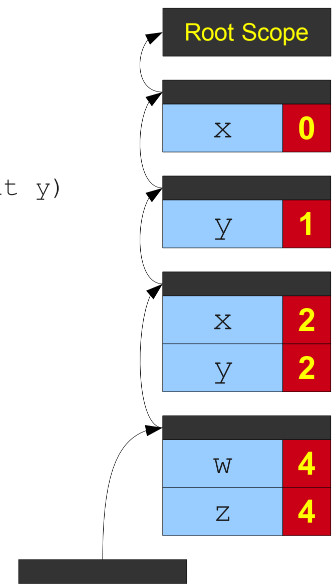

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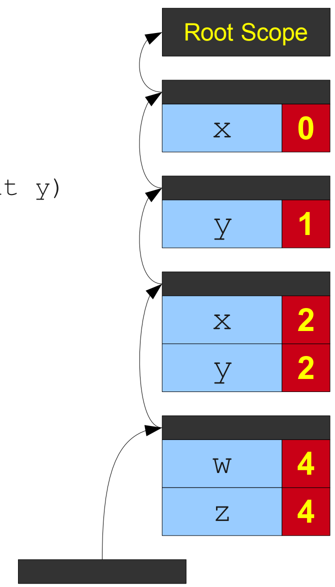

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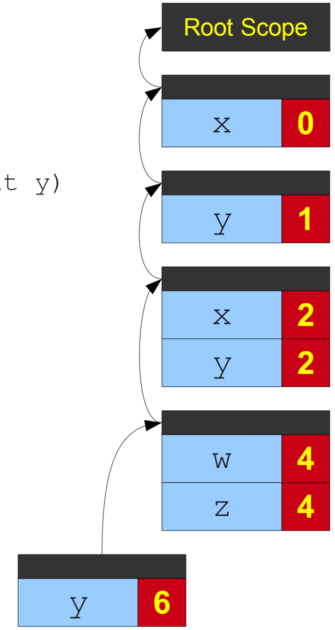

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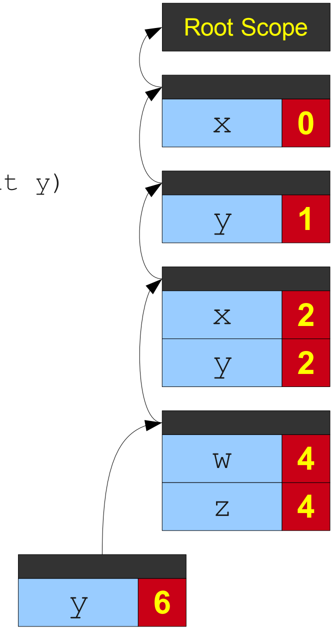

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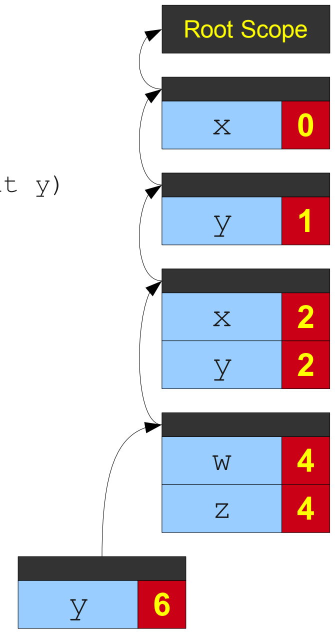

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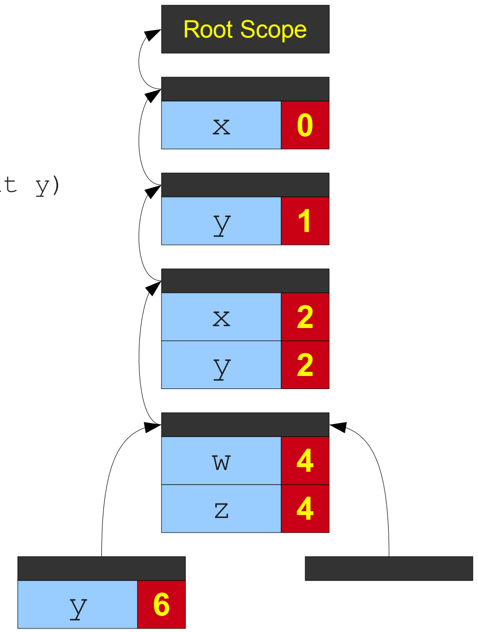

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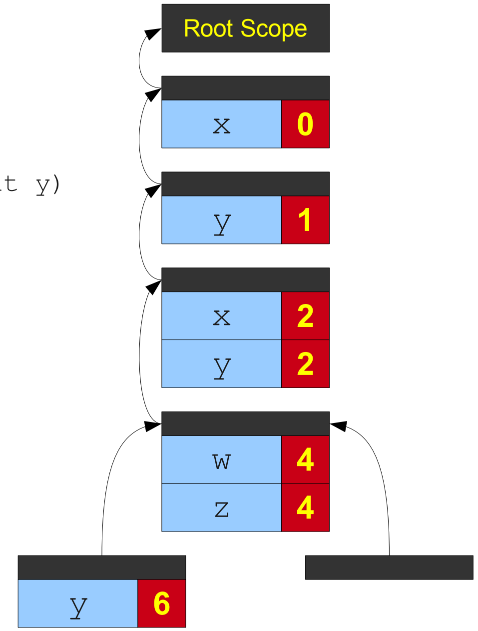

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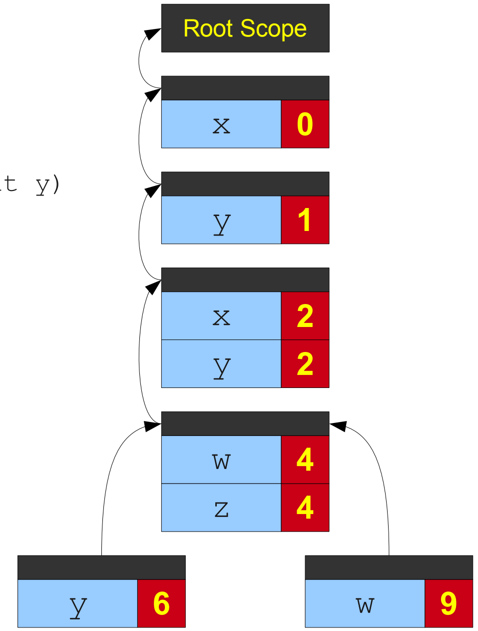

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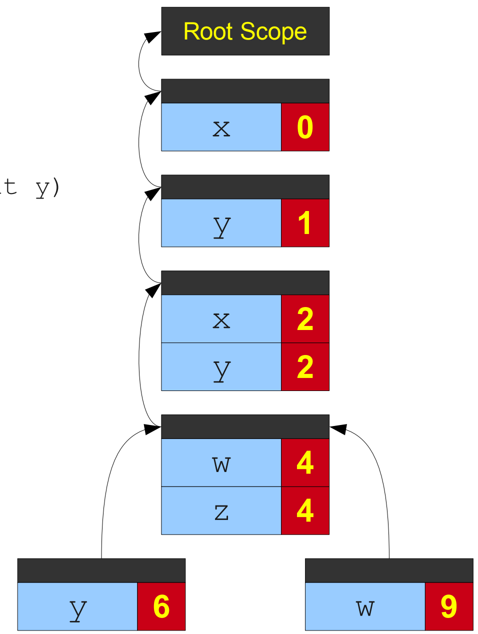

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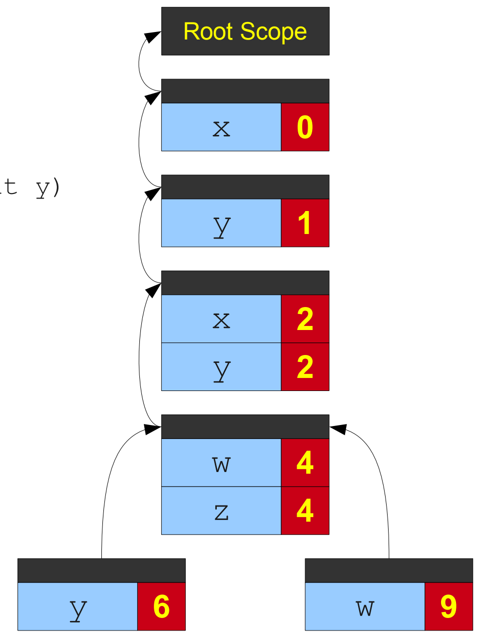

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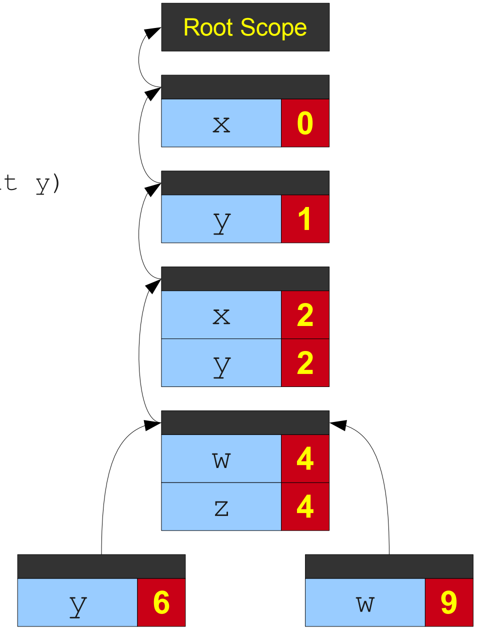

Spaghetti Stacks

- Treat the symbol table as a linked structure of scopes.
- Each scope stores a pointer to its parents, but not vice-versa.
- From any point in the program, symbol table appears to be a stack.
- This is called a **spaghetti stack**.

Why Two Interpretations?

- Spaghetti stack more accurately captures the scoping structure.
- Spaghetti stack is a **static** structure; explicit stack is a **dynamic** structure.
- Explicit stack is an optimization of a spaghetti stack; more on that later.

Scoping in Object-Oriented Languages

Scoping with Inheritance

```
public class Base {
    public int publicBaseInt = 1;
    protected int baseInt = 2;
}
```

Scoping with Inheritance


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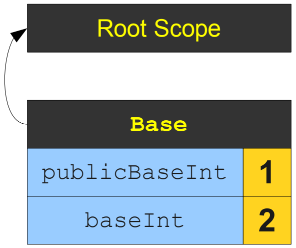
Scoping with Inheritance




```
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    public int publicBaseInt = 1;
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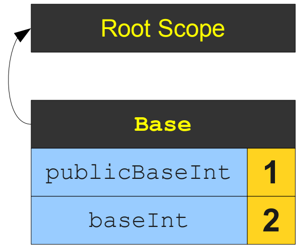
```

Scoping with Inheritance




```
public class Base {
    public int publicBaseInt = 1;
    protected int baseInt = 2;
}

public class Derived extends Base {
    public int derivedInt = 3;
    public int publicBaseInt = 4;

    public void doSomething() {
        System.out.println(publicBaseInt);
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

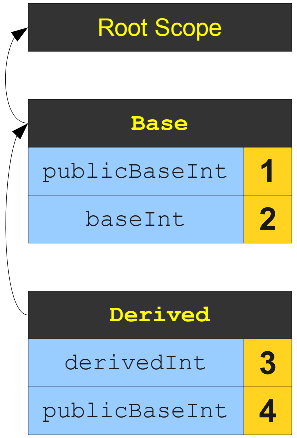
Scoping with Inheritance

```
public class Base {
    public int publicBaseInt = 1;
    protected int baseInt = 2;
}

public class Derived extends Base {
    public int derivedInt = 3;
    public int publicBaseInt = 4;

    public void doSomething() {
        System.out.println(publicBaseInt);
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```



Scoping with Inheritance

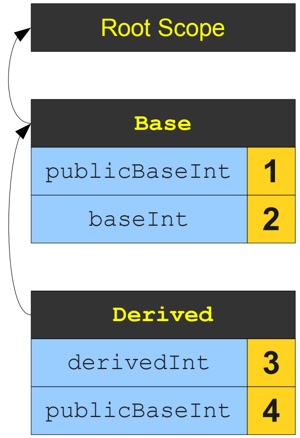
```
public class Base {
    public int publicBaseInt = 1;
    protected int baseInt = 2;
}

public class Derived extends Base {
    public int derivedInt = 3;
    public int publicBaseInt = 4;

    public void doSomething() {
        System.out.println(publicBaseInt);
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
>
```



Scoping with Inheritance

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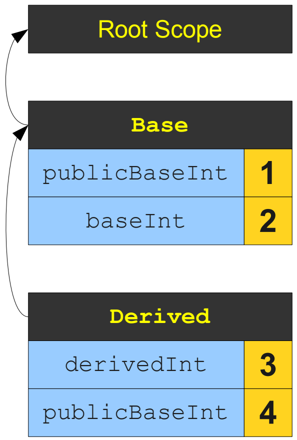
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
>
```



Scoping with Inheritance

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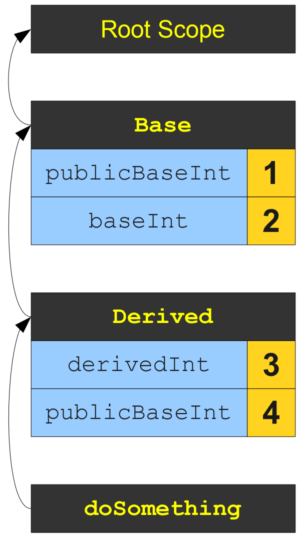
        System.out.println(publicBaseInt);
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
>
```



Scoping with Inheritance

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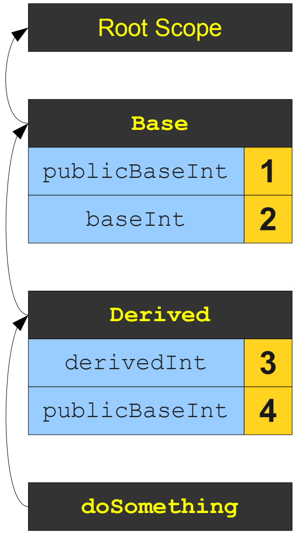
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
>
```



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}

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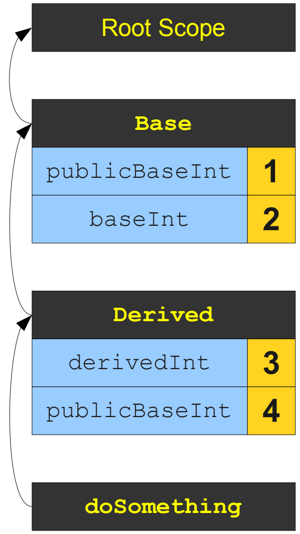
        System.out.println(publicBaseInt);
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
> 4
```



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```
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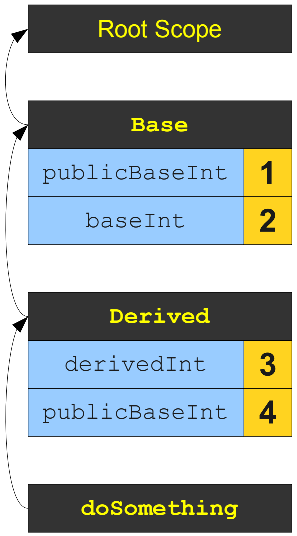
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
> 4
```



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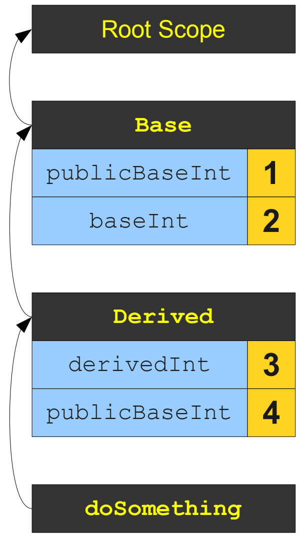
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
> 4
  2
```



Scoping with Inheritance

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}

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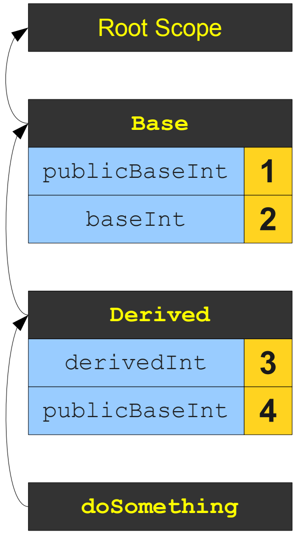
    public void doSomething() {
        System.out.println(publicBaseInt);
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
> 4
  2
```



Scoping with Inheritance

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}

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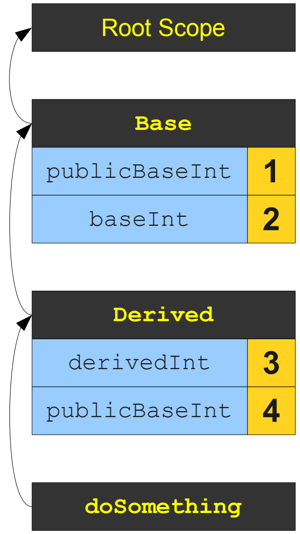
        System.out.println(publicBaseInt);
        System.out.println(baseInt);
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
> 4
  2
  3
```



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        int publicBaseInt = 6;
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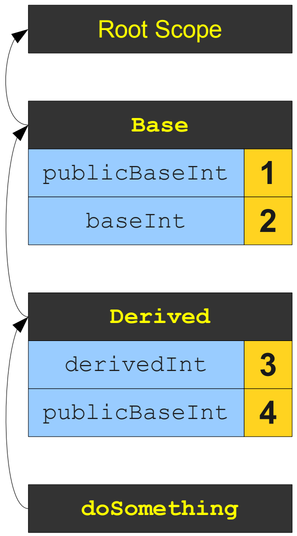
    }
}
```

```
> 4
  2
  3
```



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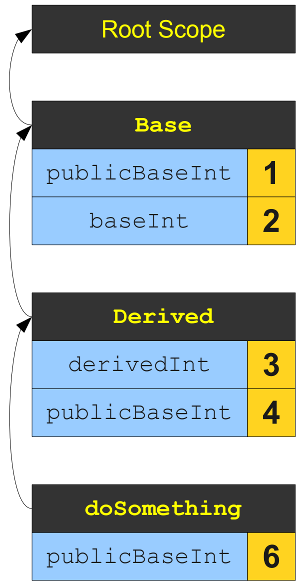
        System.out.println(derivedInt);

        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
> 4
  2
  3
```



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        int publicBaseInt = 6;
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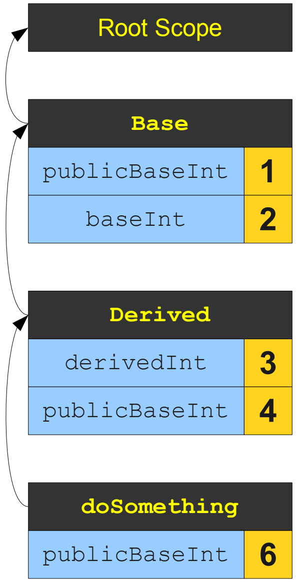
    }
}
```

```
> 4
  2
  3
```



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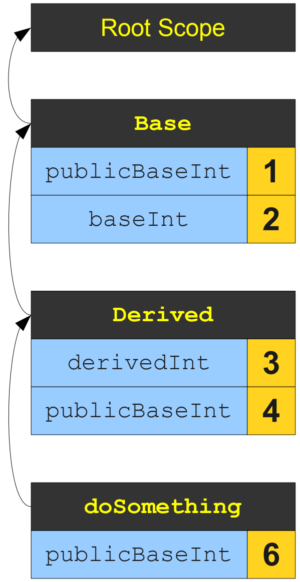
    }
}
```

```
> 4
  2
  3
  6
```



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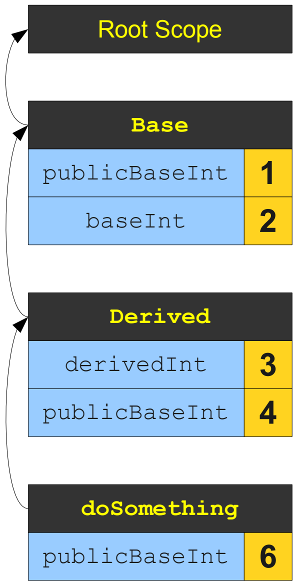
        int publicBaseInt = 6;
        System.out.println(publicBaseInt);
    }
}
```

```
> 4
  2
  3
  6
```



Inheritance and Scoping

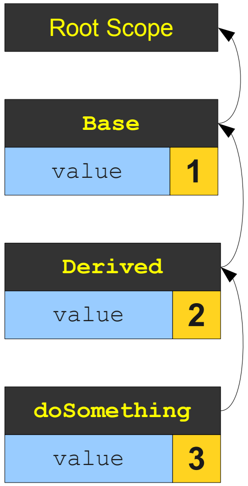
- Typically, the scope for a derived class will store a link to the scope of its base class.
- Looking up a field of a class traverses the scope chain until that field is found or a semantic error is found.

Explicit Disambiguation

```
public class Base {
    public int value = 1;
}

public class Derived extends Base {
    public int value = 2;

    public void doSomething() {
        int value = 3;
        System.out.println(value);
        System.out.println(this.value);
        System.out.println(super.value);
    }
}
```



Explicit Disambiguation

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}

public class Derived extends Base {
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    public void doSomething() {
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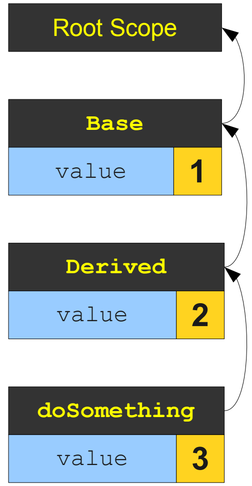
        System.out.println(this.value);
        System.out.println(super.value);
    }
}
```



Explicit Disambiguation

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        System.out.println(this.value);
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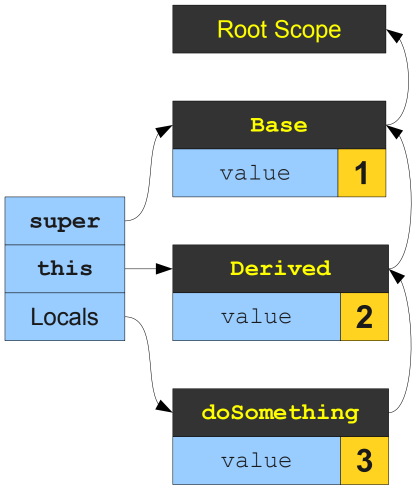
    }
}
```



Explicit Disambiguation

```
public class Base {
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        System.out.println(this.value);
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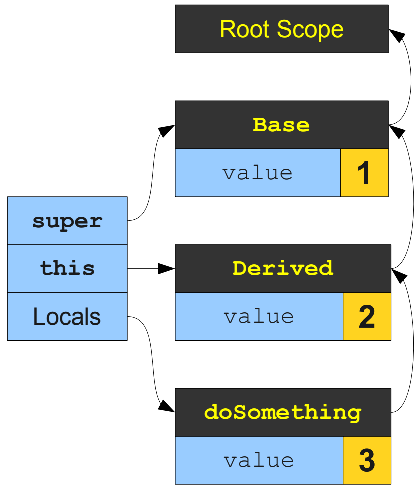
    }
}
```



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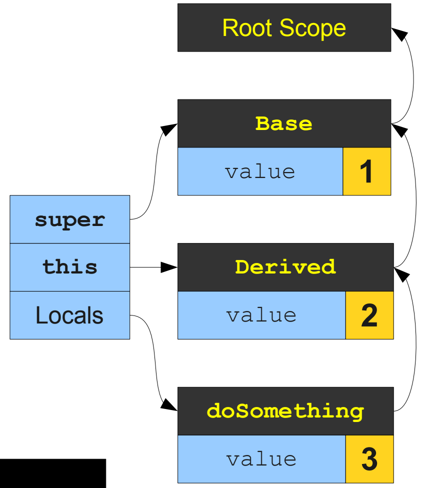


```
>
```

Explicit Disambiguation

```
public class Base {
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        int value = 3;
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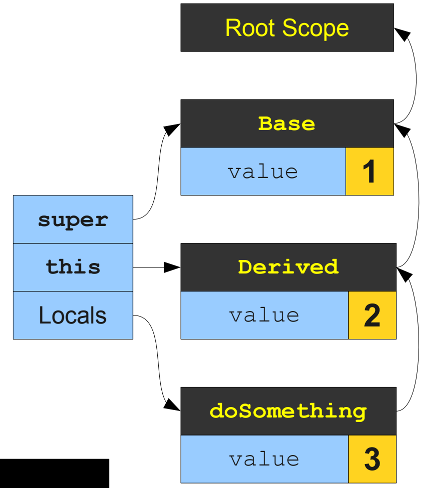


```
>
```

Explicit Disambiguation

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        System.out.println(value);
        System.out.println(this.value);
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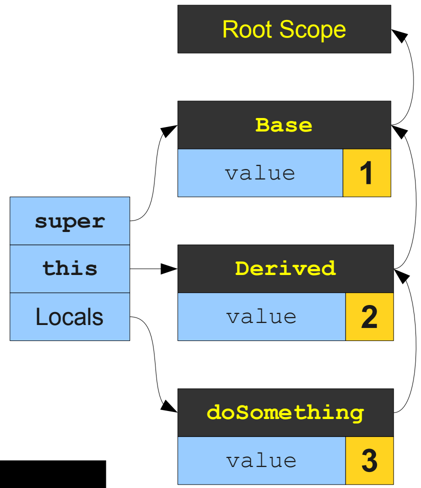


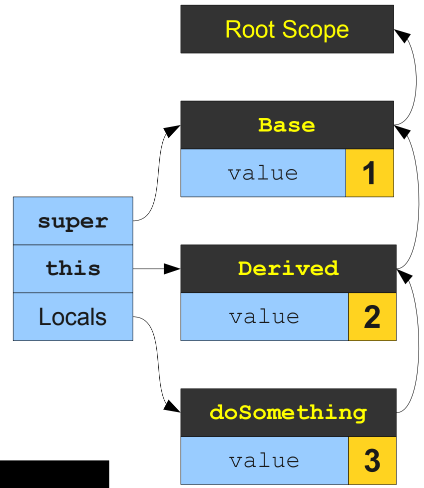

```
> 3
```

Explicit Disambiguation

```
public class Base {
    public int value = 1;
}

public class Derived extends Base {
    public int value = 2;

    public void doSomething() {
        int value = 3;
        System.out.println(value);
        System.out.println(this.value);
        System.out.println(super.value);
    }
}
```




```
> 3
```

Explicit Disambiguation

```
public class Base {
    public int value = 1;
}

public class Derived extends Base {
    public int value = 2;

    public void doSomething() {
        int value = 3;
        System.out.println(value);
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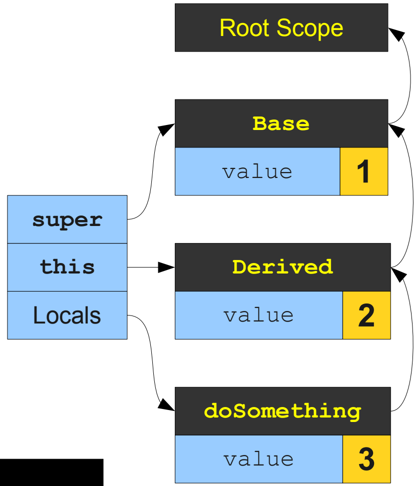
    }
}
```




```
> 3
  2
```

Explicit Disambiguation

```
public class Base {
    public int value = 1;
}

public class Derived extends Base {
    public int value = 2;

    public void doSomething() {
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        System.out.println(value);
        System.out.println(this.value);
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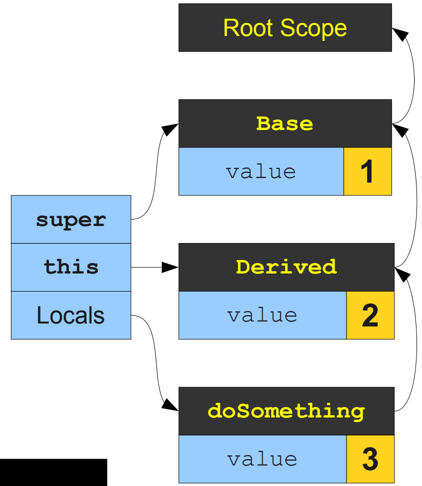
```




```
> 3
  2
```

Explicit Disambiguation

```
public class Base {
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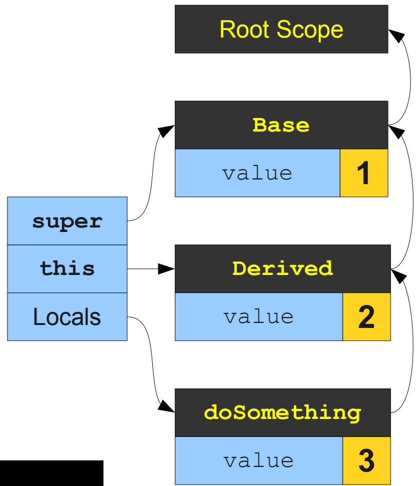


```
> 3
  2
  1
```

Explicit Disambiguation

```
public class Base {
    public int value = 1;
}

public class Derived extends Base {
    public int value = 2;

    public void doSomething() {
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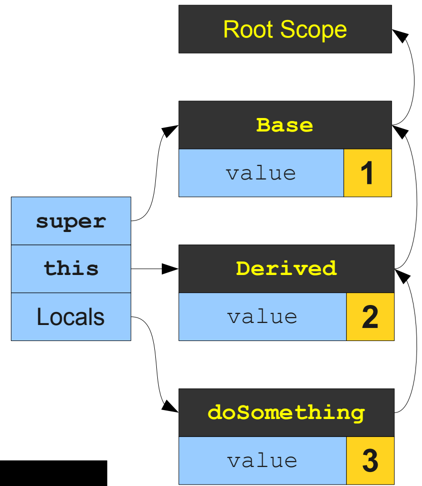


```
> 3
  2
  1
```

Disambiguating Scopes

- Maintain a second table of pointers into the scope stack.
- When looking up a value in a specific scope, begin the search from that scope.
- Some languages allow you to jump up to any arbitrary base class (for example, C++).

Scoping in Practice

Scoping in C++ and Java

```
class A {
public:
    /* … */

private:
    B* myB
};

class B {
public:
    /* … */

private:
    A* myA;
};
```

```
class A {
    private B myB;
};

class B {
    private A myA;
};
```

Scoping in C++ and Java

```
class A {
public:
    /* … */

private:
    B* myB
};

class B {
public:
    /* … */

private:
    A* myA;
};
```

Error: B not declared

```
class A {
    private B myB;
};

class B {
    private A myA;
};
```

Perfectly fine!

Single- and Multi-Pass Compilers

- Our predictive parsing methods always scan the input from left-to-right.
  - **L**L(1), **L**R(0), LA**L**R(1), etc.
- Since we only need one token of lookahead, we can do scanning and parsing simultaneously in one pass over the file.
- Some compilers can combine scanning, parsing, semantic analysis, and code generation into the same pass.
  - These are called **single-pass compilers**.
- Other compilers rescan the input multiple times.
  - These are called **multi-pass compilers**.

Single- and Multi-Pass Compilers

- Some languages are designed to support single-pass compilers.
  - e.g. C, C++.
- Some languages **require** multiple passes.
  - e.g. Java, C#.
- Most modern compilers use a huge number of passes over the input.

Scoping in Multi-Pass Compilers

- Completely parse the input file into an abstract syntax tree (first pass).
- Walk the AST, gathering information about classes (second pass).
- Walk the AST checking other properties (third pass).
- Could combine some of these, though they are logically distinct.

Scoping with Multiple Inheritance

```
class A {
public:
    int x;
};

class B {


};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance


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class A {
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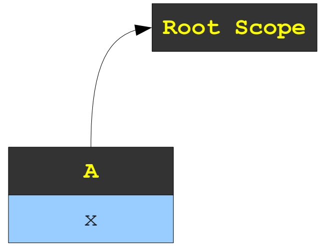
Scoping with Multiple Inheritance

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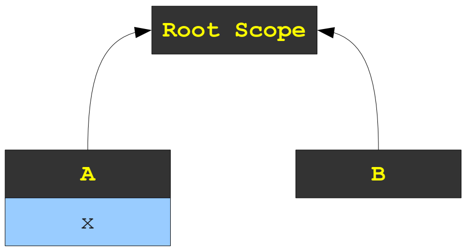
Scoping with Multiple Inheritance

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};

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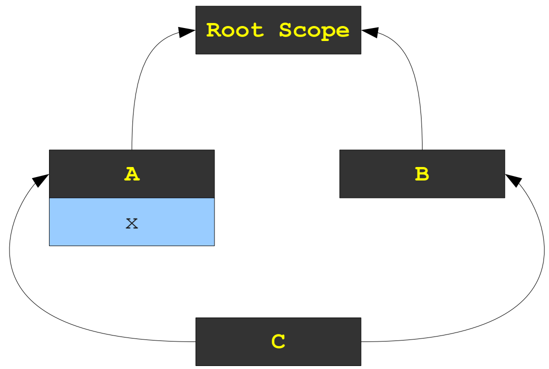
    }
}
```

Scoping with Multiple Inheritance

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};

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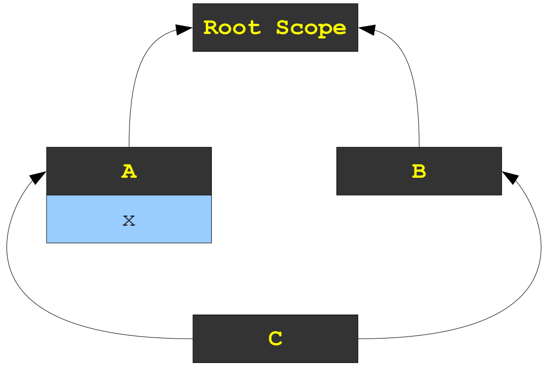
}
```

Scoping with Multiple Inheritance

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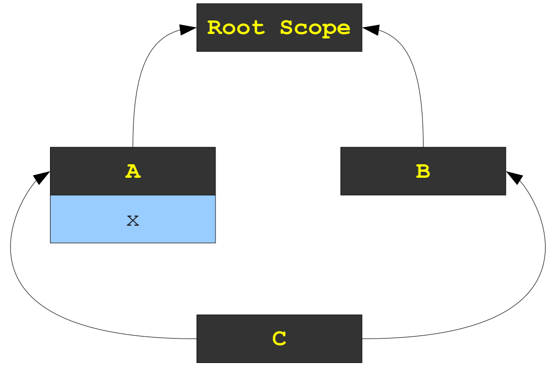
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance

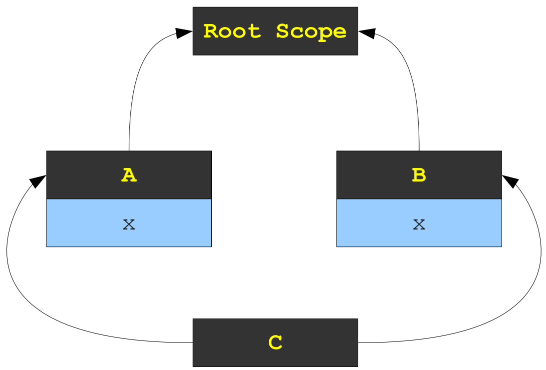



```
class A {
public:
    int x;
};

class B {
public:
    int x;
};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance

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class A {
public:
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public:
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};

class C: public A, public B {
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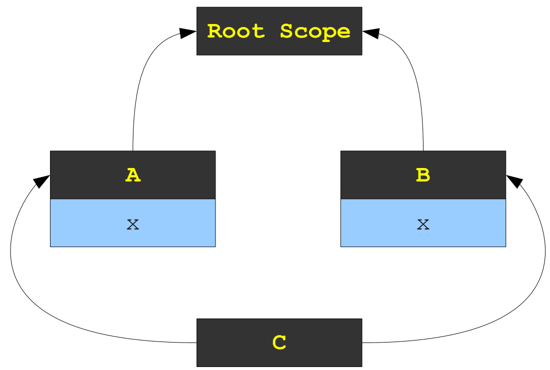
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance

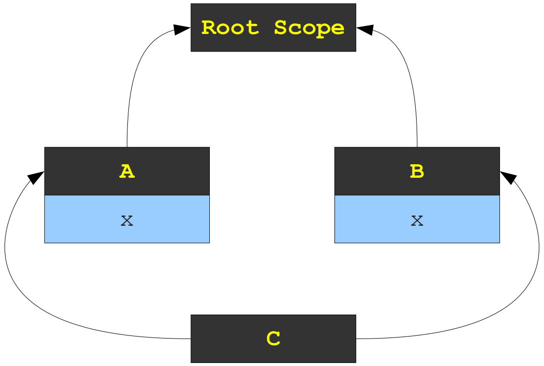



```
class A {
public:
    int x;
};

class B {
public:
    int x;
};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance



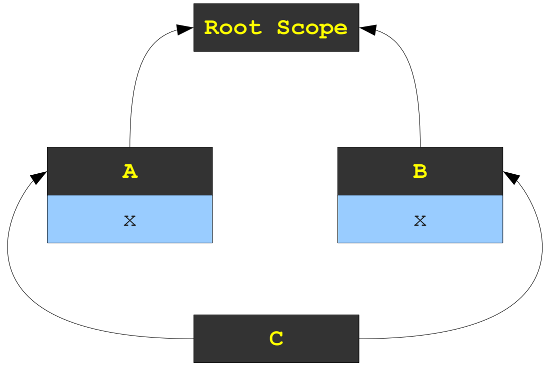

```
class A {
public:
    int x;
};

class B {
public:
    int x;
};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Ambiguous – which x?

Scoping with Multiple Inheritance

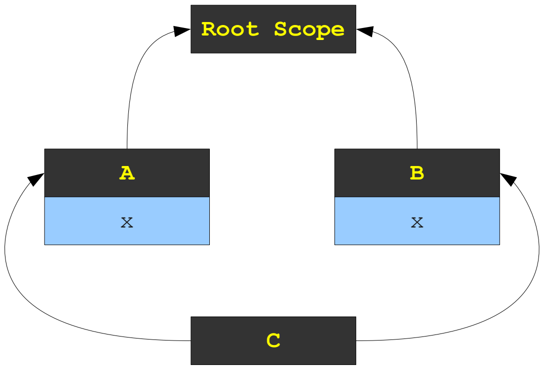



```
class A {
public:
    int x;
};

class B {
public:
    int x;
};

class C: public A, public B {
public:
    void doSomething() {
        cout << A::x << endl;
    }
}
```

Scoping with Multiple Inheritance

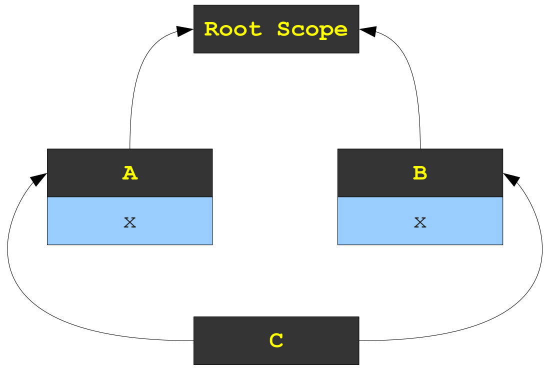



```
class A {
public:
    int x;
};

class B {
public:
    int x;
};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance



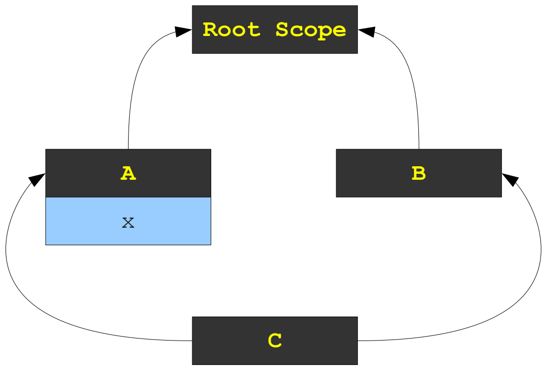

```
class A {
public:
    int x;
};

class B {


};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance



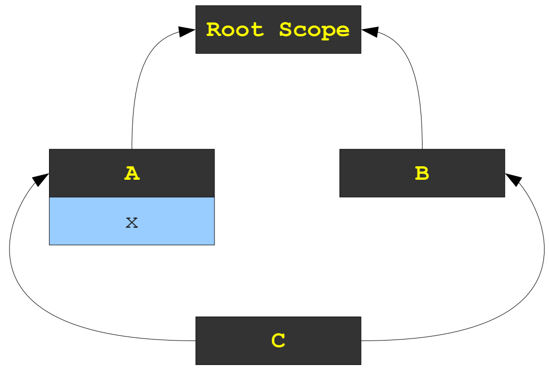

```
class A {
public:
    int x;
};

class B {


};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance




```
int x;

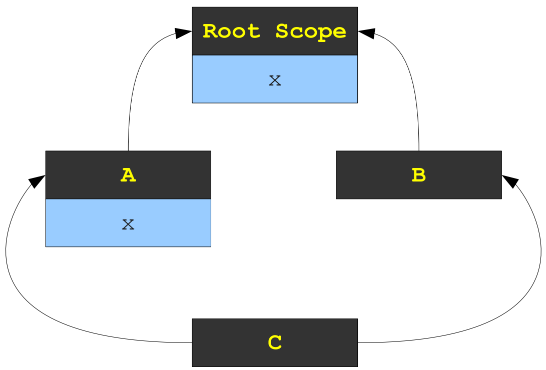
class A {
public:
    int x;
};

class B {


};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance




```
int x;

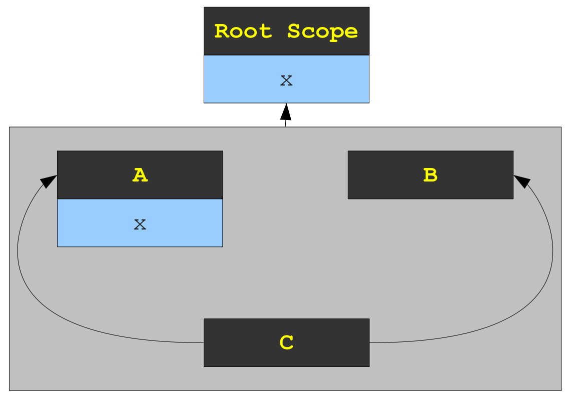
class A {
public:
    int x;
};

class B {


};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

Scoping with Multiple Inheritance




```
int x;

class A {
public:
    int x;
};

class B {


};

class C: public A, public B {
public:
    void doSomething() {
        cout << x << endl;
    }
}
```

(Simplified) C++ Scoping Rules

- Inside of a class, search the entire class hierarchy to see the set of names that can be found.
  - This uses the standard scoping lookup.
- If only one name is found, the lookup succeeds unambiguously.
- If more than one name is found, the lookup is ambiguous and requires disambiguation.
- Otherwise, restart the search from outside the class.

Summary

- **Semantic analysis** verifies that a syntactically valid program is correctly-formed and computes additional information about the meaning of the program.
- **Scope checking** determines what objects or classes are referred to by each name in the program.
- Scope checking is usually done with a **symbol table** implemented either as an **explicit stack** or a **spaghetti stack**.
- In object-oriented programs, the scope for a derived class is often placed inside of the scope of a base class.
- Some semantic analyzers operate in multiple passes in order to gain more information about the program.
- With multiple inheritance, a name may need to be searched for along multiple paths.