The Use and I:
Transitivity of Module Uses and its Impact

Lydia Duncan, Cray Inc.

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User Features

The Use and I: Transitive Uses

- **Symbols visible to B via a 'use' also visible:**
  - within C's main
  - other uses of B

```
module A {
 var bar = 13;
 proc foo() { … }
}
```

```
module B {
 use A;

 var baz = 19;
 proc flip(x: int) { … }
}
```

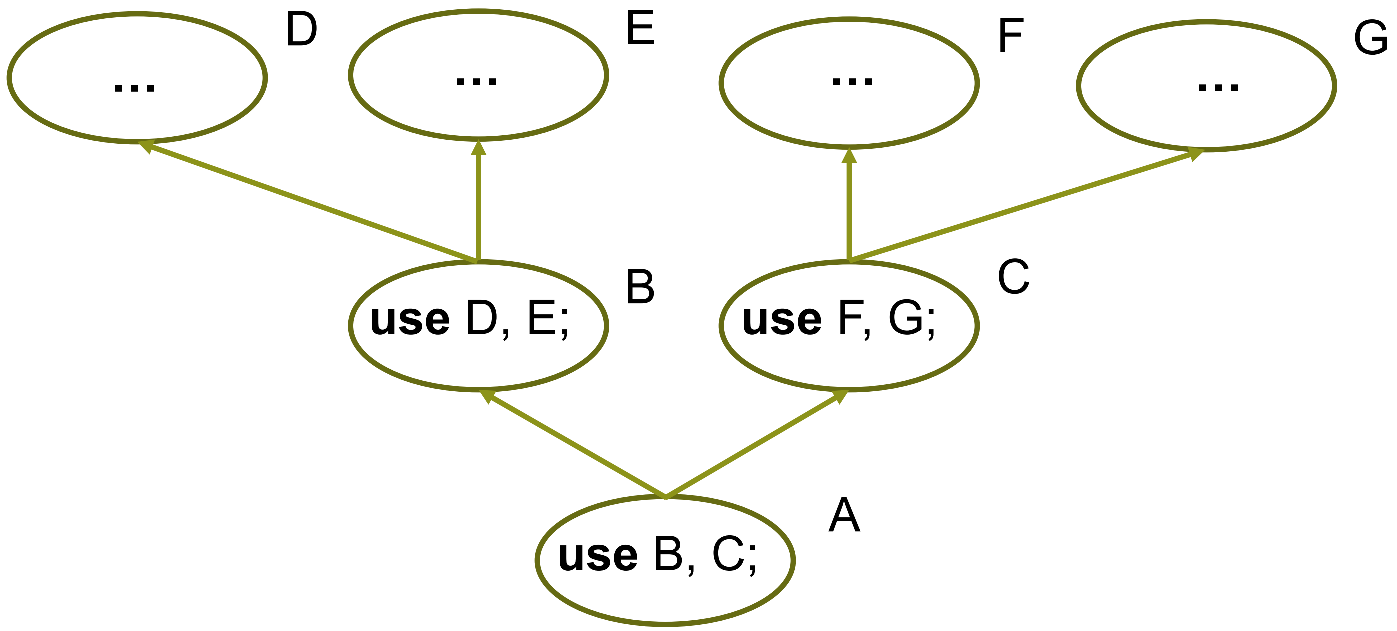
```
module C {
 var flop = 7;

 proc main() {
  use B;

  flip(bar);
 }
}
```

The Use and I: Transitive Uses

- **Symbols visible to B via a 'use' also visible to uses of B**
  - Best represented as a tree of 'use's



The Use and I: Transitive Uses

- **Symbols visible to B via a 'use' also visible to uses of B**
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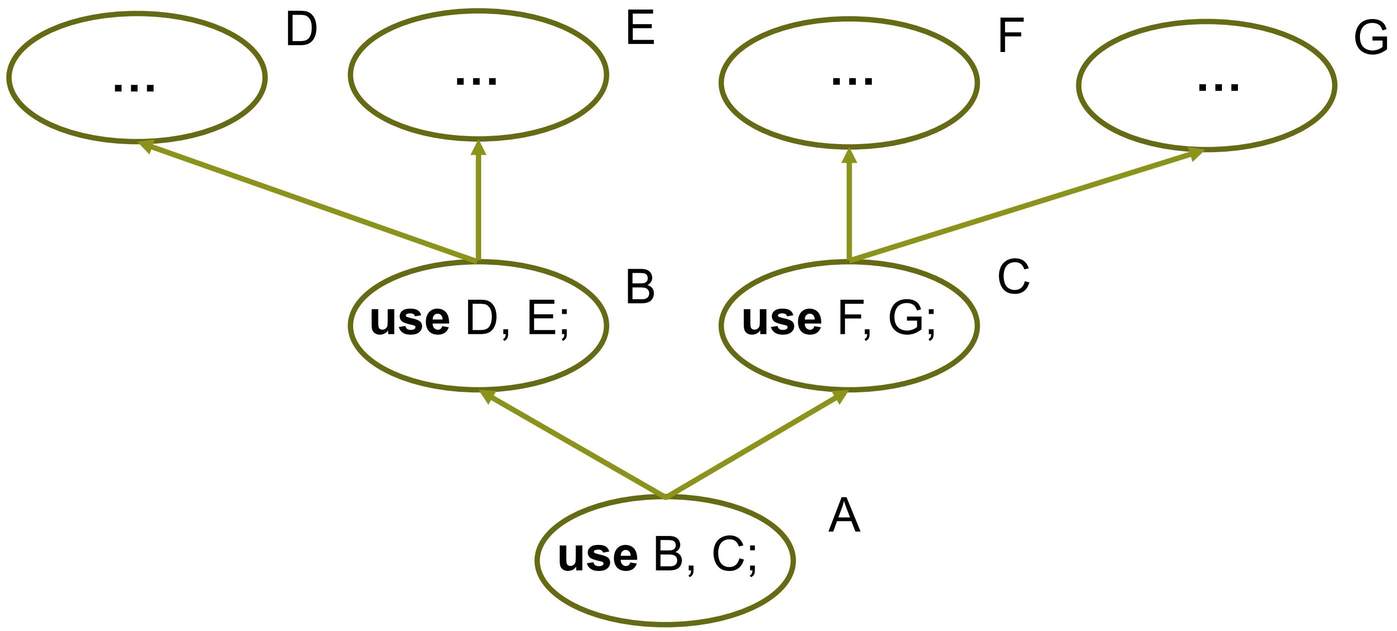
  - Each path in tree is a "use chain" (e.g. A->B->D, A->C->F)



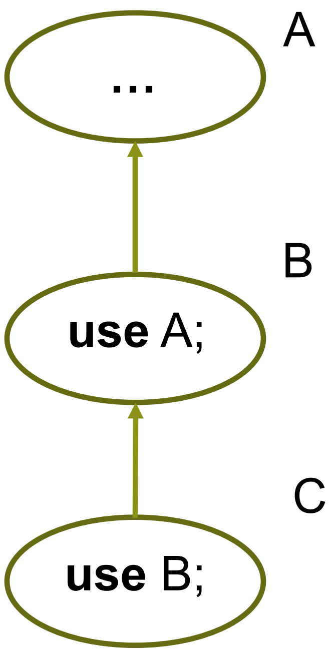
The Use and I: Transitive Uses

- **Symbols now visible to B also visible:**
  - within C's main
  - other uses of B

```
module A {
  var bar = 13;
  proc foo() { … }
}
```

```
module B {
  use A;

  var baz = 19;
  proc flip(x: int) { … }
}
```

```
module C {
  var flop = 7;

  proc main() {
    use B;

    flip(bar);
  }
}
```



The Use and I: Transitive Uses

- **Symbols visible to B via a 'use' also visible to uses of B**
  - Can avoid extra work

```
module A {
 class foo { … }
}
```

```
module B {
 use A;

 proc foo.bar() { … }
}
```

```
module C {
 proc main() {
  use B; // Instead of use A, B;

  var baz = new foo();
  // foo visible because B uses A
  baz.bar();
 }
}
```

The Use and I: Transitive Uses

- **Symbols visible to B via a 'use' also visible to uses of B**
  - Can avoid extra work
  - But can lead to unexpected issues
    - C's writer might not notice use of A

```
module A {
 var bar = 13;
 proc foo() { … }
}
```

```
module B {
 use A;

 var baz = 19;
 proc flip(x: int) { … }
}
```

```
module C {
 var bar = 7;

 proc main() {
  use B;

  flip(bar); // Finds A.bar, not C.bar
 }
}
```

The Use and I: Transitive Uses

- **Symbols visible to B via a 'use' also visible to uses of B**
  - Can avoid extra work
  - But can lead to unexpected issues
  - Same issues can occur with just B

```
module B {
 var bar = 19;
 proc flip(x: int) { … }
}
```

```
module C {
 var bar = 7;

 proc main() {
  use B;

  flip(bar); // Finds B.bar, not C.bar
 }
}
```

The Use and I: Import Control

- **Chapel 1.13 adds import control for use statements**
  - 'except' keyword prevents unqualified access to symbols in list

    ```
    use B except bar; // All of B's symbols other than bar can be named directly
    ```
  - 'only' keyword limits unqualified access to symbols in list

    ```
    use B only flip;     // Only B's flip can be named directly
    ```
  - Permits user to avoid importing unnecessary symbols
    - Including symbols which cause conflicts

```
module B {
 var bar = 19;
 proc flip(x: int) { … }
}
```

```
module C {
 var bar = 7;

 proc main() {
  use B except bar;

  flip(bar); // Finds C.bar, not B.bar
 }
}
```

  - Can rename imported symbols

    ```
    use B only bar as baz;
    // Can reference B.bar via baz
    ```

The Use and I: Import Control

- **Import control must affect all uses in use chain**
  - Would be equally incorrect to find A's bar or B's bar.

```
module A {
 var bar = 13;
 proc foo() { … }
}
```

```
module B {
 use A;

 var bar = 19;
 proc flip(x: int) { … }
}
```

```
module C {
 var bar = 7;

 proc main() {
  use B except bar;

  flip(bar); // Finds C.bar
 }
}
```

The Use and I: Import Control

- **Nested import control must be considered**
  - Shouldn't find symbols excluded by deeper import control

```
module A {
 var bar = 13;
 proc foo() { … }
}
```

```
module B {
 use A only foo;

 var goop = 19;
 proc flip(x: int) { … }
}
```

```
module C {
 var bar = 7;

 proc main() {
  use B except goop;

  flip(bar); // Finds C.bar
 }
}
```

The Use and I: Renaming

- Renaming a symbol should not allow access to old name

```
module A {
 var bar = 13;
 proc foo() { … }
}
```

```
module B {
 use A;

 var bar = 19;
 proc flip(x: int) { … }
}
```

```
module C {
 var bar = 7;

 proc main() {
  use B only bar as baz;

  flip(bar); // Finds C.bar
 }
}
```

The Use and I: Renaming

- **Renaming a symbol should not allow access to old name**
  - And nested renaming should not break this condition

```
module A {
 var bar = 13;
 proc foo() { … }
}
```

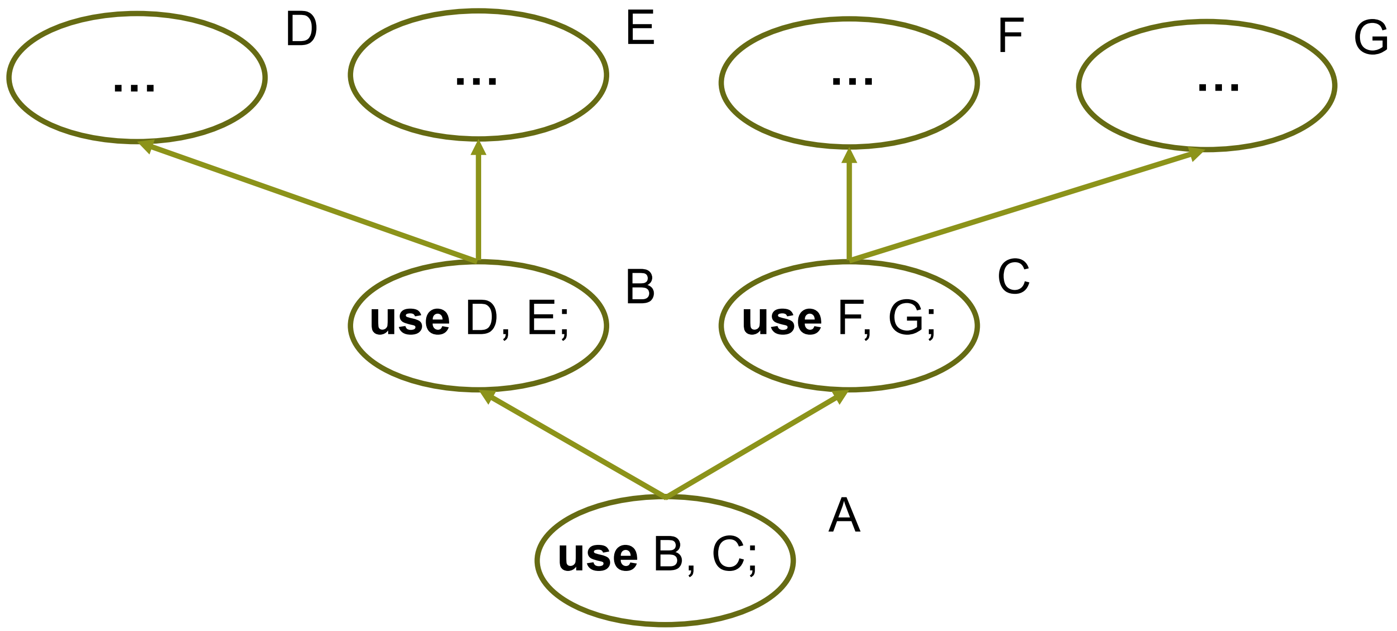
```
module B {
 use A only bar as baz;

 var goop = 19;
 proc flip(x: int) { … }
}
```

```
module C {
 var bar = 7;

 proc main() {
  use B only baz as biff;

  flip(bar); // Finds C.bar
 }
}
```

Compiler Implementation

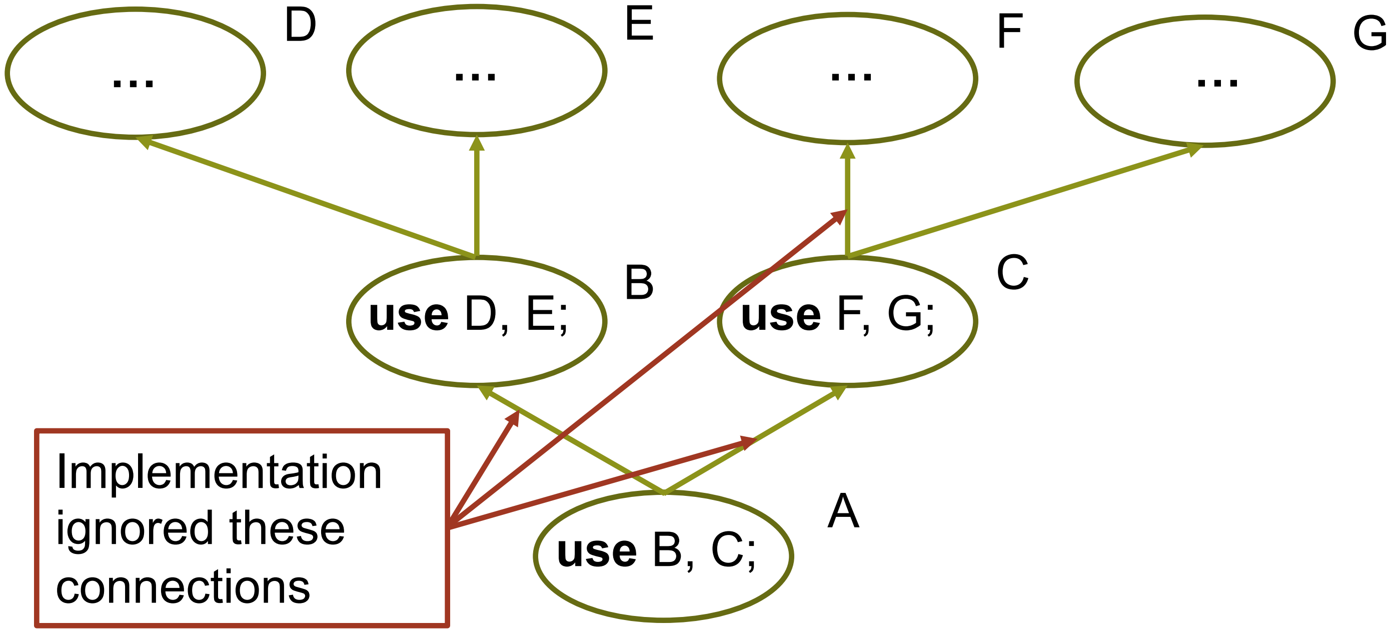
The Use and I: Transitive Uses

- **Symbols visible to B via a ‘use’ also visible to uses of B**
  - Best represented as a tree of ‘use’s
  - Each path in tree is a “use chain” (e.g. A->B->D, A->C->F)



The Use and I: Scope Resolve

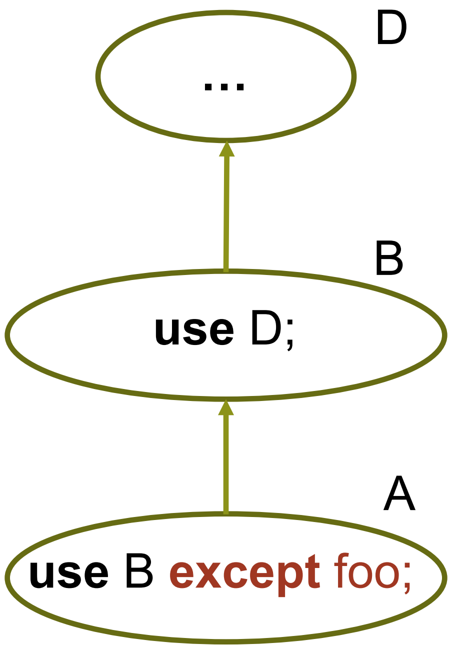
- **Scope resolution**
  - Handles variable, module name resolution
  - Traverses in breadth-first order
  - 'Use' tree built once per scope after module names resolved
    - Traversed many times



Traversal order:
- A
- <gap>
- B
- C
- <gap>
- D
- E
- F
- G
- …

The Use and I: Scope Resolve

- **With 'except' and 'only' keyword, 'use' chains matter more**
  - Earlier limits should affect search of later modules in chain
  - Need to apply these limits when creating 'use' tree



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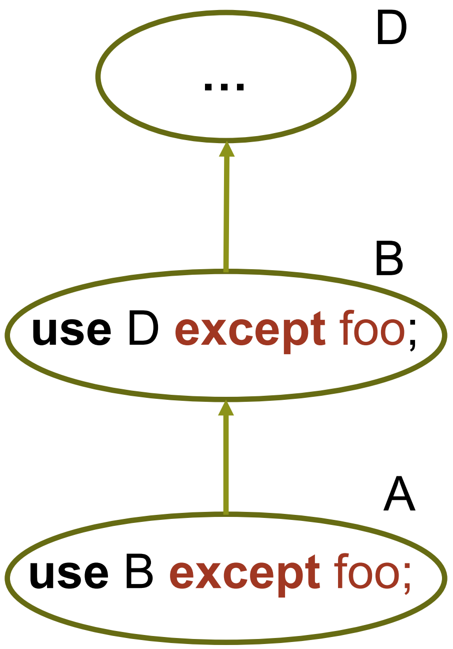
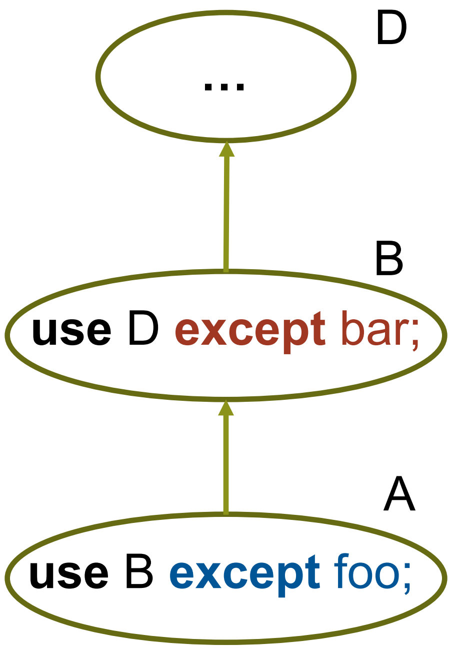


Note: In the case where B is 'use'd in multiple 'use' chains, these modifications should not be visible outside of the 'use' from A

The Use and I: Scope Resolve

- **With 'except' and 'only' keyword, 'use' chains matter more**
  - Earlier limits should affect search of later modules in chain
  - Need to apply these limits when creating 'use' tree
    - This can get tricky when multiple limits are present



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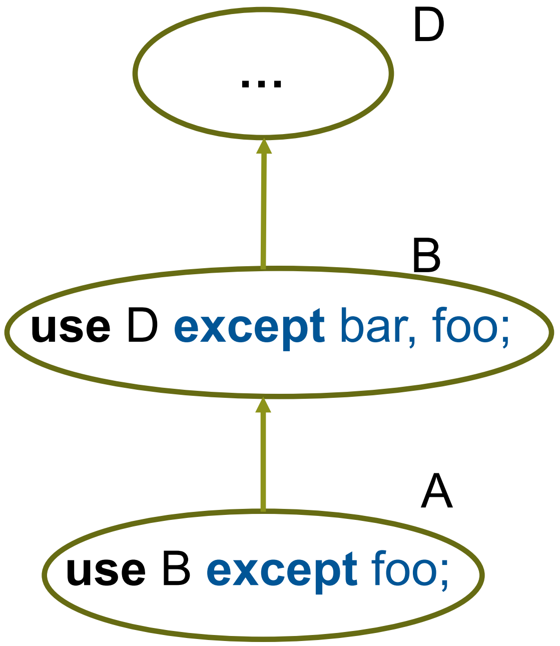
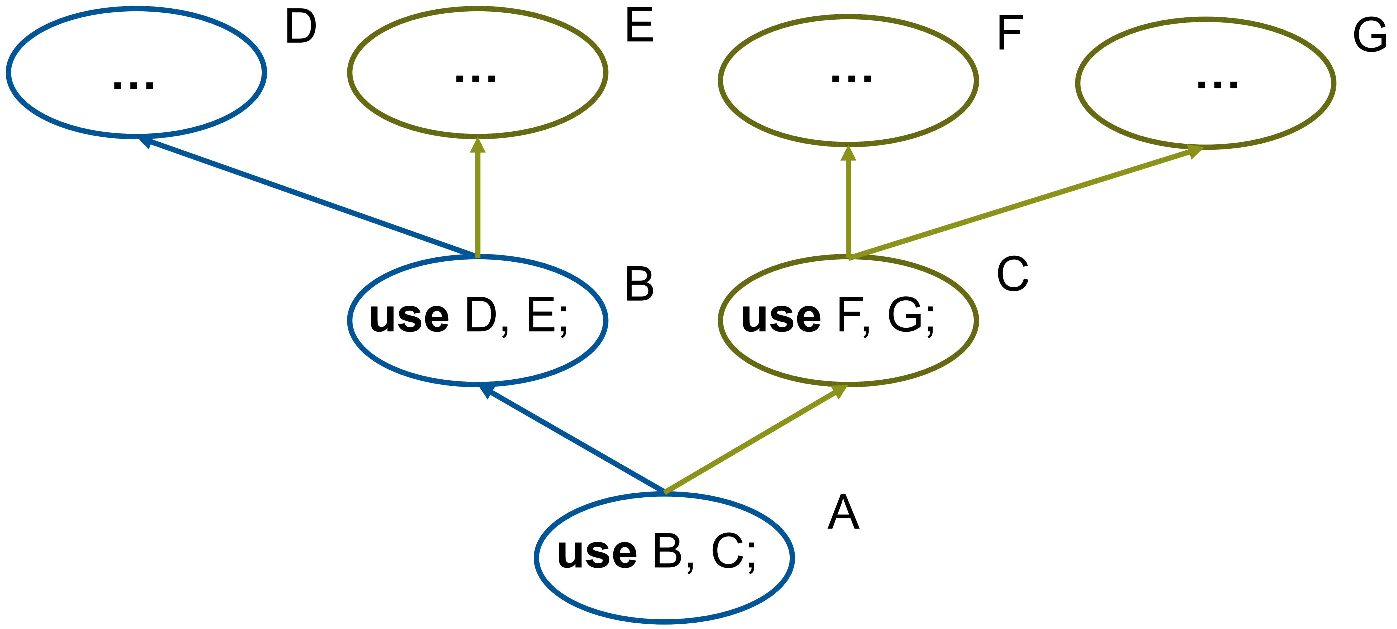


The Use and I: Function Resolution

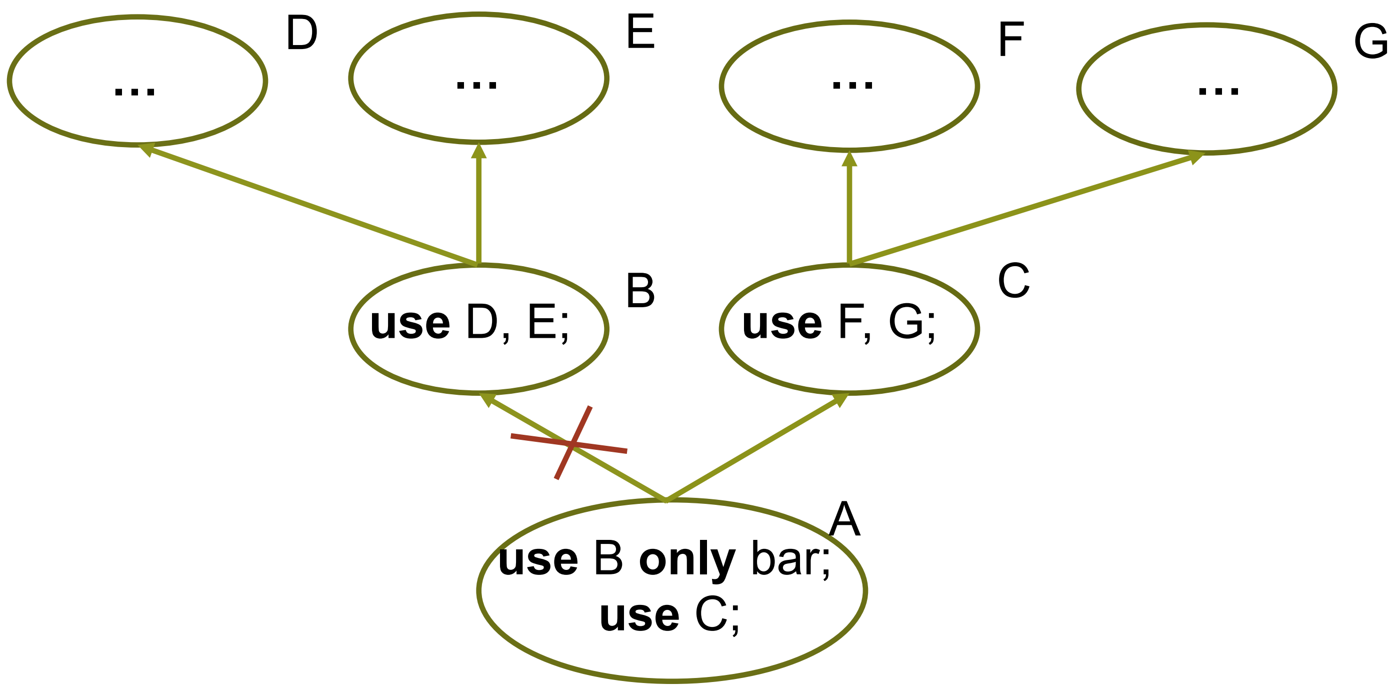
- **Function resolution**
  - Handles functions, some field resolution
    - Chooses best match from all matches at all visible scopes
  - Traverses ‘use’s depth-first
  - Later ‘use’s in chain accessed through earlier ‘use’s



Traversal order:
- A
- B
- D
- E
- C
- F
- G
- …

The Use and I: Function Resolution

- **Can determine whether to follow a 'use' chain**
  - If 'except' or 'only' list precludes desired name, skip that branch
  - Single check saves compilation time



Traversal order:
- A
- ~~B~~
- ~~D~~
- ~~E~~
- C
- F
- G
- …

The Use and I: Conclusions

- **Control over 'use' transitivity should be in user's hands**
  - Module designer has best knowledge of symbols to expose/hide
  - Intend to provide via reuse of 'public'/'private' keywords

```
private use M;
public use N;
```

- **Starting from "transitive by default" was beneficial**
  - Design of features forced to account for transitivity immediately
  - Found tricky cases early
- **Still deciding on default behavior**

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The Use and I: Private and Public

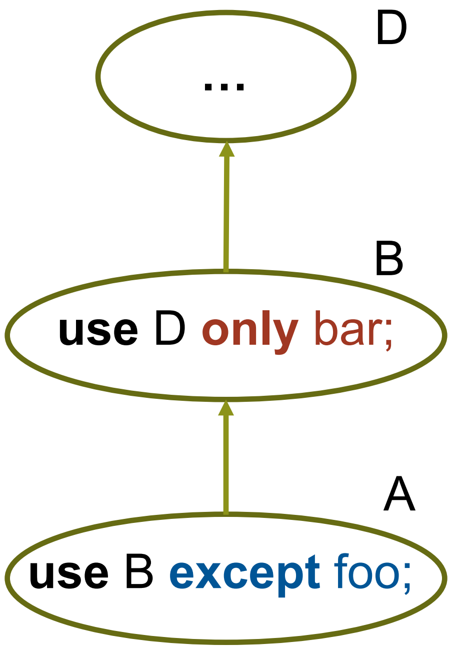
- **Declaring symbol “private” impacts outside access**
  - No explicit naming allowed from outer scope
  - ‘Use’ will not allow unqualified access of symbol either
  - Still visible from scopes nested within defining scope

```
private var foo = …;
proc bar() { … }  // Can reference foo within bar, etc.
```

- **Implementation:**
  - Same check on symbol match visibility used in both passes
    - Scope resolve looks at further ‘use’ depth if only private symbols found
    - Function resolution merely avoids that match

The Use and I: Scope Resolve

- **With 'except' and 'only' keyword, 'use' chains matter more**
  - Earlier limits should affect search of later modules in chain
  - Need to apply these limits when creating 'use' tree
    - This can get tricky when multiple limits are present



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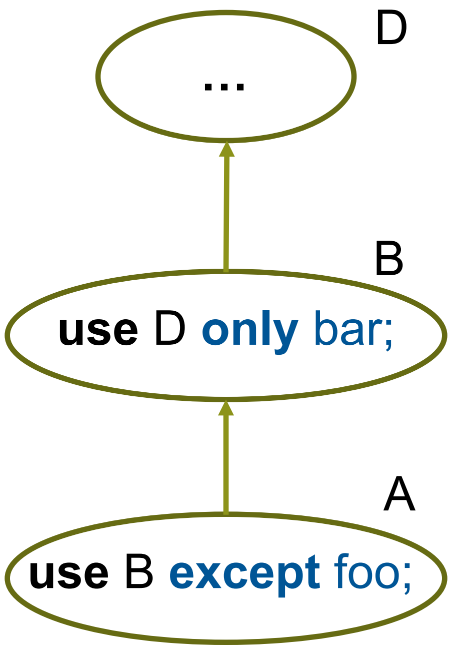

If an outer 'except' list is distinct from an inner 'only' list, the 'only' list will be unchanged

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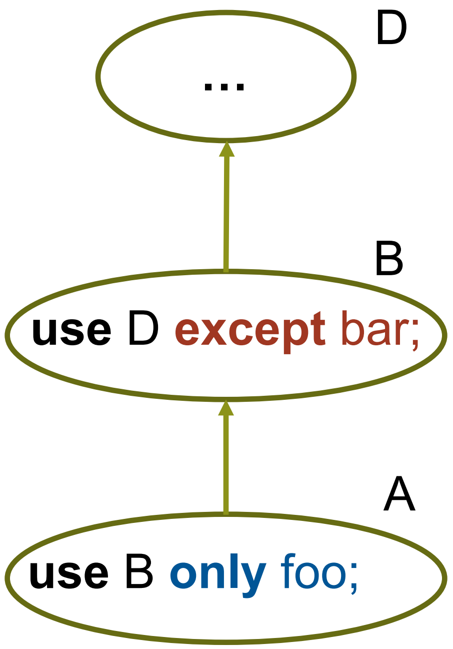

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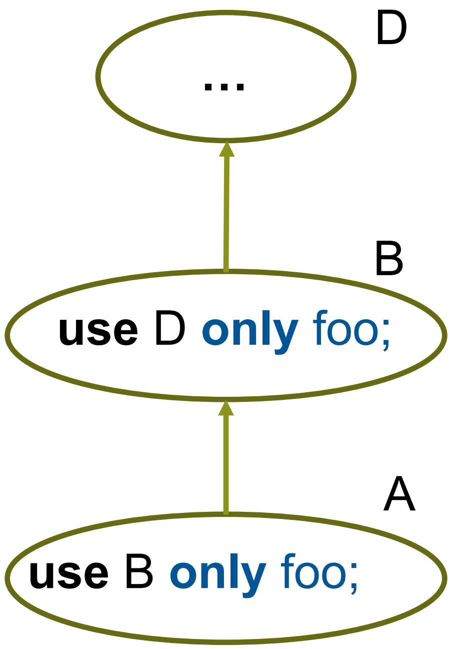

If an outer 'only' list is distinct from an inner 'except' list, the 'only' list will replace the 'except' list.

The Use and I: Scope Resolve

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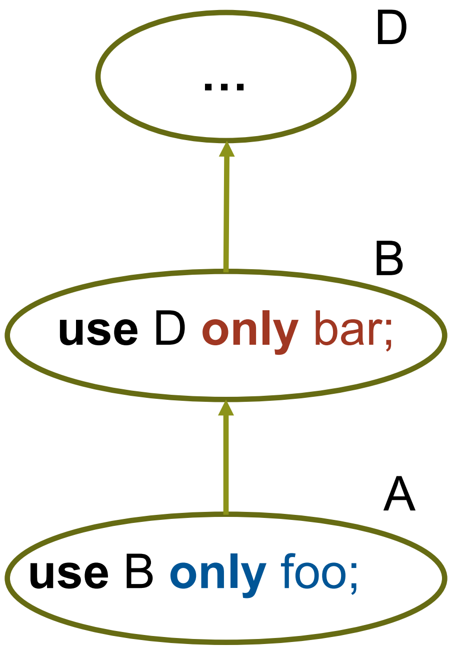

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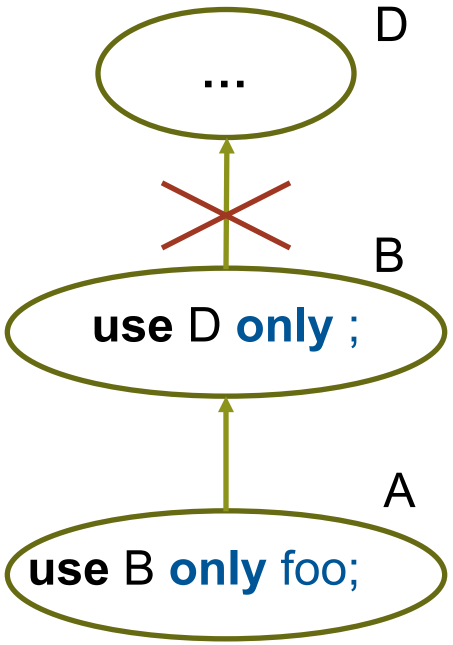

If an outer 'only' list is distinct from an inner 'only' list, it will be as if that 'use' does not occur.

And any overlap will be handled appropriately