CSC488/2107 Winter 2019 — Compilers & Interpreters

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Agenda

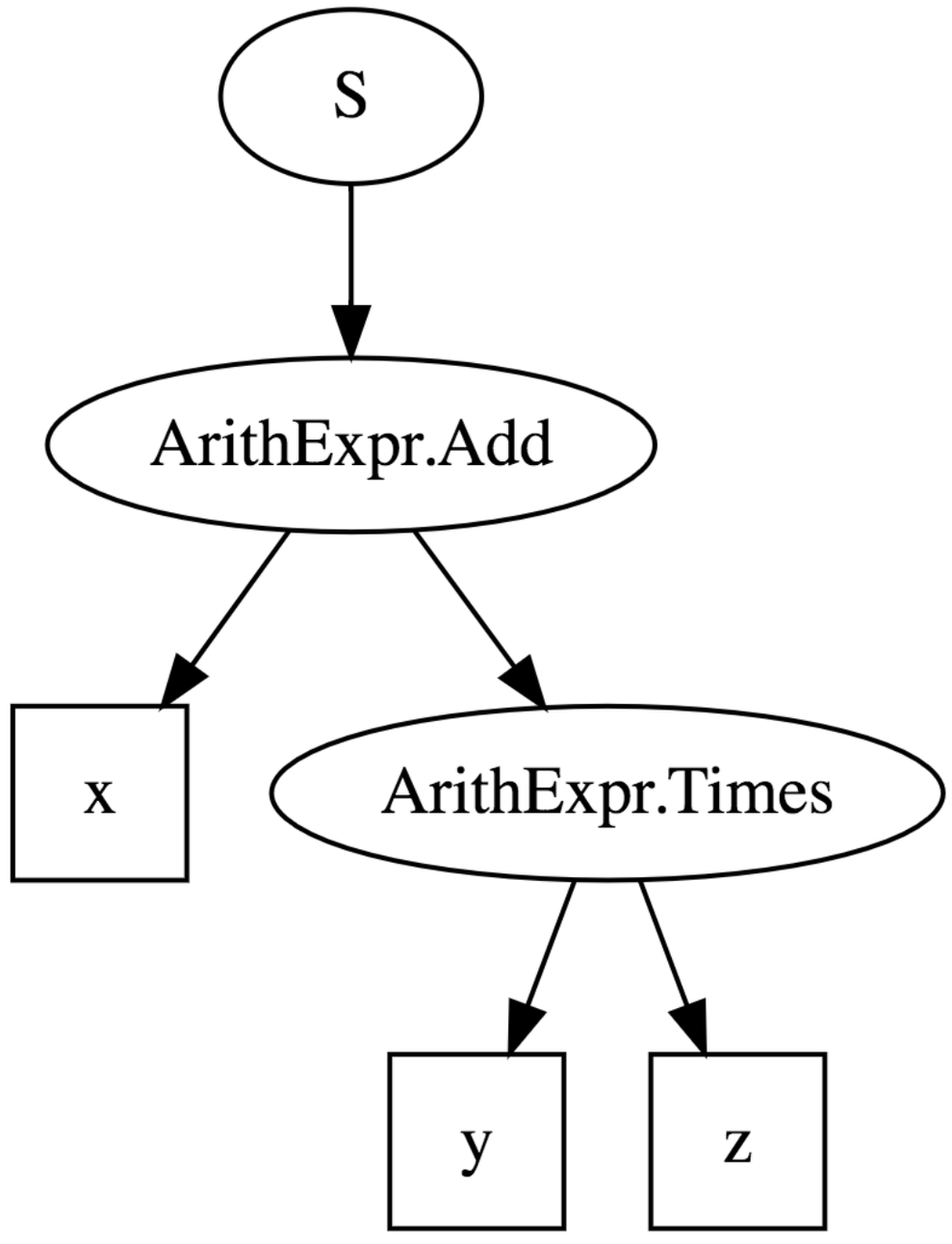
- Abstract Syntax Trees
- Identifiers and names
- Symbol tables

Abstract Syntax Trees

- An tree-structured *intermediate representation* of a program that abstracts non-essential syntactic details, while retaining the fundamental shape of the input

- Generated by the parser, consumed by subsequent analysis phases

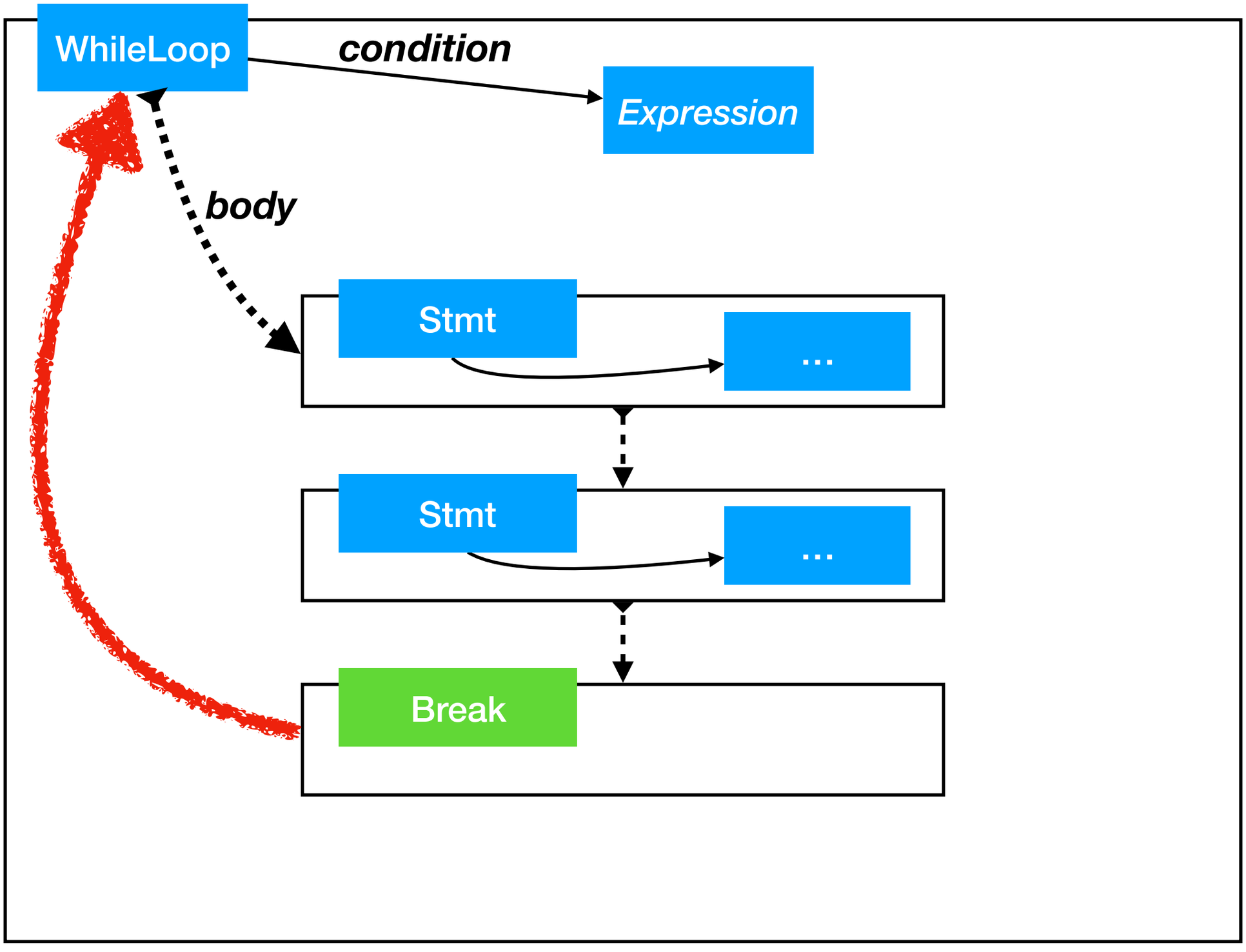
- While parse trees (concrete syntax) follow the specific productions of the grammar, the abstract syntax keeps only the semantically meaningful concepts



Annotating AST

- ASTs start as trees: single root, directed graph, acyclic
- It’s sometimes useful to annotate the tree with additional graph edges
- Additional book keeping:
  - Type information
  - Symbols
  - Runtime consideration
  - Code generation: offsets, labels, stack memory layout, etc.
- Modify in-place or generate a transformed copy in the process

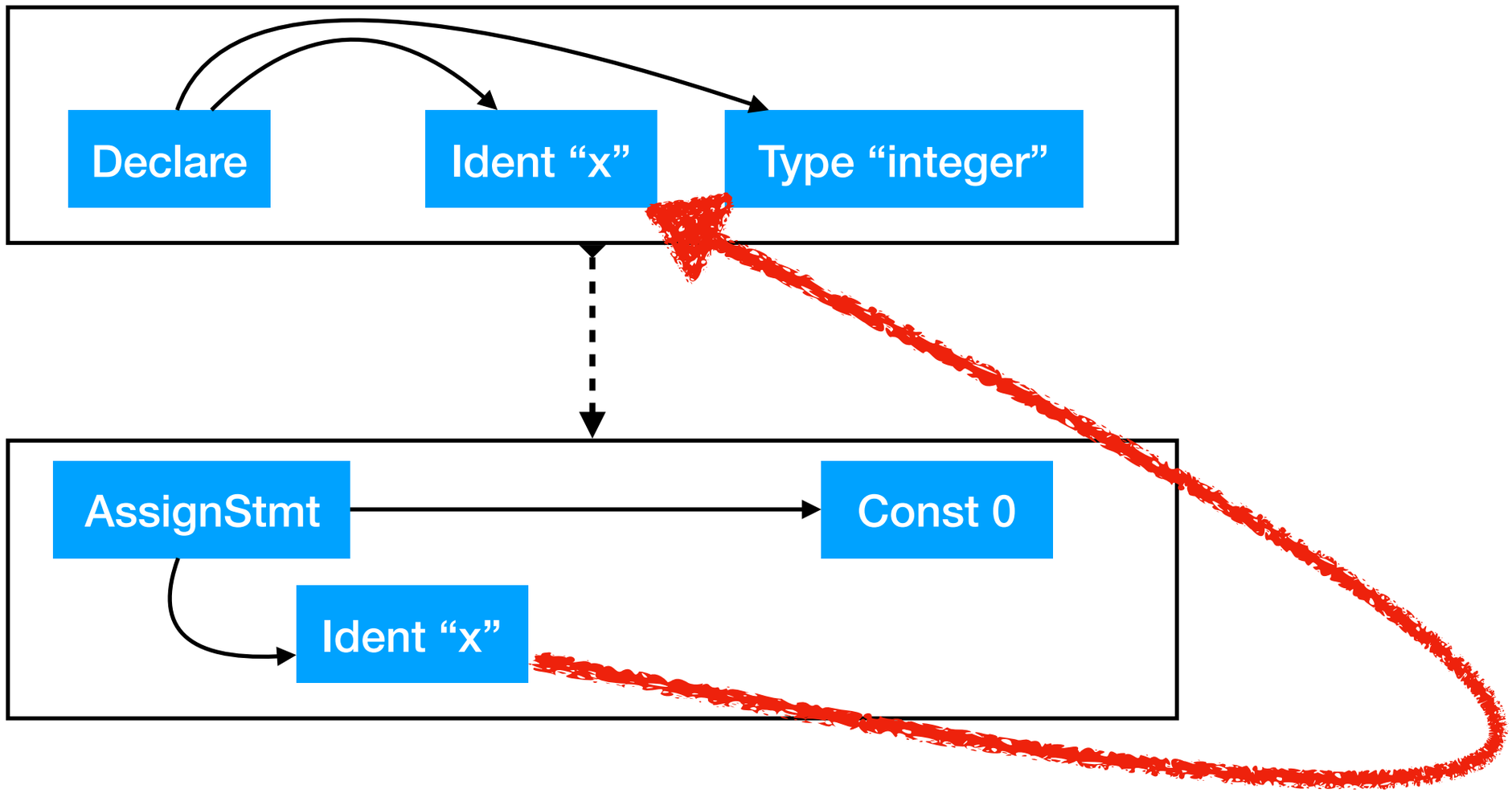
Backlinks


WhileLoop
condition
Expression
body
Stmt
...
Stmt
...
Break

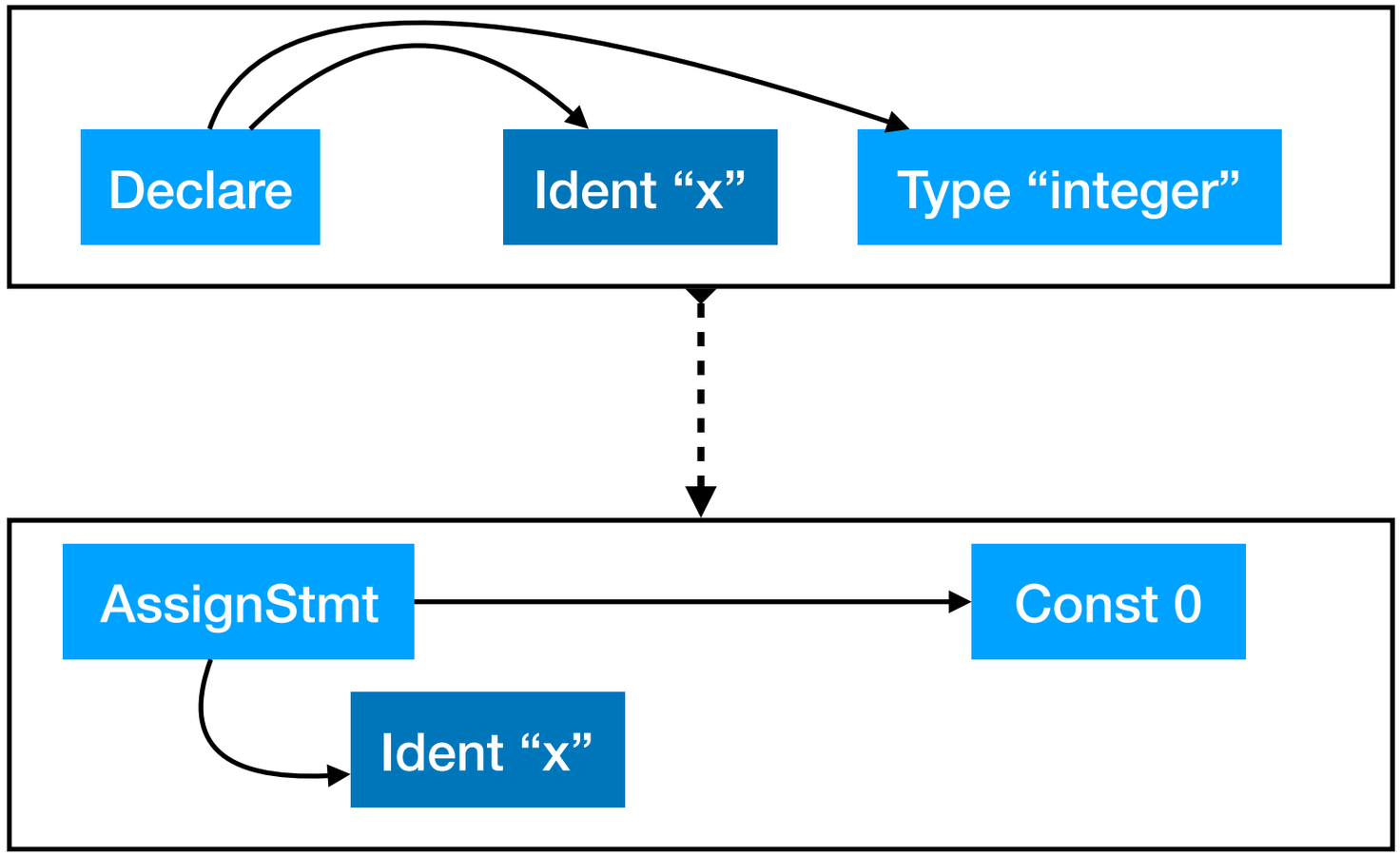
Other useful links

- From `break`'s to their enclosing loop
- From `return`'s to their enclosing function
- From `else` arms to the initial `if` or to sibling `else`'s
- From a nested function to their enclosing parent function
  - Nested scopes
- From identifier *uses* to their *declarations*

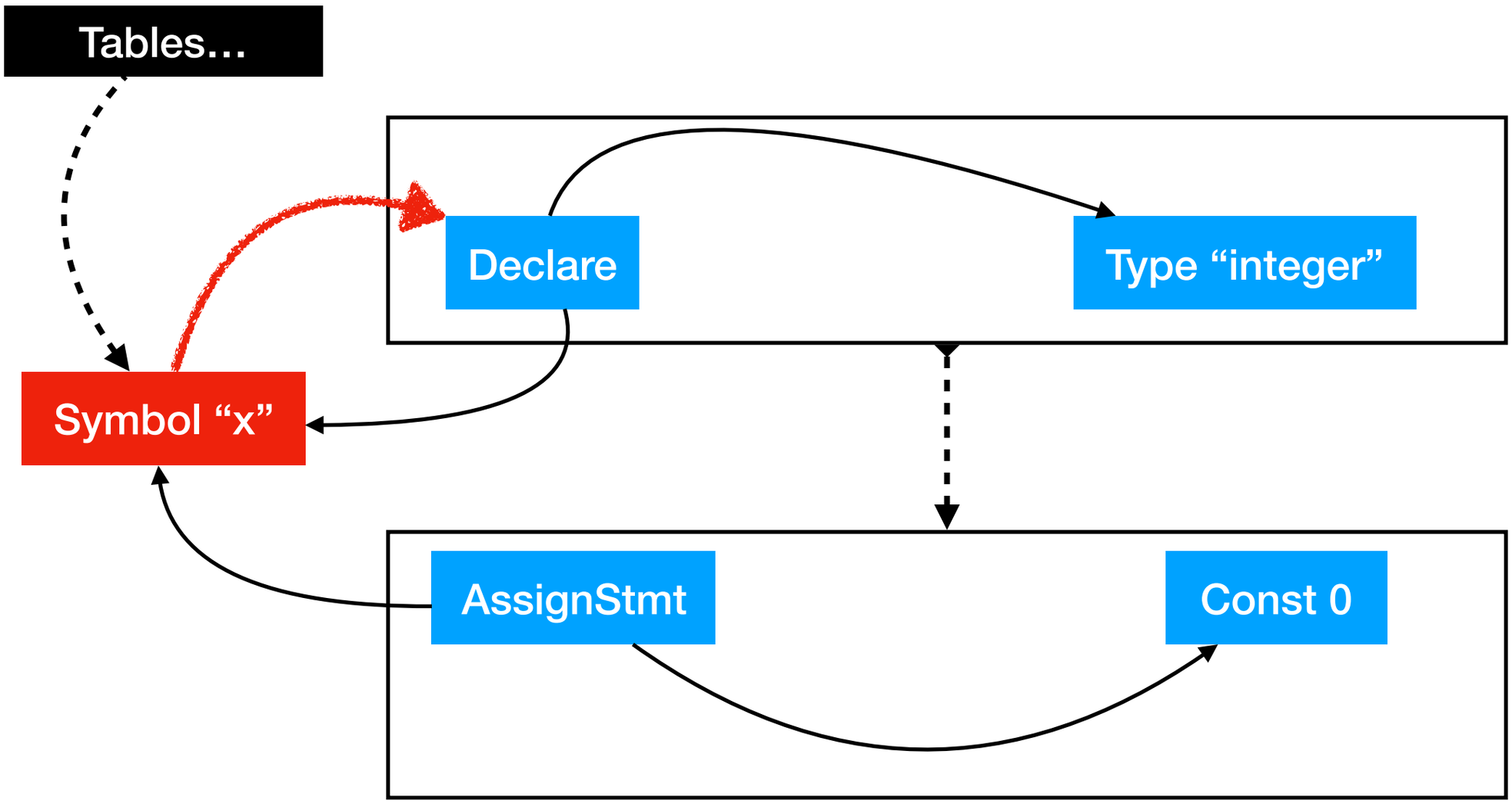
Identifier uses & declarations



From *identifiers* to *symbols*



From *identifiers* to *symbols*



Symbol tables

- An *identifier* is a language token type, while the value of an identifier is a *name* (typically a string)

- A *symbol table* maps *names* to *symbols*

- What language constructs create new *names*, and when are those names visible in subsequent parts of the program text?

- What information is useful to track for each symbol?

- Each language will have its own rules about scoping and symbol visibility:

  - Hierarchical

  - Parallel

Scoping & symbol visibility

Major & minor scopes

- Major scopes: reserved for significant constructs in the language
    - Top level program
    - Body of a function/procedure/method
    - Body of a class
    - Module definition
- Minor scope: occur within major scopes
    - Delimited by { and }
- Major scopes typically a unit of resource allocation, while minor scopes can be collapsed together
- Nested scopes can hide access to names from earlier scopes (but they don’t alter the original name/symbol)

```
var foo integer

foo = 0
```

```
var foo integer

foo = 0
```

```
var foo integer
foo = 0
{
    var foo integer
    foo = 1
}
print foo
```

```
var foo integer
foo = 0
{
    var foo boolean
    foo = true
}
print foo
```

Name resolution

- Each scope maintains a list of locally declared identifiers, or *names*, mapped to symbol table entries
    - At each point in the program, certain names are in scope and visible
- Typically search upwards through enclosing scopes to find origin of declaration
- Qualified names allow searching within another contexts
- *Importing* brings names into scope from other contexts

Qualified names (hierarchical scoping)

```
System.out.println(
    “Hello World!”)
```

Qualified names (hierarchical scoping)

```
System.out.println(
    “Hello World!”)
```

Importing names

```
import mypkg.Foo;

…
    Foo f = new Foo();
```

Importing names

```
import mypkg.Foo;

...
    Foo f = new Foo();
```

public, private, protected

```
class Parent {
  public    int anyone;
  private   int only_me;
  protected int children;
}

class Child extends Parent {
  void m() {
    anyone   = 488;  // allowed
    children = 488;  // allowed
    only_me  =  -1;  // ERROR!
  }
}
```

Parallel scopes

- Some languages define multiple contexts in which the same name can be used, without conflict
- C: struct, enum, union
  - Not C++
- Haskell: data types vs data constructors

Parallel scopes — C

```
struct s {
    int x;
};
struct s s;
s.s = 488;
```

Parallel scopes — Haskell

```
data Atom = Atom;

c :: Atom;
c = Atom;
```

Symbol table entry

- Original point of instantiation
- Type information:
    - Scalar vs array vs routine
    - Link to record/class/etc. definition
    - For routines: formal parameters and their symbol information
    - For function: return type information
- Visibility modifiers
- Uses *(optional)*

Implementing a symbol table

- Core operations:
    - Enter into a new scope
    - Exit from a scope
    - Lookup if a name exist in the current immediate scope
    - Lookup if a name exist in the current *or* a parent scope
    - Put a new name-to-symbol entry in the table
- Multi-level map of names to symbols
    - Stack of hash tables
    - Or, a hash table of lists

Implementing a symbol table

- New levels in the symbol table with typically begin with the start of major and minor scopes
  - Maps naturally between enter & exit and push & pop
- If you perform an *Ident-to-Symbol* AST transformation, do you still need the hash table anymore?
  - Debuggers depend on knowing what names are visible/ accessible at each point in the program