Simulation

- Semantic analysis uses a combination of two techniques:

- **Tabulation**

  Collection of declaration and contextual information into tables for easy lookup

- **Simulation**

  Calculation of derived attributes by simulating the execution of the program on an ideal machine.

  Two basic mechanisms are used to perform the simulation. These are the *Symbol Stack* and the *Type Stack*

  Both of these stacks are similar to the run-time Expression Stack, but instead of computing the *value* of expressions, they are used to compute the attributes and types of expressions

The Symbol Stack

- The Symbol Stack mimics the run-time resolution of references to symbols, mirroring the Expression Stack's computation of symbol references such as subscripted variables

- Computes the *effective access attributes* of the reference, which may be different from the attributes of the declared symbols themselves

Example:

If *x* is a variable field of a constant record *r*, then *r.x* is effectively a constant, not a variable (and therefore can't be assigned to)

- Programming languages vary widely in their rules for the effective attributes of complex symbol references - some are simple, some are very complex

- In general, we can say that the rule is that *minimum access* is inherited from left to right in a symbol reference - that is, a field cannot have greater access attributes than its parent

Symbol Stack - Access Calculation Example

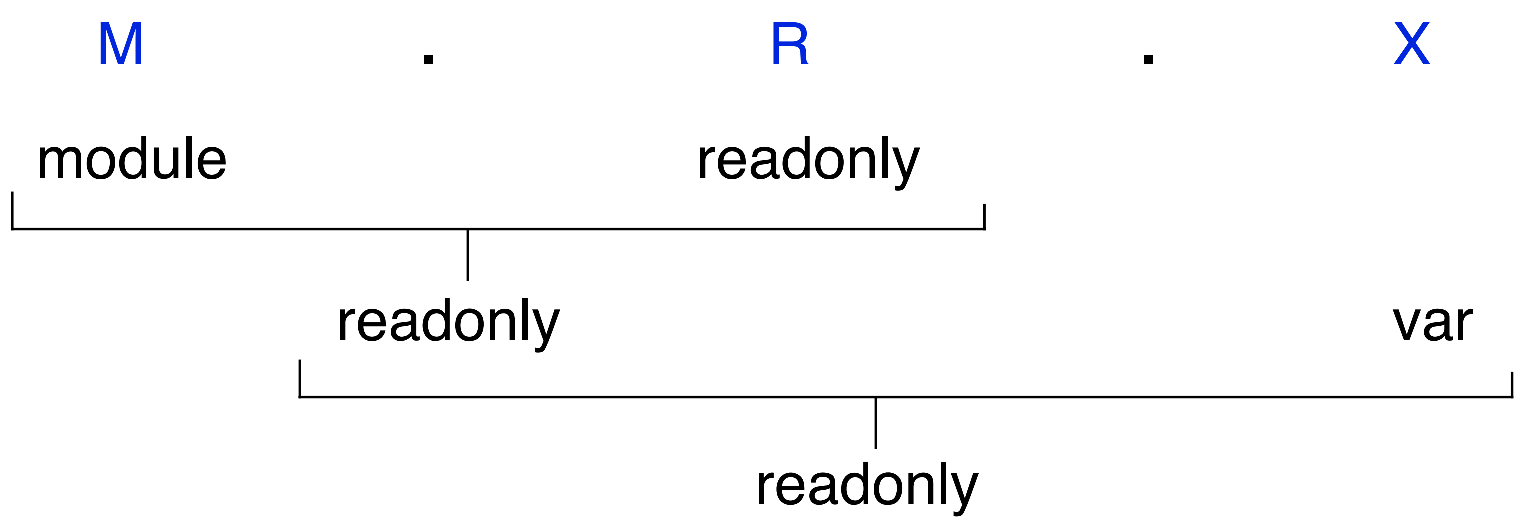
Consider the Euclid programming language reference

M.R.X

where

M is a module (i.e., static class)
R is a record variable exported **readonly** from M
(i.e., is public but not assignable)
X is a **var** field of the record

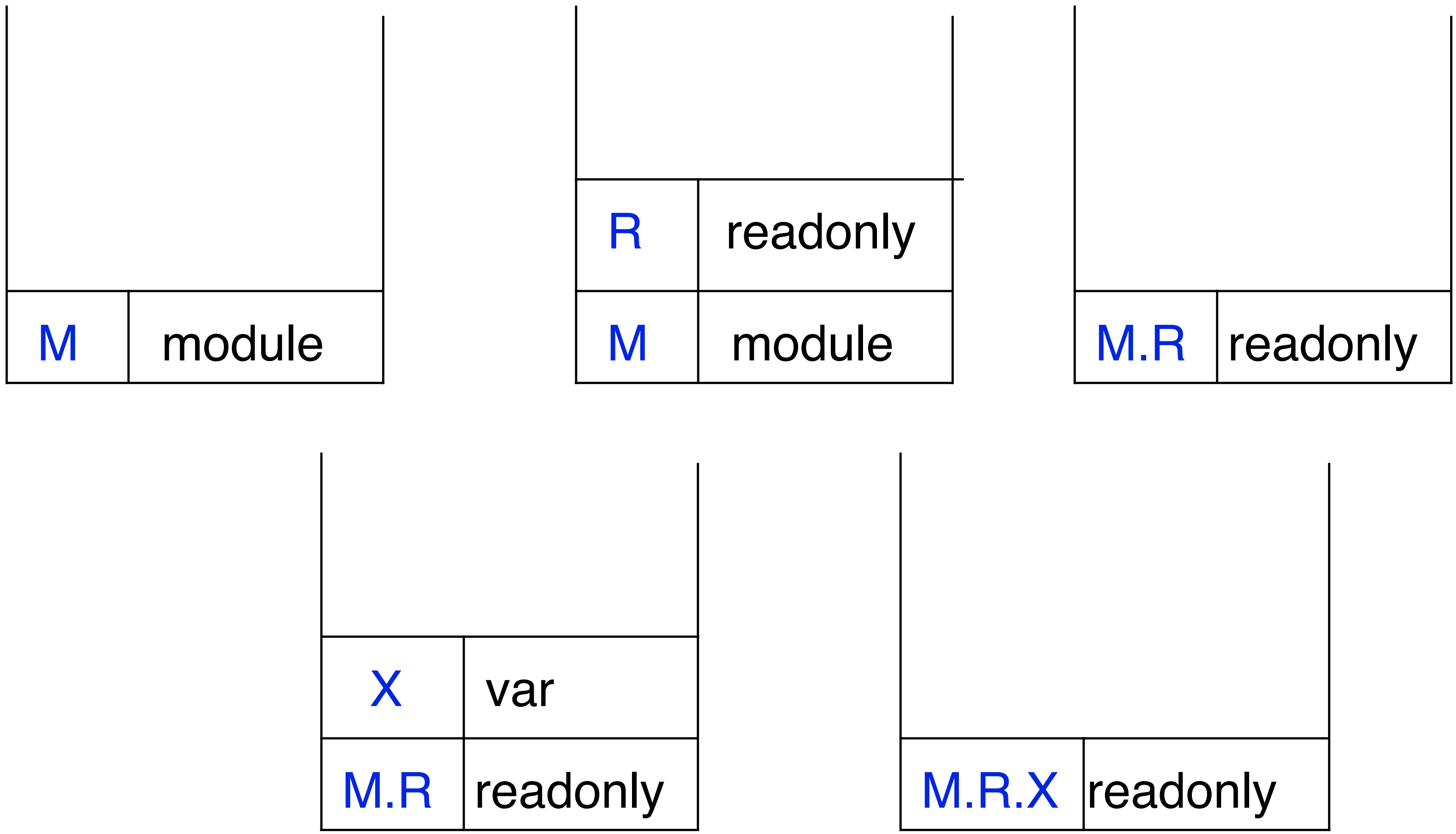
Minimum inherited access gives us the following:



Symbol Stack - Access Calculation Example

- The Symbol Stack records the effective access attributes at each stage as we process the reference

  (Note: the actual references are shown for clarity in the example - the stack does not actually store the reference expressions)



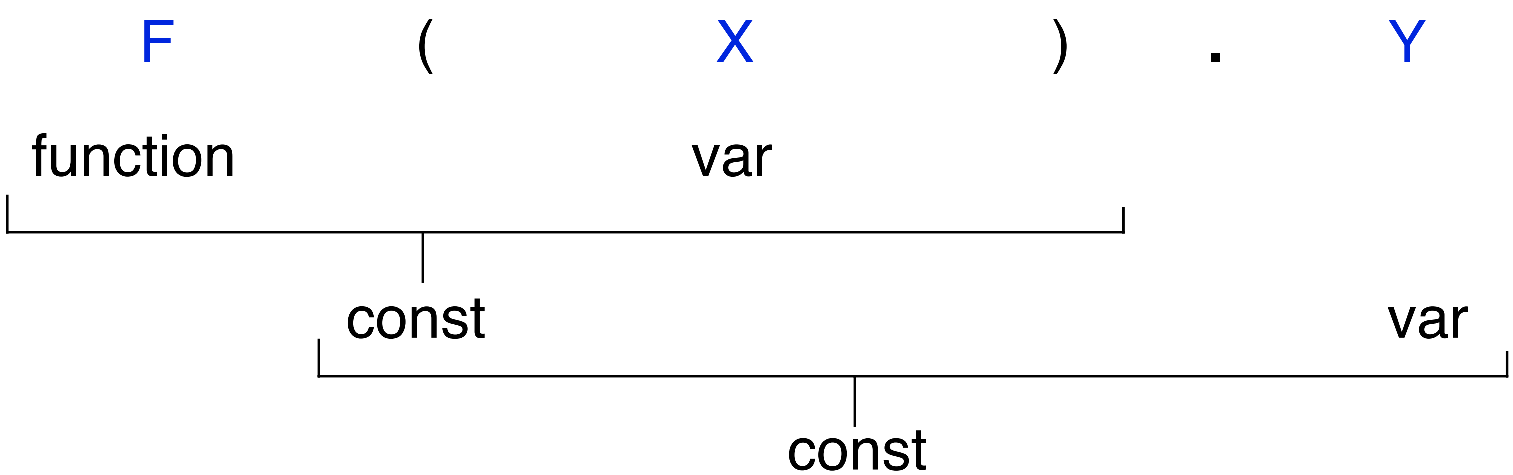
Symbol Stack - Access Calculation Example 2

F(X).Y

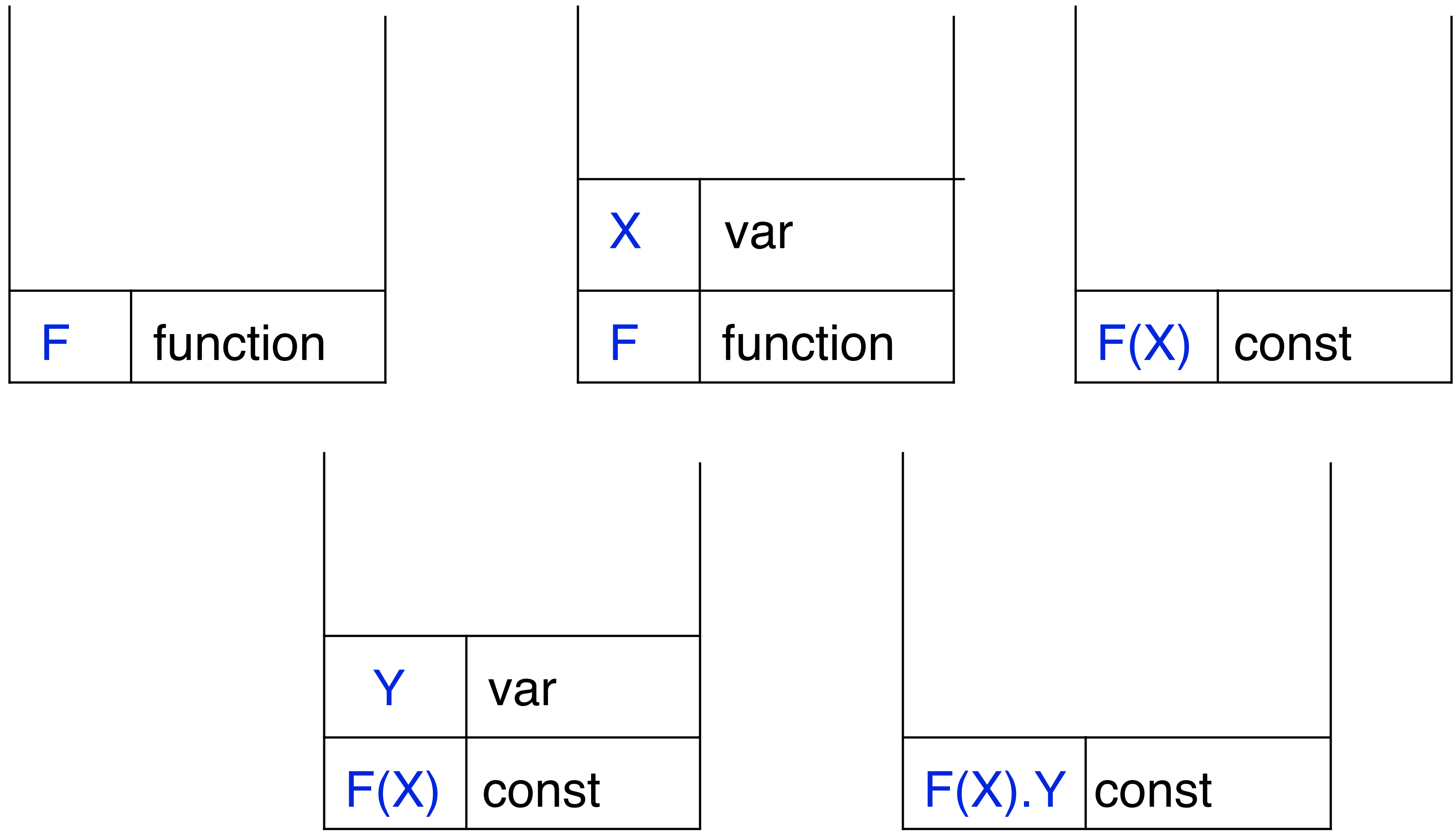
where

F is a function
X is a variable
Y is a field of the record (or object) returned by *F*

We end up with the following:



Symbol Stack - Access Calculation Example 2



(Note: the actual references are shown only for clarity -
the stack does not actually store the reference expressions,
only their attributes, such as access and memory address)

Symbol Stack – Access Calculation

- Minimum access inheritance is a general rule, and applies well to OO languages such as C++ and Java as well as to modular languages like Turing and Ada

- For example, access permissions of member variables generally follow minimum access inheritance rules - a protected variable of a superclass may not be exported as a public variable by the subclass

- However, minimum access does not apply in all cases

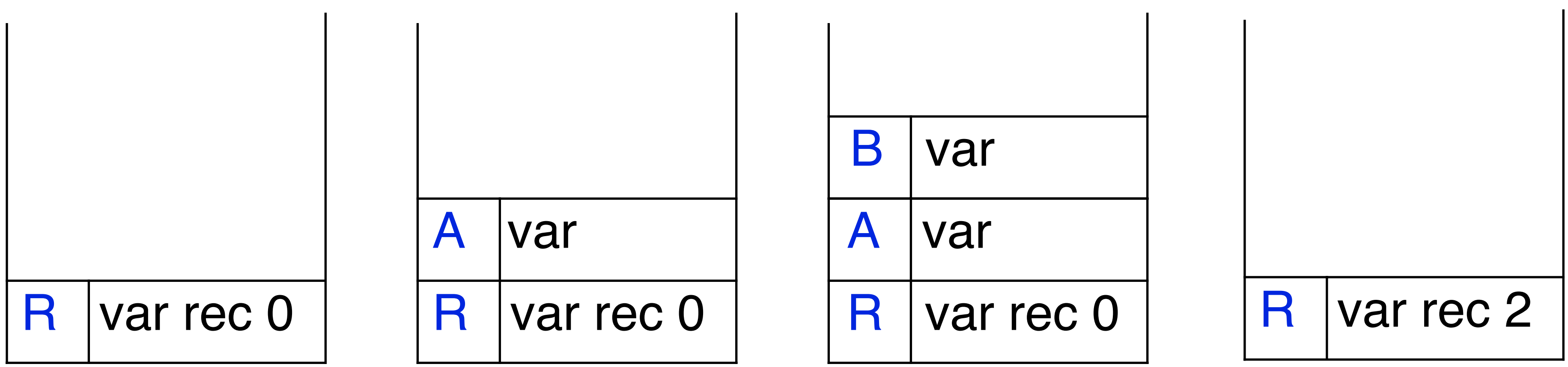
  e.g.,   If *p* is a pointer in C, then **p,* the variable pointed at by *p*, is an assignable variable even if *p* itself is a constant pointer

Symbol Stack - Declaration Processing

- The Symbol Stack is also used to accumulate declaration information for a symbol until it is complete and can be entered in the *Symbol Table*

- Example:

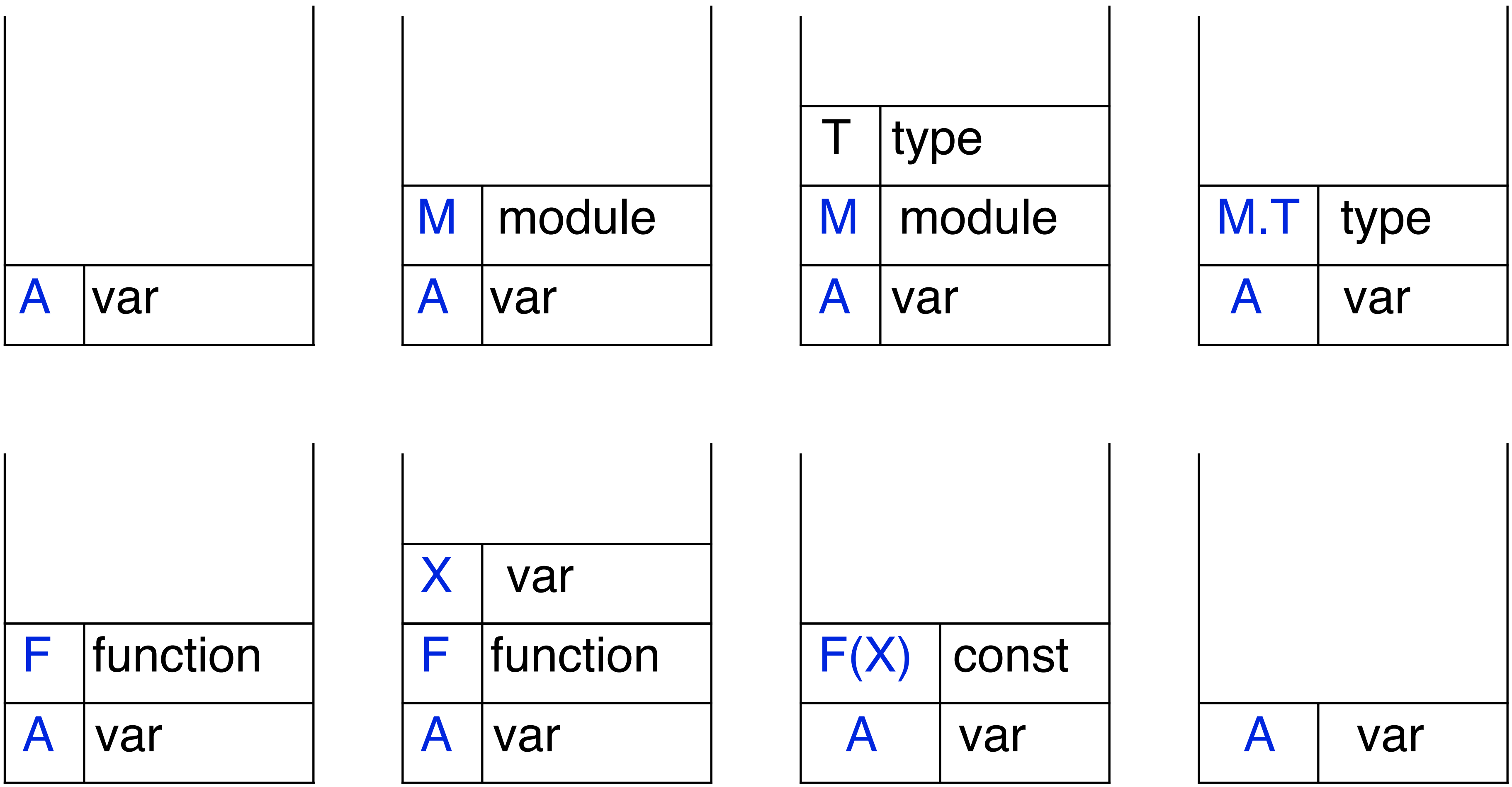
  var R : **record**
  var A : integer
  var B : integer
  end record



Symbol Stack - Declaration Processing

- Since types and inital values can be expressions, it's possible for the Symbol Stack to be used for both purposes at once
- Example:

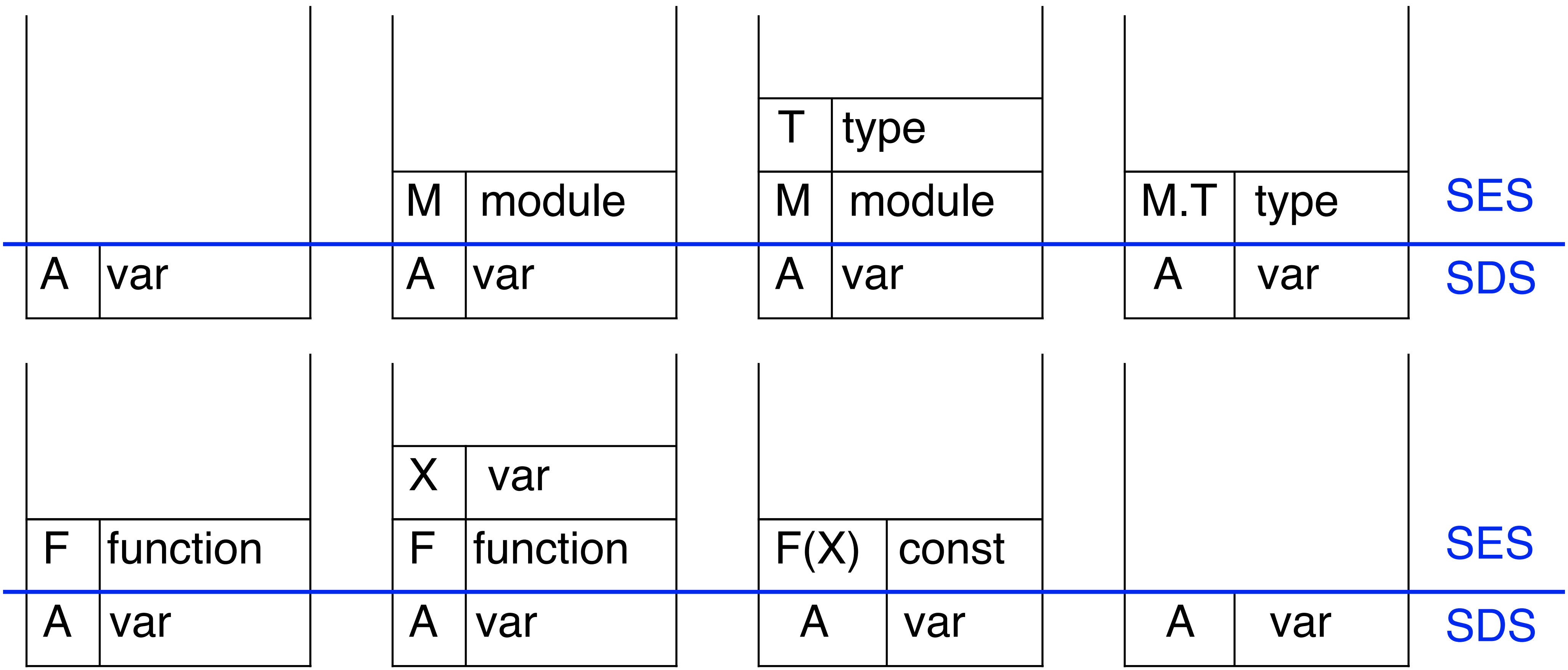
  var A : M.T := F(X)



Symbol Stack - Declaration Processing

- Conceptually, the Symbol Stack has two parts -
  - the *Symbol Declaration Stack* (SDS), which processes declarations
  - the *Symbol Expression Stack* (SES), which processes references

- They don't interfere with one another since we can prove that the SES is always empty when we need to push or pop the SDS



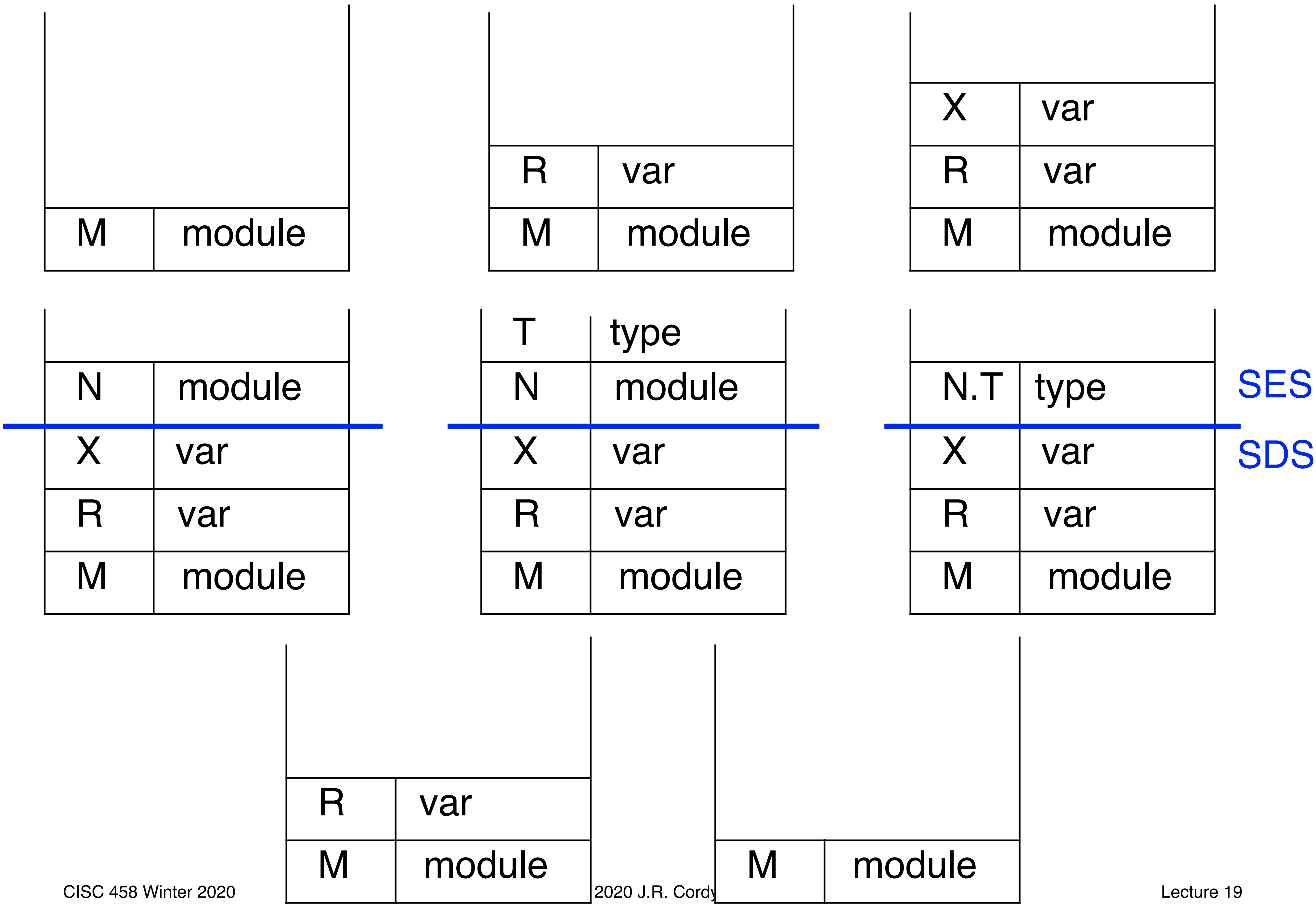
Symbol Declaration – Example

```
module M                              1
    var R : record                    2
            var X : N.T               3,4,5,6,7
            ...
        end record                    8
    ...
end module
```

where N is a previously declared module exporting type T

1. push new entry for M (SDS)
2. push new entry for R (SDS)
3. push new entry for X (SDS)
4. push reference to module N (SES)
5. push reference to type T (SES)
6. resolve reference to N.T (SES)
7. Enter X into symbol table as type N.T (SES/SDS)
8. Enter R into symbol table with record type (SDS).

Symbol Declaration – Example



Summary

- Simulation in Semantic Analysis
  - We simulate execution like an ES, except compute types and attributes rather than values
  - The Symbol Stack computes attributes of symbol declarations and references
  - Because each use (declaration, expression) nests with respect to the other, this stack can be used for both purposes at once

- **Next time**
  - The Type Stack, Semantic Mechanisms