Runtime Environments I

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Runtime System Responsibilities

- Allocation of storage for program data
- Sometimes also deallocation
  - Garbage collection
- Management of data structures the compiled program uses to access data

Data Storage Allocation

- Mostly dynamic
  - Some things can be done statically
- Main dynamic allocation possibilities:
  - *Stack*: data that do not outlive the procedure where it is declared
  - *Heap*: remaining data

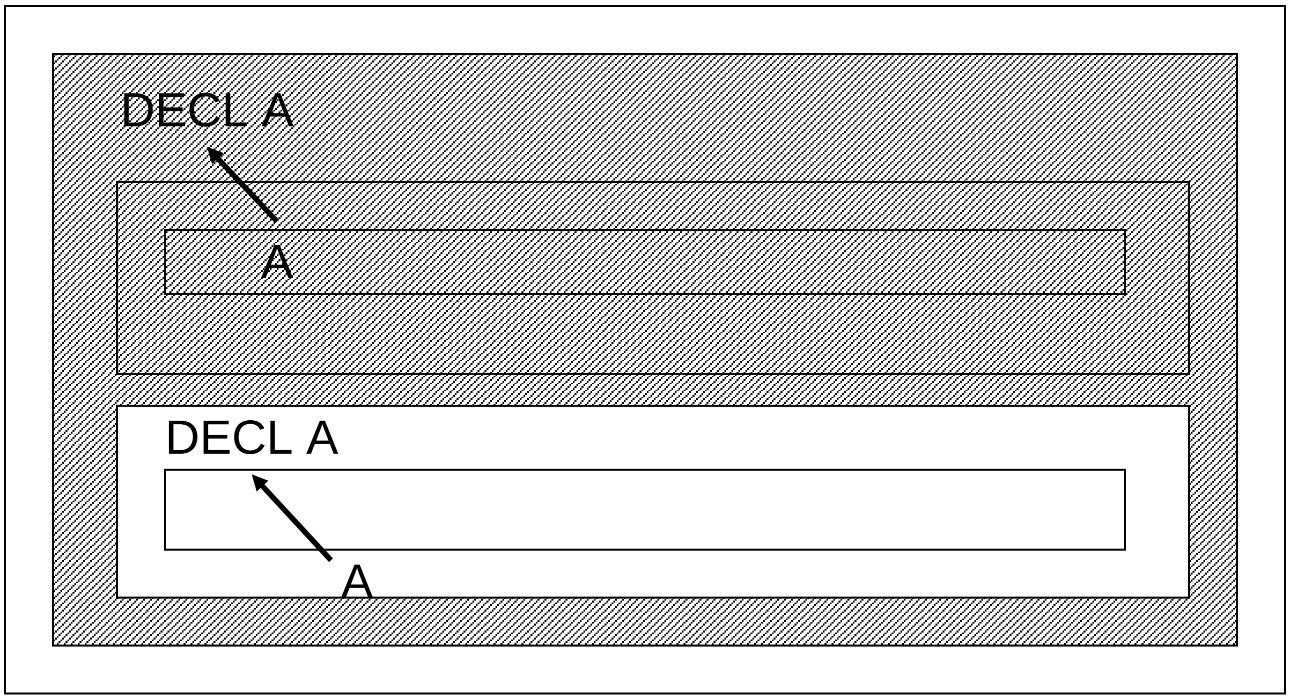
From Names to Values

- *Environment*: mapping from (variable) names to store addresses
- *State*: mapping from addresses to their values
- Both mappings can be static or dynamic
- Declaration vs Definition
  - *Declarations* specify types, interfaces
  - *Definitions* provide values, implementations

Scope of a Declaration

- The *scope of a declaration* of *x* is the context in which uses of *x* refer to this declaration
  - *Static or lexical* scope: identifiable from program source code
    - Usually relies on code block structure
  - *Dynamic* scope: otherwise

Static Scope based on Block Structure



Explicit Access Control

- Specify who can access fields in a record/class
- Accessible members are usable in any subclass unless it redefines the member
- Encapsulation through explicit control using keywords
  - E.g: C++'s public, private and protected

Dynamic Scope

- Name resolution depends on most recently called function, without there being a redeclaration
  – Macro expansion
  – Polymorphic methods

Stack Management

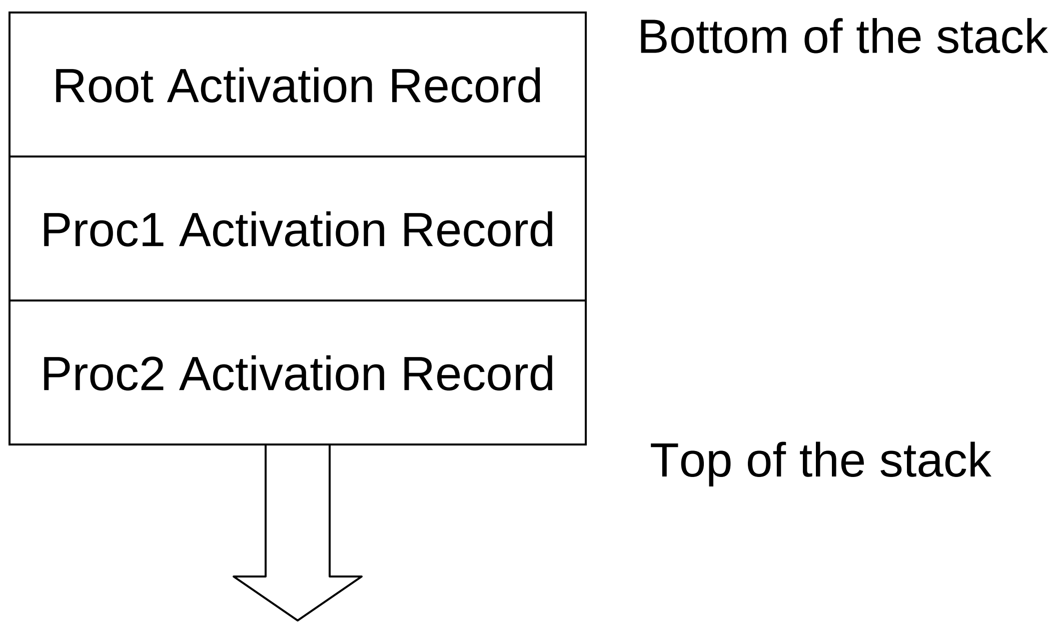
- Used for data whose usage is restricted to the procedure where it is declared or procedures it calls
- Each time a procedure is invoked, it reserves its space at the top of the stack
- When the procedure returns, its space is popped off the stack
- The stack structure is adequate because procedure calls (*activations*) nest in time
  - If *p* calls *q*, *q* must finish before *p* can call another procedure or finish

Activation Tree

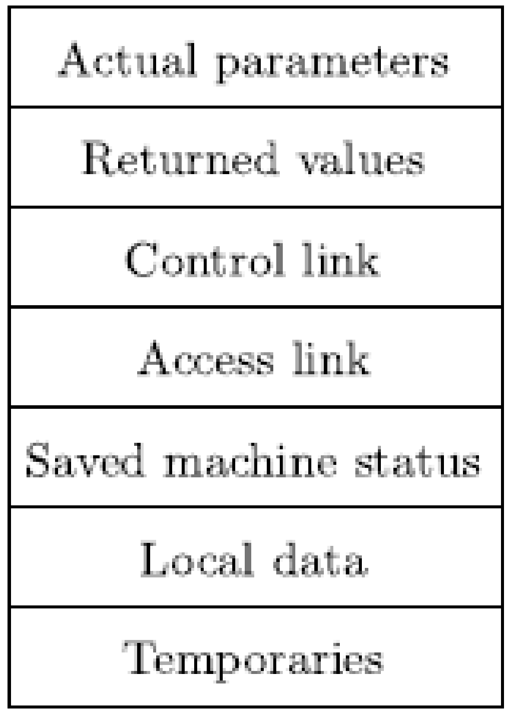
- Represents the activation of procedures during the execution of the program
- Activations happen top-to-bottom and left-to-right (preorder traversal)
- Returns happen bottom-to-top and left-to-right (postorder traversal)
- The activations open when control reaches a node of the tree are its ancestors

Activation Records (or Frames)

- Stack space allocated for an activation of a procedure in the (control) stack
- Traditional representation:



What’s Inside an Activation Record



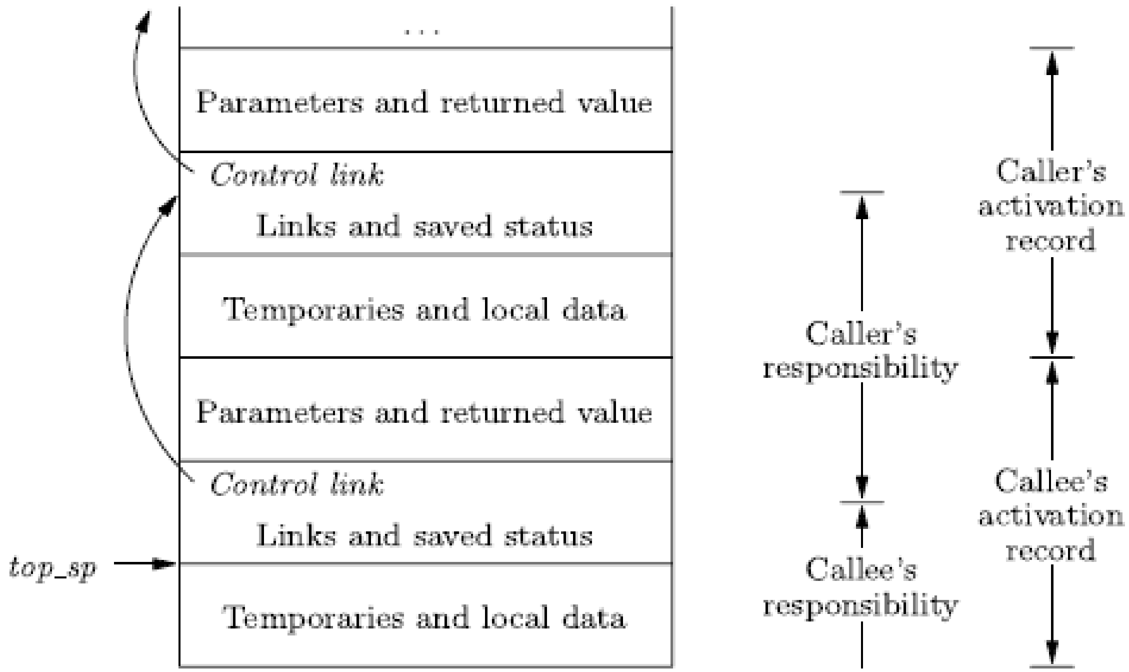
Procedure Call/Return Implementation

- The *calling sequence* fills in the activation record of the procedure called
- The *return sequence* restore the state upon return using the activation record
- Both can be a shared responsibility of the calling procedure (*caller*) and the called procedure (*callee*)
  – In general it is better the callee does most work

Usual Disposition of Data in the Activation Record

- Values communicated between caller and calle are usually put at the beginning
- Fields with a fixed width come in the middle
- Variable length data usually go at the end (top) of the record
  - Dynamically sized arrays
- Top-of-stack pointer usually points to the end of the fixed-length fields

Example


...
Parameters and returned value
Control link
Links and saved status
Temporaries and local data
Parameters and returned value
Control link
Links and saved status
Temporaries and local data
top_sp
Caller's responsibility
Callee's responsibility
Caller's activation record
Callee's activation record

Parameter Passing Mechanisms

- Association of formal and actual parameters policies:
  - Call-by-value
  - Call-by-reference
  - Call-by-name (obsolete)

Access to non-local data

- Simple for languages that do not allow nested procedure declarations:
  - Variables are either local to the procedure
  - Or globally/statically declared
- In languages with nested procedures
  - the declaration for a non-local name can be found statically, but
  - dynamic mechanisms are needed to find the relevant activation record of the caller that contains the data

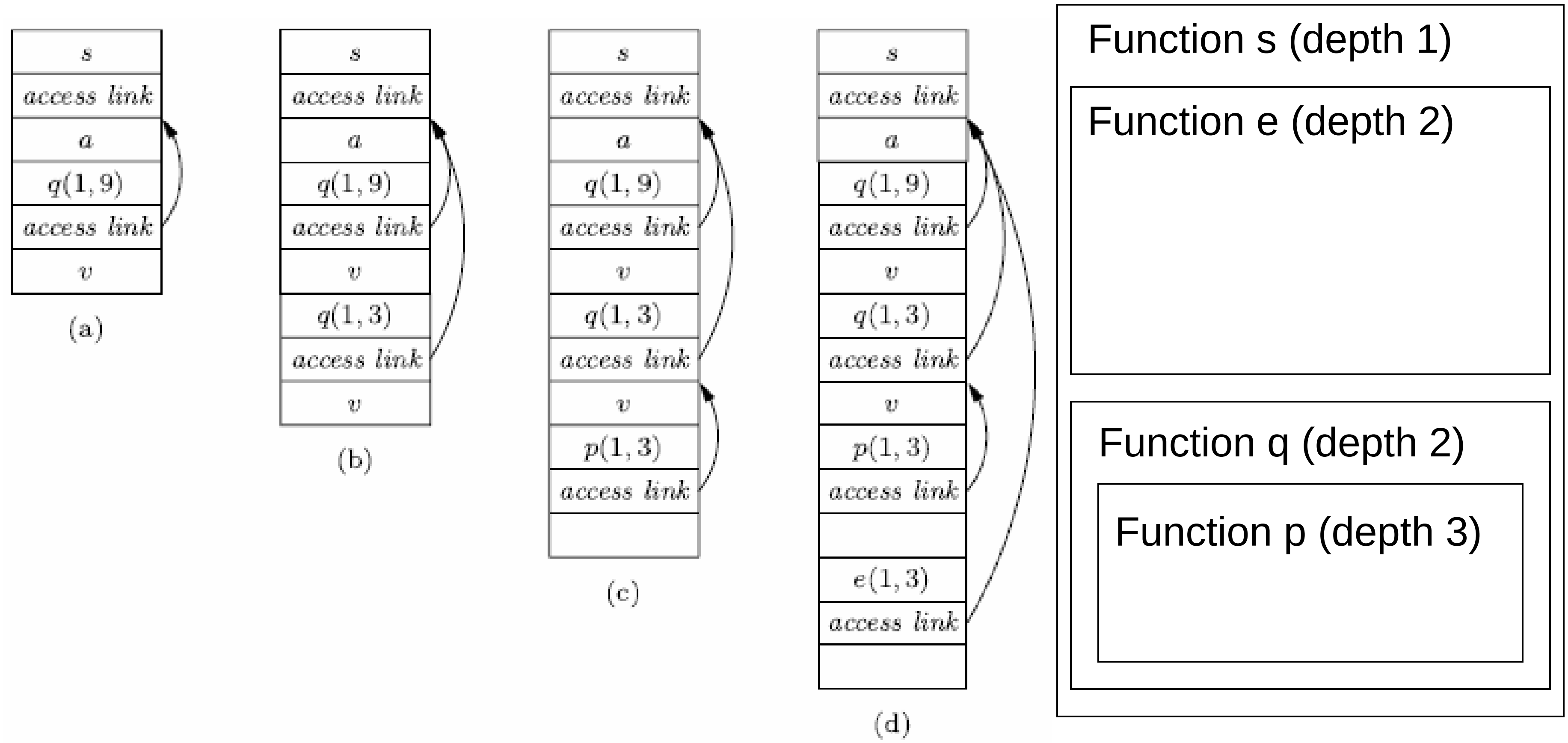
Access Link

- Points to most recent activation record for immediately enclosing function.
- Access links form a chain from the current (highest) nesting level activation record to the lowest one
- All accessible activation records are in the chain
  - *N* hops to reach activation record with nesting depth current-N

Access Link Calculation

- When q calls p:
  - depth p > depth $q \Rightarrow q$ immediately encloses p
    - Access link for p points to q's activation record
  - depth p = depth $q \Rightarrow$ (mutually) recursive call
    - Access link for p = Access link for q
  - depth p > depth $q \Rightarrow$ both are nested inside a common procedure r
    - depth(p) – depth(q) hops to find access link for p

Access Link Illustration



Display

- Array *d* with one pointer per nesting depth
  - *d[i]* points to highest activation record for any procedure at nesting level *i*
- Any variable defined in a procedure at nesting level *i*, can be found through d[i]
  - No need to follow a chain of access links
- When a procedure overwrites *d[i]*, it must first save it, then restore it when it returns

Example of Display Evolution