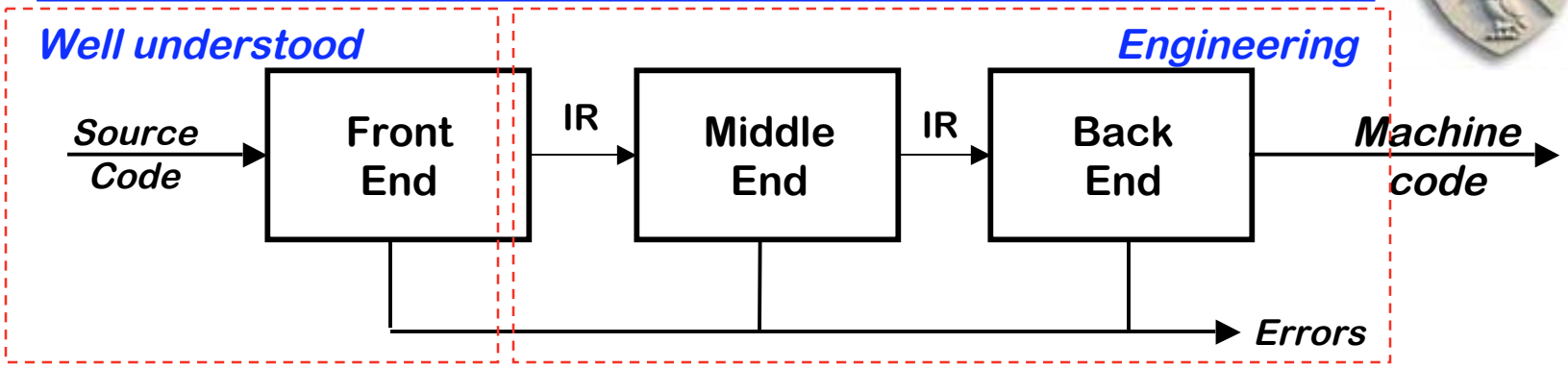
The Procedure Abstraction
Part I: Basics

COMP 412
Fall 2005

Procedure Abstraction

- Begins Chapter 6 in EAC
- The compiler must deal with interface between compile time and run time (static versus dynamic)
  - Most of the tricky issues arise in implementing "procedures"
- Issues
  - Compile-time versus run-time behavior
  - Finding storage for EVERYTHING, and mapping names to addresses
  - Generating code to compute addresses that the compiler cannot know!
  - Interfaces with other programs, other languages, and the OS
  - Efficiency of implementation

Where are we?

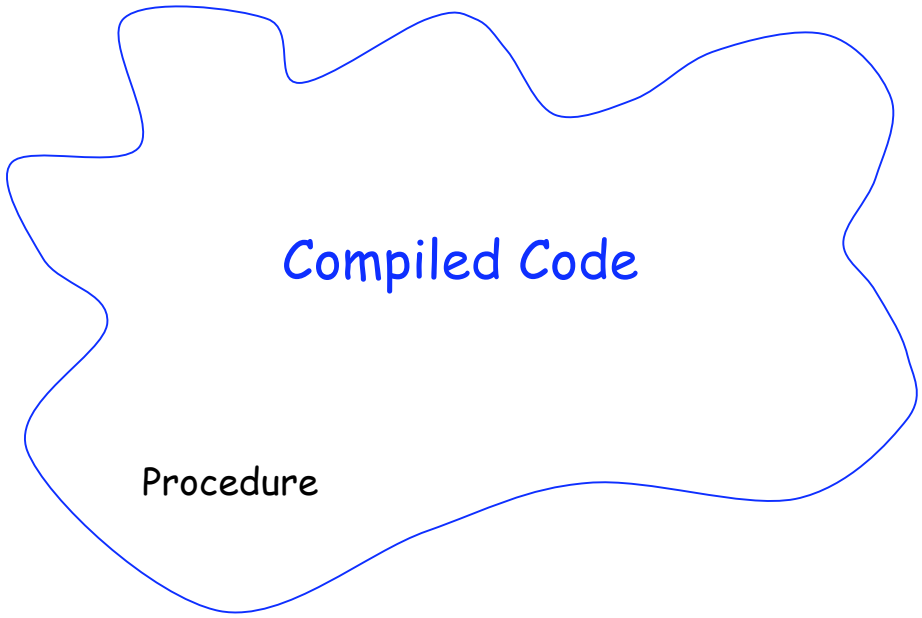


The latter half of a compiler contains more open problems, more challenges, and more gray areas than the front half

- This is "compilation," as opposed to "parsing" or "translation"
- Implementing promised behavior
  - Defining and preserving the meaning of the program
- Managing target machine resources
  - Registers, memory, issue slots, locality, power, …
  - These issues determine the quality of the compiler

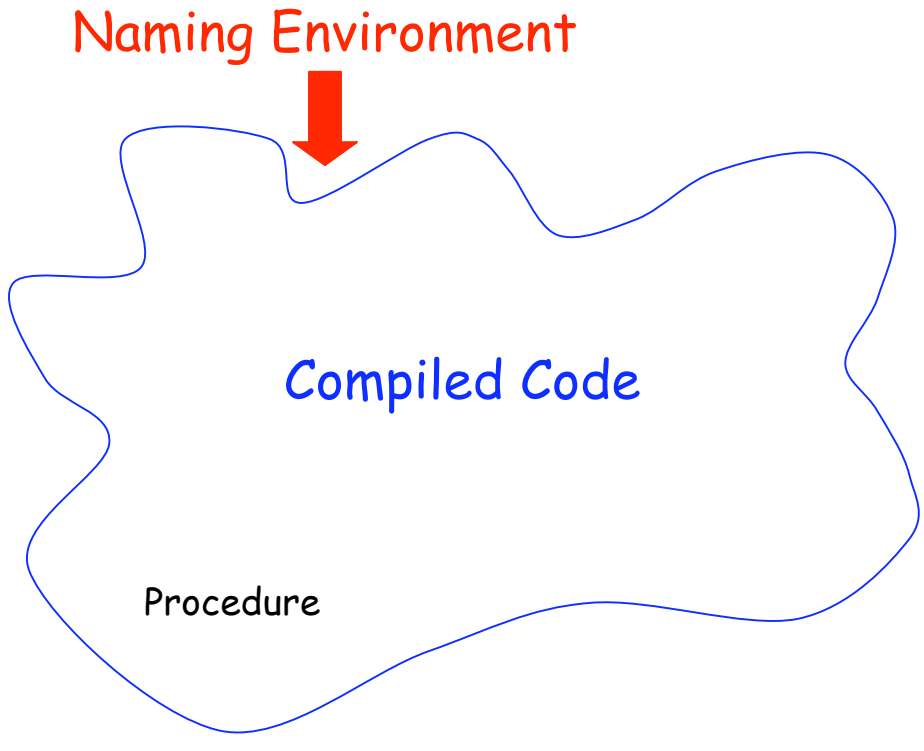
The Procedure & Its Three Abstractions

The compiler produces code for each procedure



The individual code bodies must fit together to form a working program

The Procedure & Its Three Abstractions



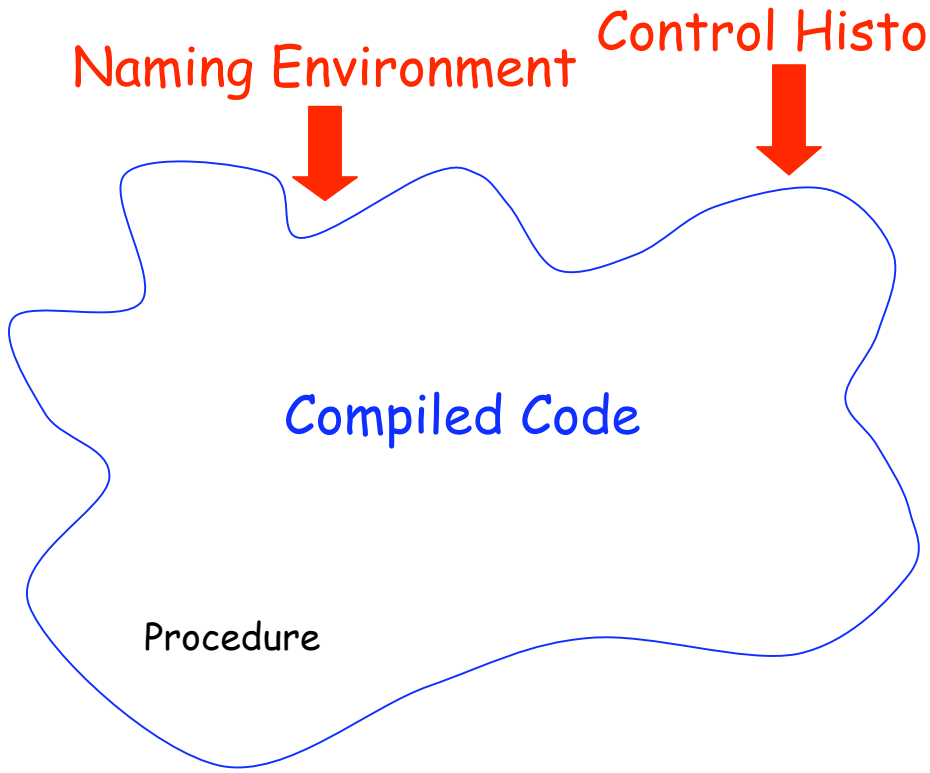
"Naming" includes the ability to find and access the object in memory

Each procedure inherits a set of names

⇒ Variables, values, procedures, objects, locations, …

⇒ Clean slate for new names, "scoping" can hide other names

The Procedure & Its Three Abstractions



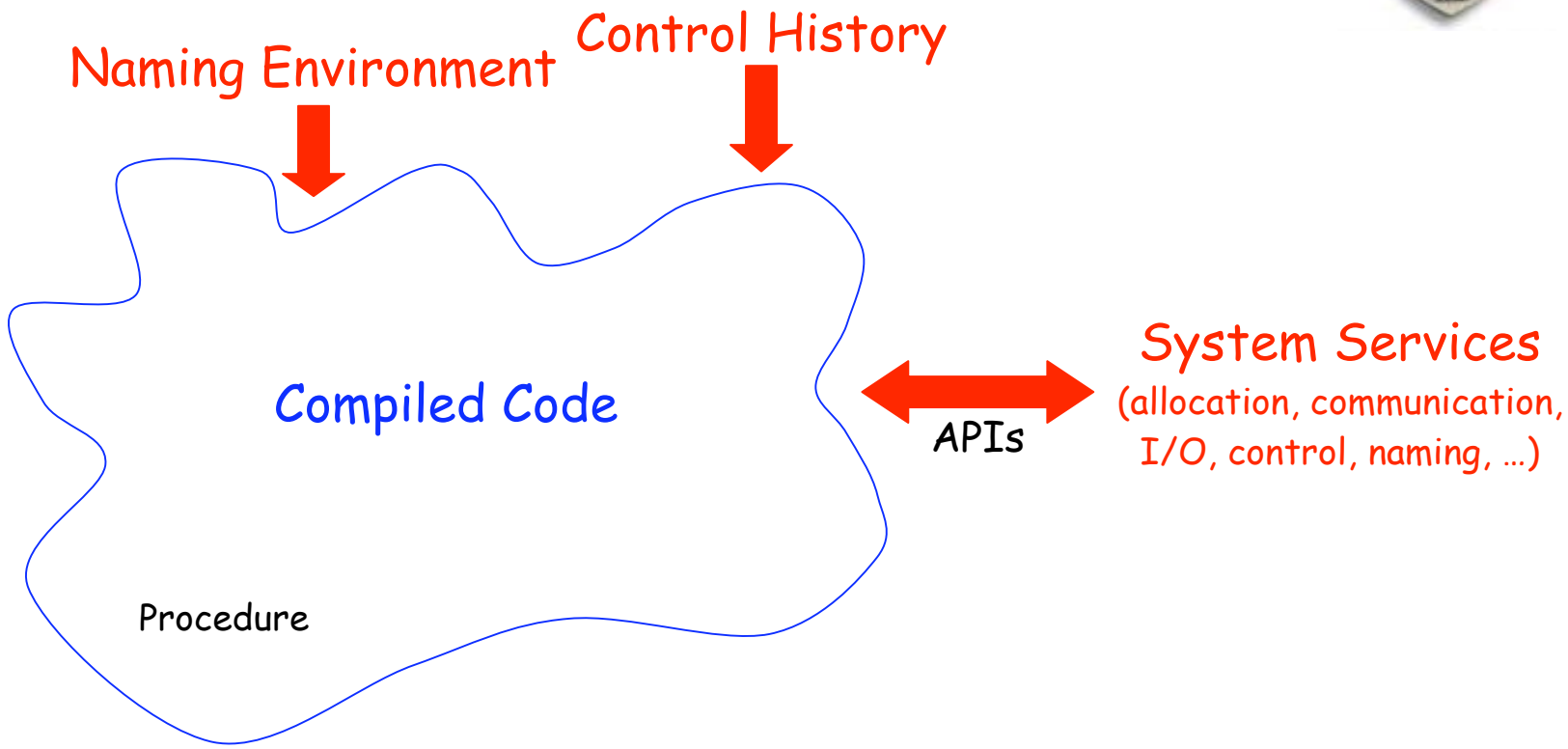
Each procedure inherits a control history

⇒ Chain of calls that led to its invocation

⇒ Mechanism to return control to caller

Some notion of parameterization (ties back to naming)

The Procedure & Its Three Abstractions



Each procedure has access to external interfaces

⇒ Access by name, with parameters *(may include dynamic link & load)*

⇒ Protection for both sides of the interface

The Procedure: Three Abstractions

- Control Abstraction
  - Well defined entries & exits
  - Mechanism to return control to caller
  - Some notion of parameterization (usually)
- Clean Name Space
  - Clean slate for writing locally visible names
  - Local names may obscure identical, non-local names
  - Local names cannot be seen outside
- External Interface
  - Access is by procedure name & parameters
  - Clear protection for both caller & callee
  - Invoked procedure can ignore calling context
- Procedures permit a critical separation of concerns

The Procedure (Realist's View)

Procedures are the key to building large systems

- Requires system-wide compact
  - Conventions on memory layout, protection, resource allocation calling sequences, & error handling
  - Must involve architecture (**ISA**), **OS**, & compiler
- Provides shared access to system-wide facilities
  - Storage management, flow of control, interrupts
  - Interface to input/output devices, protection facilities, timers, synchronization flags, counters, …
- Establishes a private context
  - Create private storage for each procedure invocation
  - Encapsulate information about control flow & data abstractions

The Procedure (Realist's View)

Procedures allow us to use separate compilation

- Separate compilation allows us to build non-trivial programs
- Keeps compile times reasonable
- Lets multiple programmers collaborate
- Requires independent procedures

Without separate compilation, we *would not* build large systems

The procedure linkage convention

- Ensures that each procedure inherits a valid run-time environment and that the callers environment is restored on return
  - The compiler must generate code to ensure this happens according to conventions established by the system

The Procedure (More Abstract View)

A procedure is an abstract structure constructed via software

Underlying hardware directly supports little of the abstraction—it understands bits, bytes, integers, reals, and addresses, but not:

- Entries and exits
- Interfaces
- Call and return mechanisms
  - may be a special instruction to save context at point of call
- Name space
- Nested scopes

All these are established by a carefully-crafted system of mechanisms provided by compiler, run-time system, linkage editor and loader, and OS

Run Time versus Compile Time

These concepts are often confusing to the newcomer

- Linkages (*and code for procedure body*) execute at run time
- Code for the linkage is emitted at compile time
- The linkage is designed long before either of these

This issue (compile time versus run time) confuses students more than *any other* issue in Comp 412

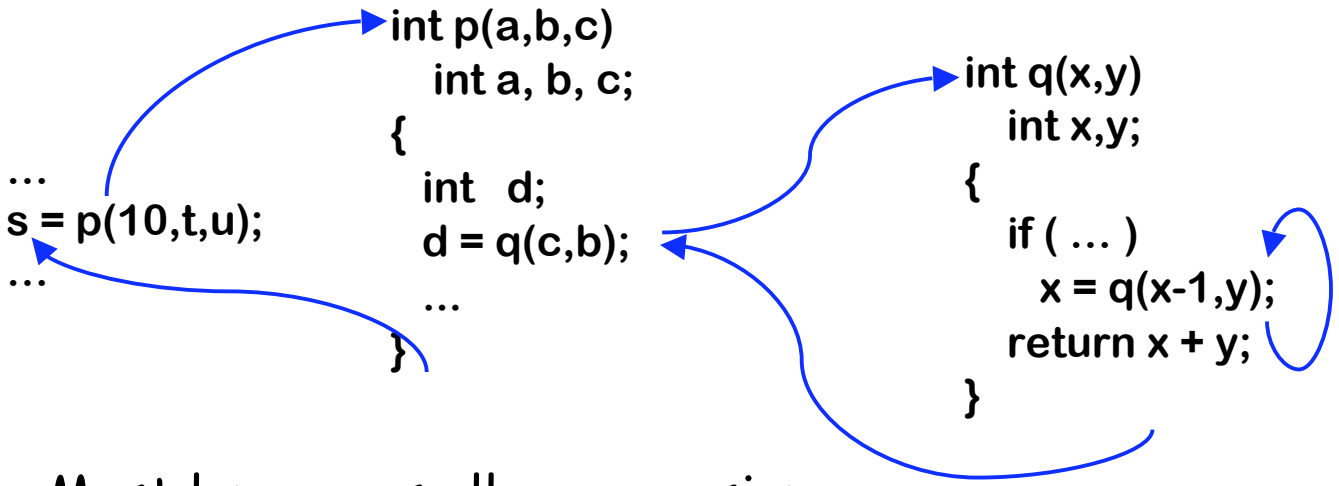
- We will emphasize the distinction between them

The Procedure as a Control Abstraction

Procedures have well-defined control-flow

The Algol-60 procedure call

- Invoked at a call site, with some set of *actual parameters*
- Control returns to call site, immediately after invocation

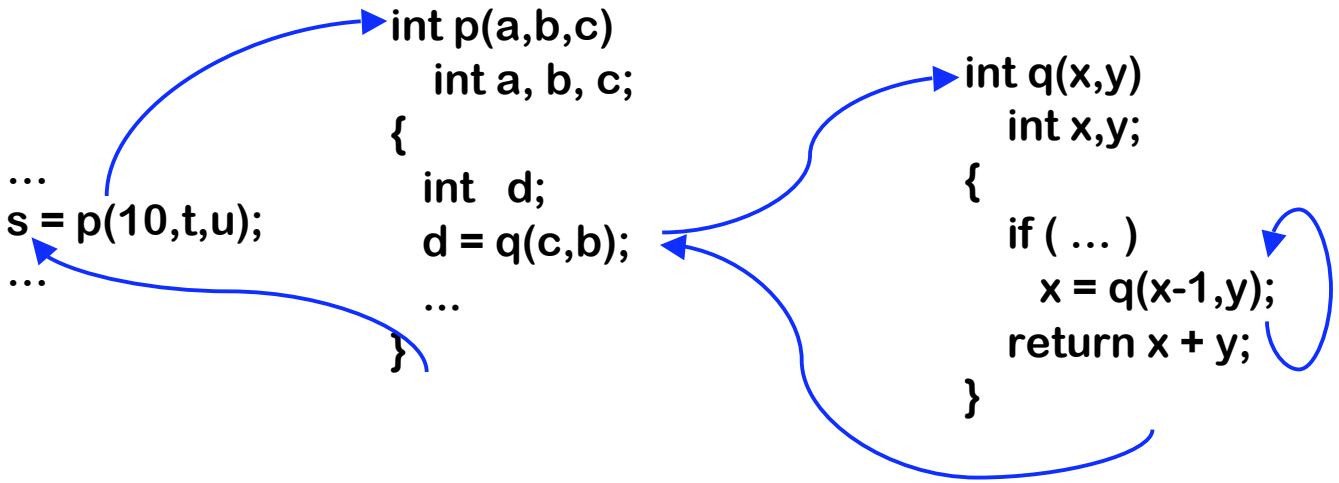


- Most languages allow recursion

The Procedure as a Control Abstraction

Implementing procedures with this behavior

- Requires code to save and restore a "return address"
- Must map actual parameters to formal parameters ($c \rightarrow x$, $b \rightarrow y$)
- Must create storage for local variables (&, maybe, parameters)
  - *p* needs space for *d* (&, maybe, *a*, *b*, & *c*)
  - where does this space go in recursive invocations?

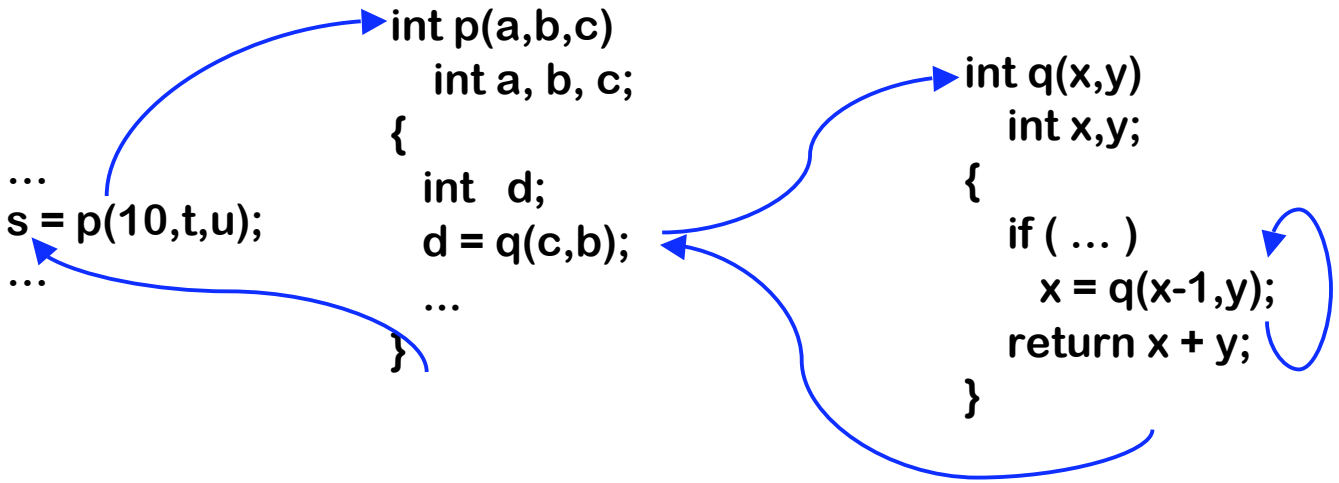


Compiler emits code that causes all this to happen at run time

The Procedure as a Control Abstraction

Implementing procedures with this behavior

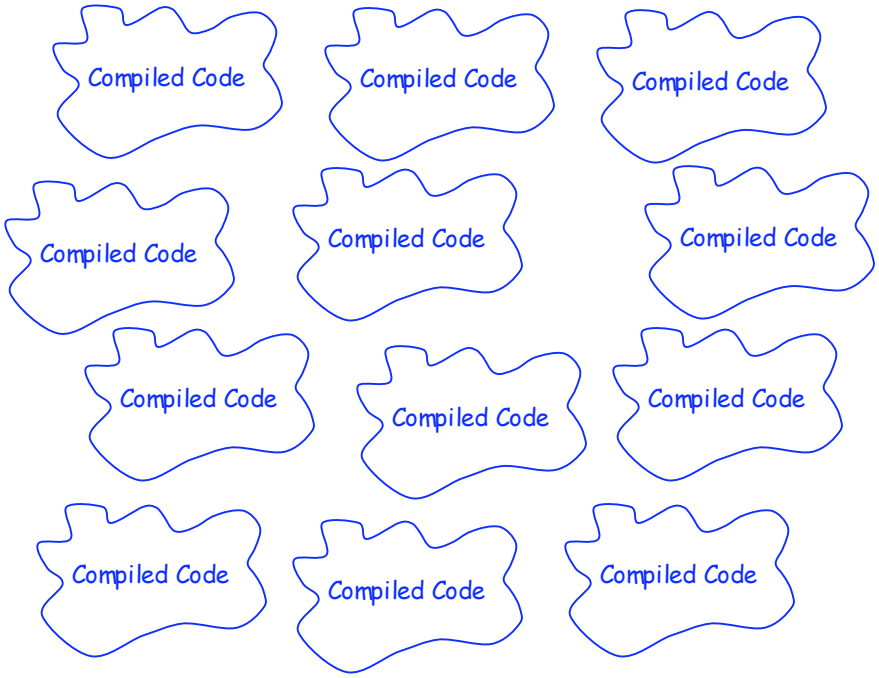
- Must preserve *p*'s state while *q* executes
  - recursion causes the real problem here
- *Strategy*: Create unique location for each procedure activation
  - Can use a "stack" of memory blocks to hold local storage and return addresses

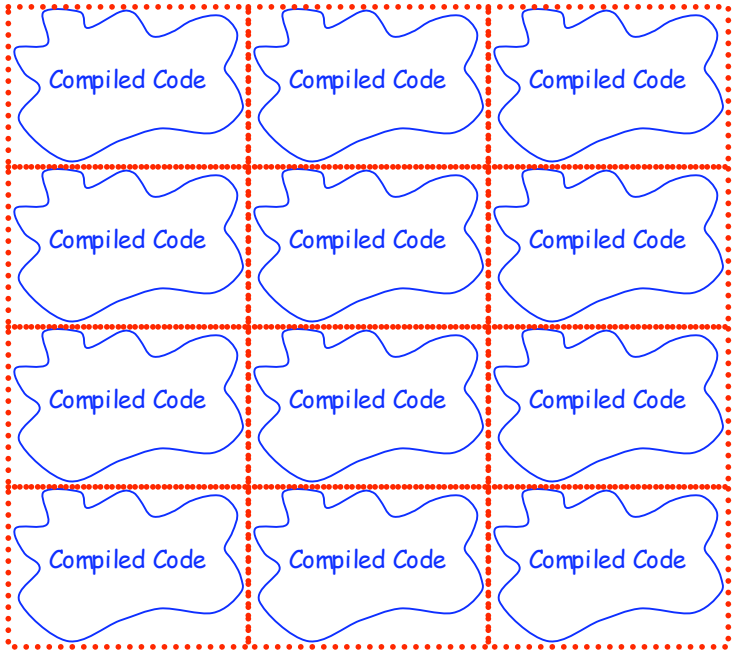


Compiler emits code that causes all this to happen at run time

The Procedure as a Control Abstraction

In essence, the procedure linkage wraps around the unique code of each procedure to give it a uniform interface





Similar to building a brick wall rather than a rock wall