Lecture 4

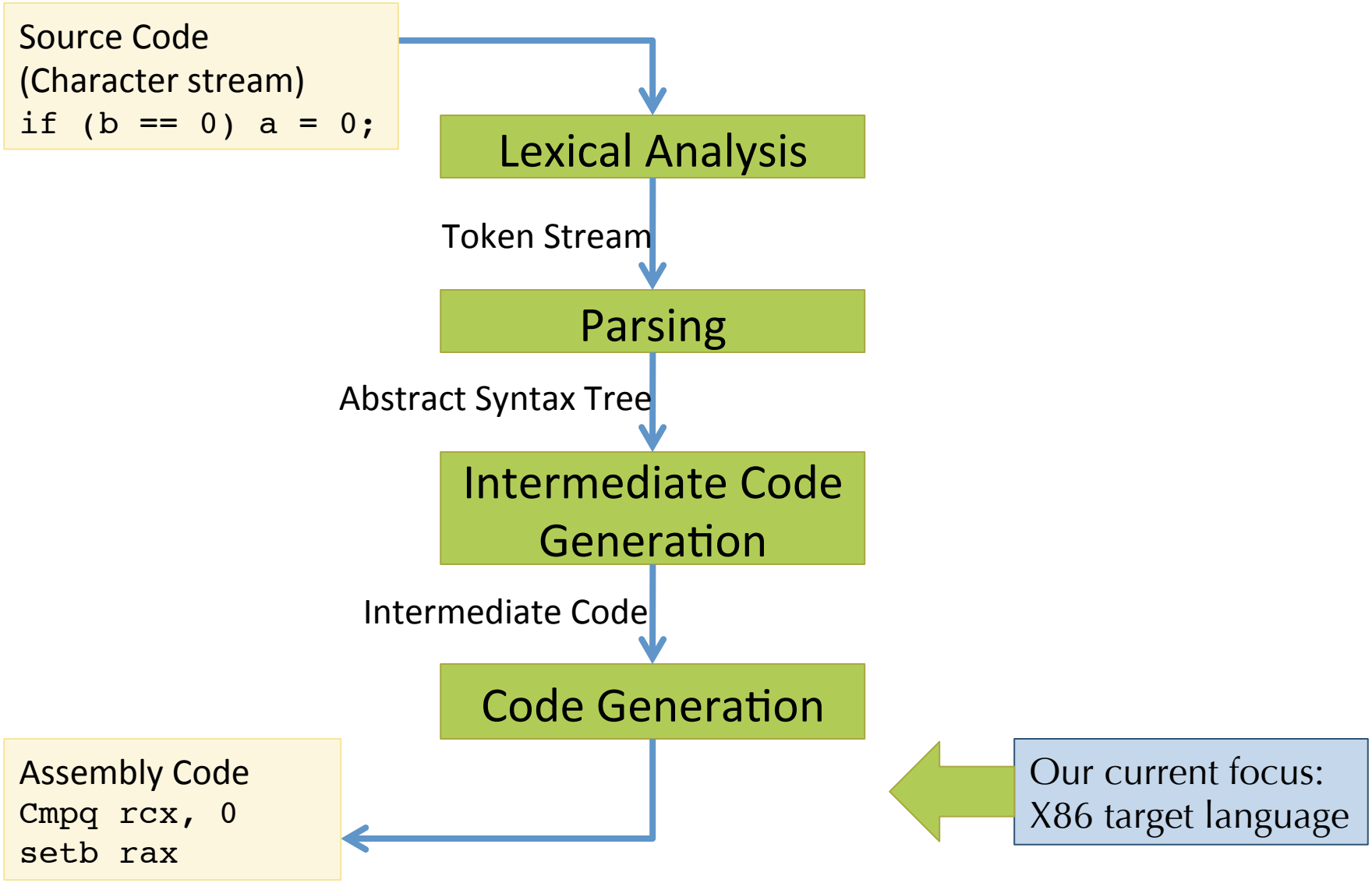
CIS 341: COMPILERS

Announcements

- HW2: X86lite
  - Available on the course web pages.
  - Due: Monday, February 2nd at 11:59:59pm
  - Pair-programming:
    - There's a pair-search survey on Piazza
    - Register the group on the submission page
    - Submission by any group member counts for the group

- Registration:
  - If you were on the wait list, you should have been contacted
  - If you are *not* registered, please see me after class

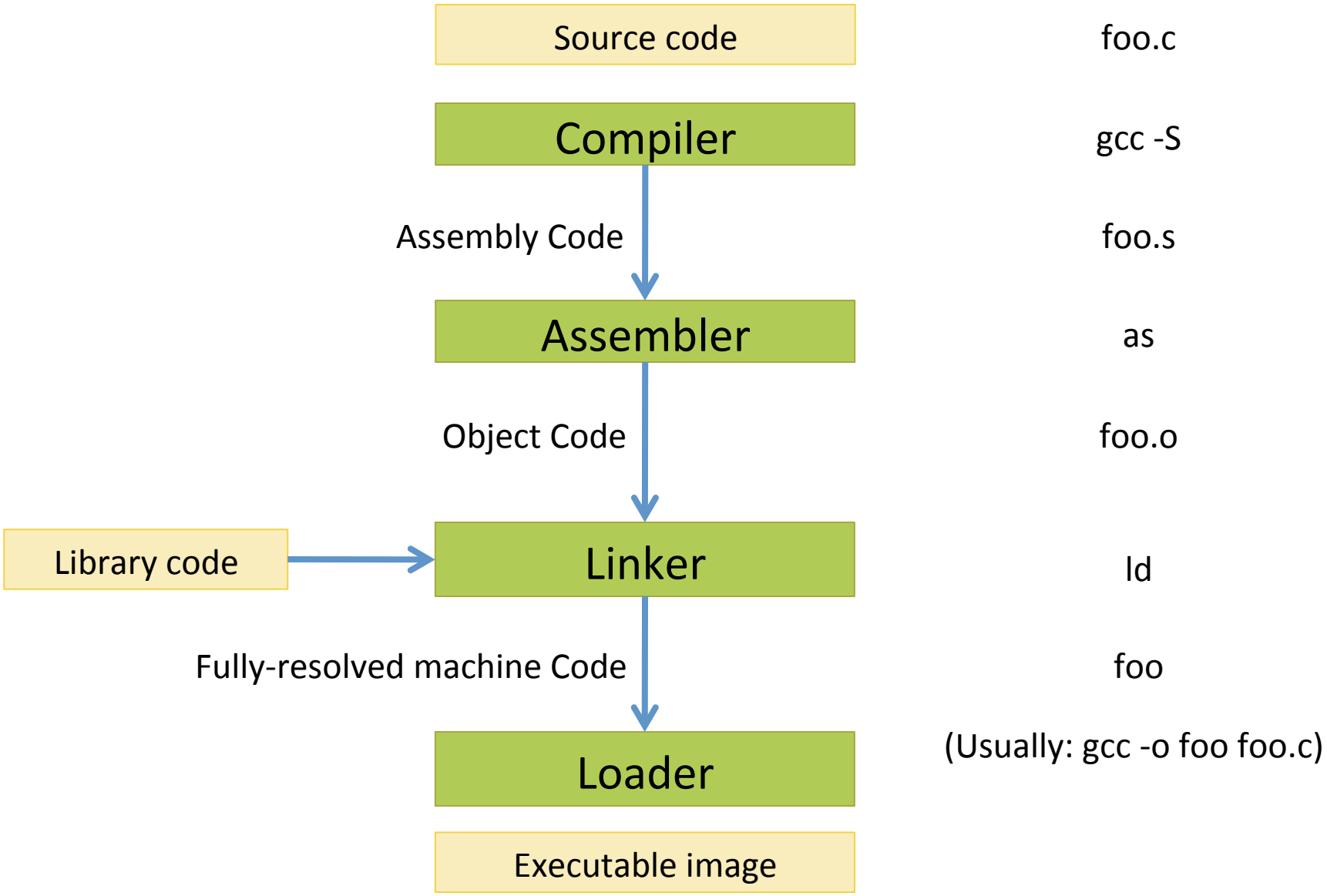
(Simplified) Compiler Structure



See www.cis.upenn.edu/~cis341/15sp/hw/hw2/x86lite.shtml

X86LITE

Compilation & Execution

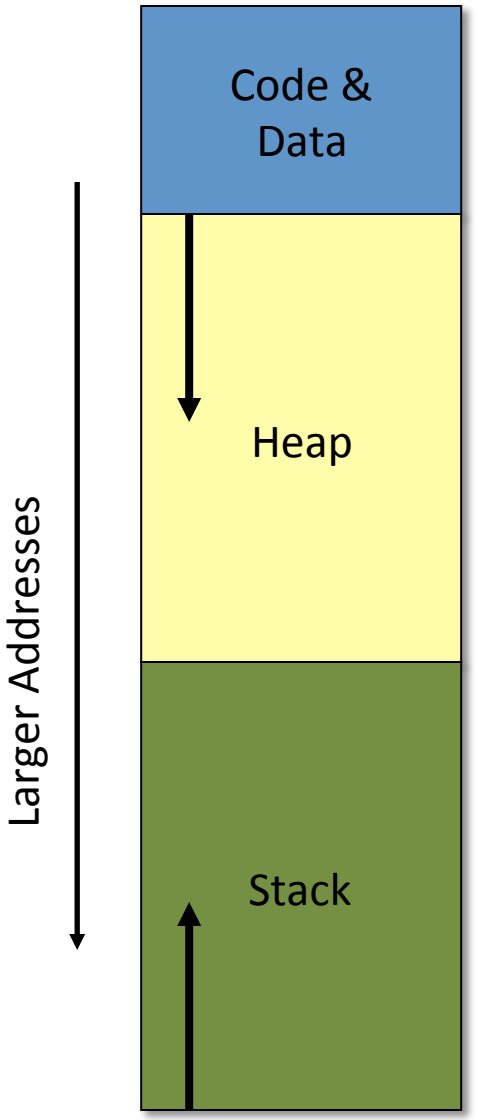


PROGRAMMING IN X86LITE

3 parts of the C memory model

- The code & data (or "text") segment
  - contains compiled code, constant strings, etc.
- The Heap
  - Stores dynamically allocated objects
  - Allocated via "malloc"
  - Deallocated via "free"
  - C runtime system
- The Stack
  - Stores local variables
  - Stores the return address of a function

- In practice, most languages use this model.



Local/Temporary Variable Storage

- Need space to store:
  - Global variables
  - Values passed as arguments to procedures
  - Local variables (either defined in the source program or introduced by the compiler)

- Processors provide two options
  - Registers: fast, small size (32 or 64 bits), limited number
  - Memory: slow, very large amount of space (4+ GB)

- In practice on X86:
  - Registers are limited (and have restrictions)
  - Divide memory into regions including the *stack* and the *heap*

Calling Conventions

- Specify the locations (e.g. register or stack) of arguments passed to a function
- Designate registers either:
  - Caller Save – e.g. freely usable by the called code
  - Callee Save – e.g. must be restored by the called code
- Protocol for deallocating stack-allocated arguments
  - Caller cleans up
  - Callee cleans up (makes variable arguments harder)

32-bit cdecl calling conventions

- "Standard" on X86 for many C-based operating systems (i.e. almost all)
  - Still some wrinkles about return values (e.g. some compilers use `EAX` and `EDX` to return small values)
  - This is evolving due to 64 bit (which allows for packing multiple values in one register)
- Arguments are passed on the stack in right-to-left order
- Return value is passed in `EAX`
- Registers `EAX`, `ECX`, `EDX` are caller save
- Other registers are callee save
  - Ignoring these conventions will cause havoc (bus errors or seg faults)

- Many other variants: fastcall, syscall, thiscall

x86-64 calling conventions

- Microsoft x64
  - Used by Visual C++ and Windows (but supported by gcc, intel C++, etc.)
  - 4 register arguments
  - 4-quad "shadow space"

- System V AMD64 ABI
  - Used by linux, bsd, Mac OSX
  - First six inteter/pointer arguments are passed in registers:
    - rdi, rsi, rdx, rcx, r8, r9
    - Arguments seven and up, passed on the stack
  - Stack aligned on 16-byte boundaries
  - Callee save registers: rbp, rbx, r12—r15
  - Caller save register: everything else
  - Caller cleans up stack arguments

Call Stacks: Caller's protocol

- Function call:

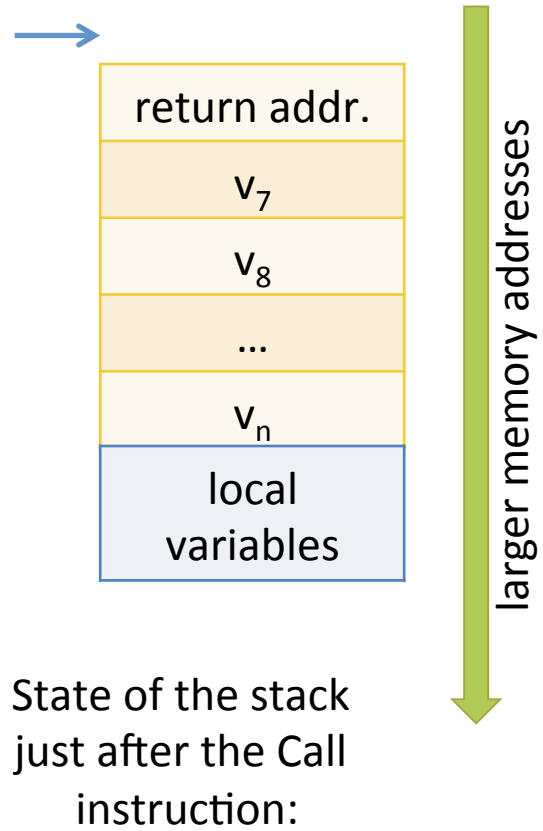
  `f(`e_1`, `e_2`, …, `e_n`);`

1. Save caller-save registers:
   - all but rbp, rbx, r12-r15
2. Evaluate e_1 to v_1, e_2 to v_2, … , e_n to v_n
3. Move v_1 .. v_6 into registers as on previous slide.
4. Push v_7 to v_n onto the top of the stack.
5. Use `Call` to jump to the code for `f`
   - pushing the return address onto the stack.

- Invariant: returned value passed in `rax`

- After call:

1. clean up the pushed arguments by popping the stack.
2. Restore caller-saved registers



Call Stacks: Callee's protocol

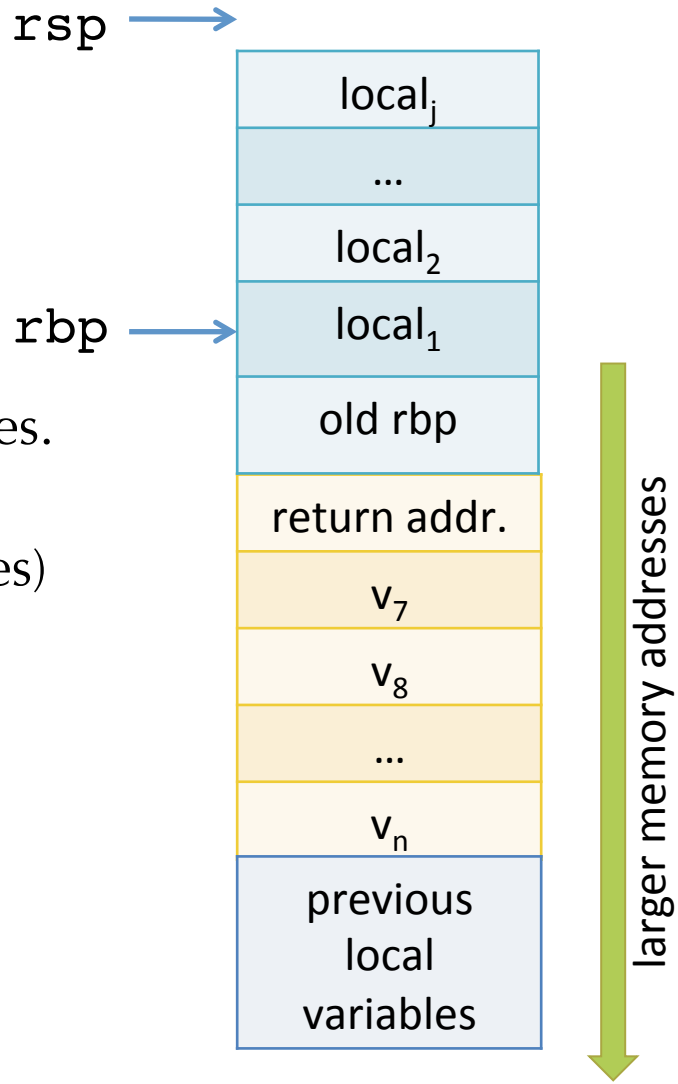
- On entry:

1. Save old frame pointer
   - rbp is callee save
2. Create new frame pointer
   - `movq rsp, rbp`
3. Allocate stack space for local variables.

- Invariants: (assuming quad-size values)
  - Function argument n > 6 is located at:
    rbp + (n-5) * 8
  - Local variable $local_j$ is located at:
    rbp – (j – 1) * 8

- On exit:

1. Pop local storage
2. Restore rbp



State of the stack after Step 3 of entry.