Storage and Scope

C Programming and Software Tools

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Blocks

- A *block* is a set of statements delimited by curly braces: { }
  - i.e., body of **a** loop, function definition, or anywhere you want to define a new *scope*, for example…

```
int sum = 0;
int main (void)
{
    int i;
    for ( i=0 ; i<n ; i++ ) {
        …
    }
    if (n > 60) {
        …
    }
    …
}
```

Scope of Variables

- *(for the moment, this discussion is only for programs whose source code is contained entirely in one file)*

A variable defined or declared outside of any block has *global scope*

- the variable is *visible* (read/writable) to all functions that appear after it in the source file

```
int main
(void)
{ … }

int i = 15;

int f(…)
{…}

int g(…)
{…}
```

Scope… (cont'd)

- A variable defined inside a block has scope only within that block
- Variables with different scopes (even if they have the same name) are independent variables
- If two or more variables have the same name, to resolve a variable reference the rule is:

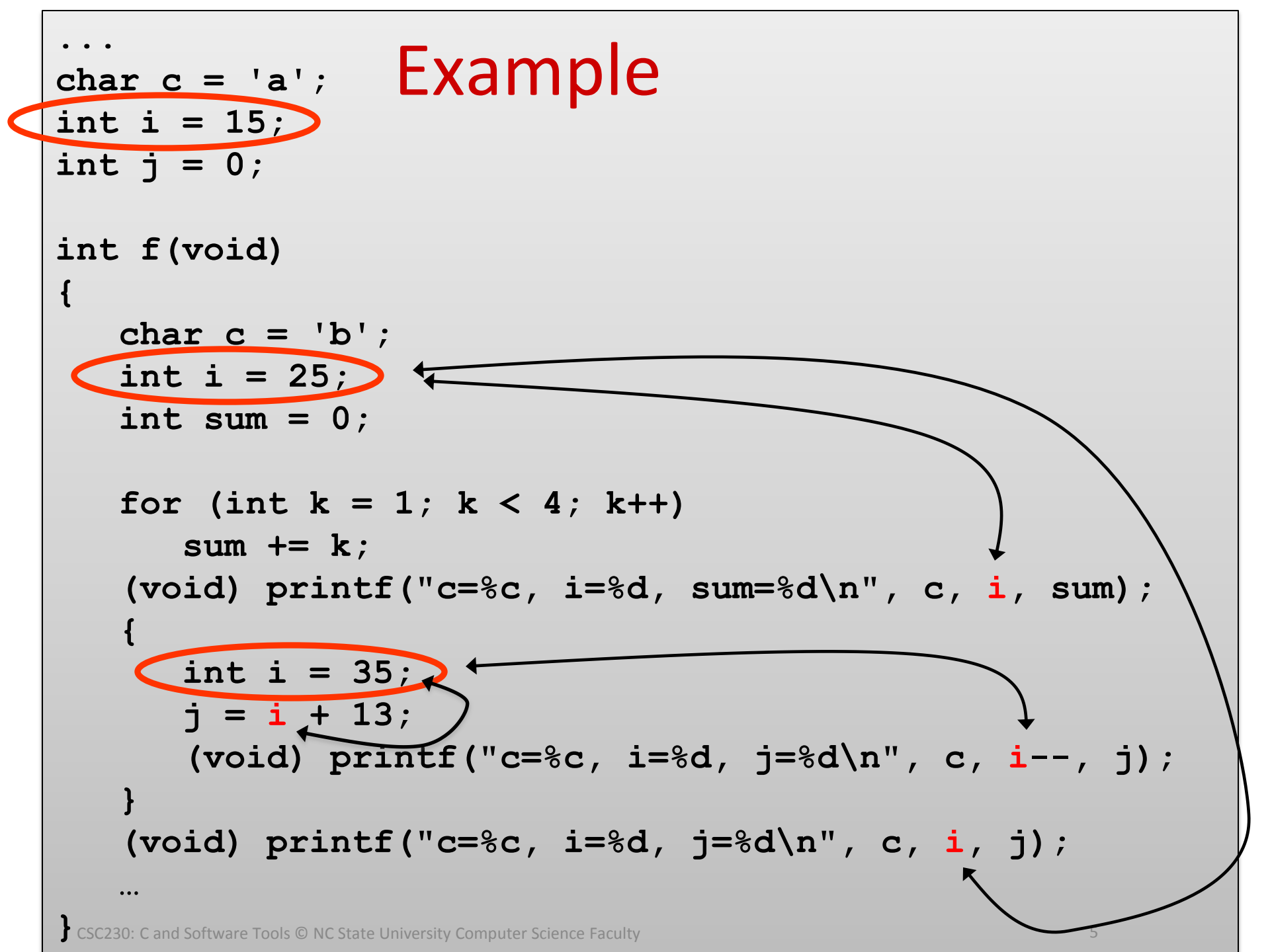
"most local scope wins"

Example

```
...
char c = 'a';
int i = 15;
int j = 0;

int f(void)
{
   char c = 'b';
   int i = 25;
   int sum = 0;

   for (int k = 1; k < 4; k++)
      sum += k;
   (void) printf("c=%c, i=%d, sum=%d\n", c, i, sum);
   {
      int i = 35;
      j = i + 13;
      (void) printf("c=%c, i=%d, j=%d\n", c, i--, j);
   }
   (void) printf("c=%c, i=%d, j=%d\n", c, i, j);
   …
}
```



Scope… (cont'd)

- Is it a good idea to avoid reusing the same variable name?
  - Often, but not always

☠ *common source of bugs* ☠
confusion about scoping, and use of common names

Special Case: Scope of Labels

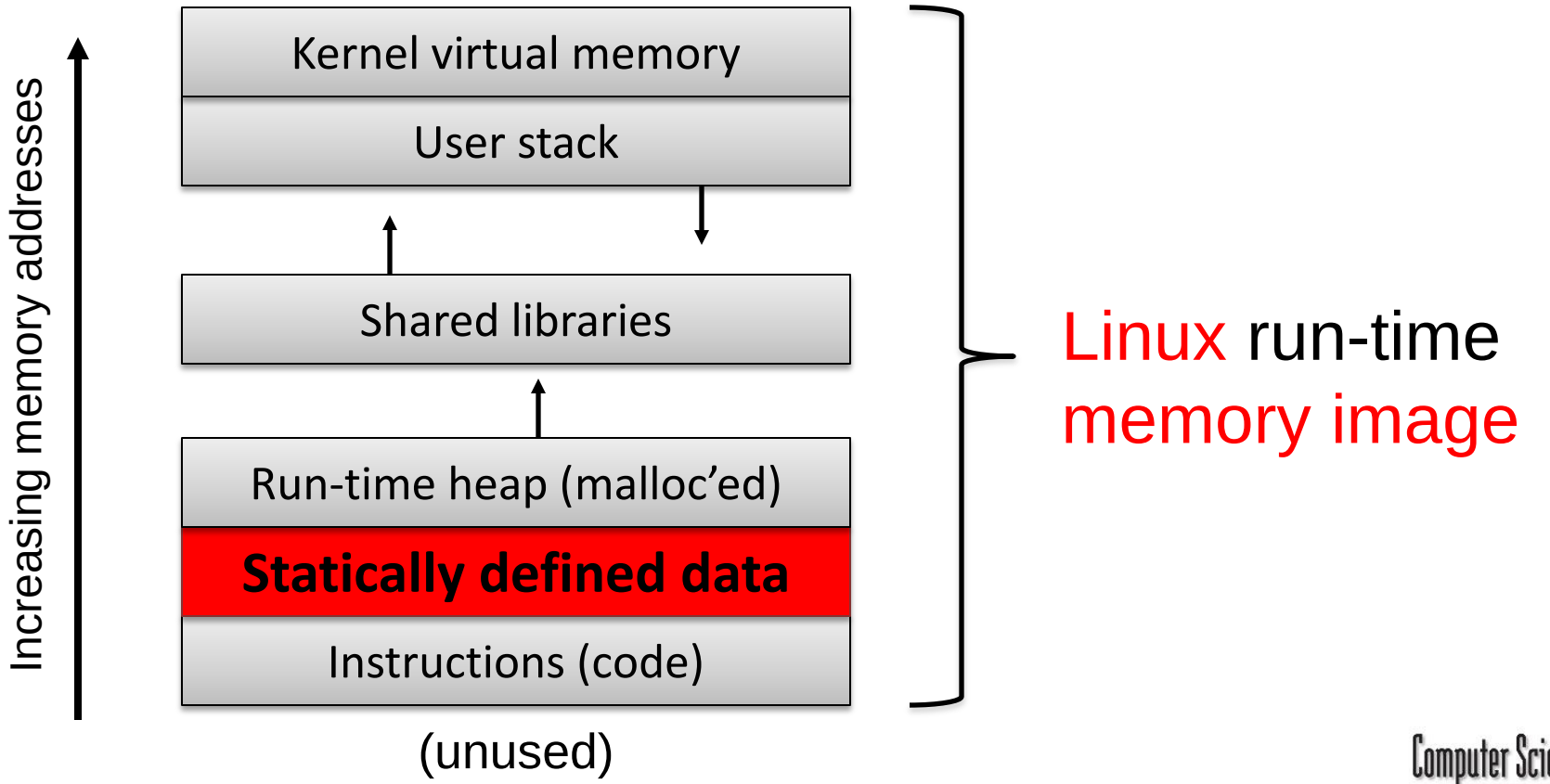
- The scope of (`goto`) labels is just the function they are contained in
  - so: you cannot `goto` a label defined in another function

```
int f1(int b) {
    if (b < 10)
        goto labelx;
    (void) printf("b < 10\n");
labelx:
    return 0;
}

int f2(int a) {
    if (a > 5)
        goto labelx;
    (void) printf("a > 5\n");
labelx:
    return 0;
}
```

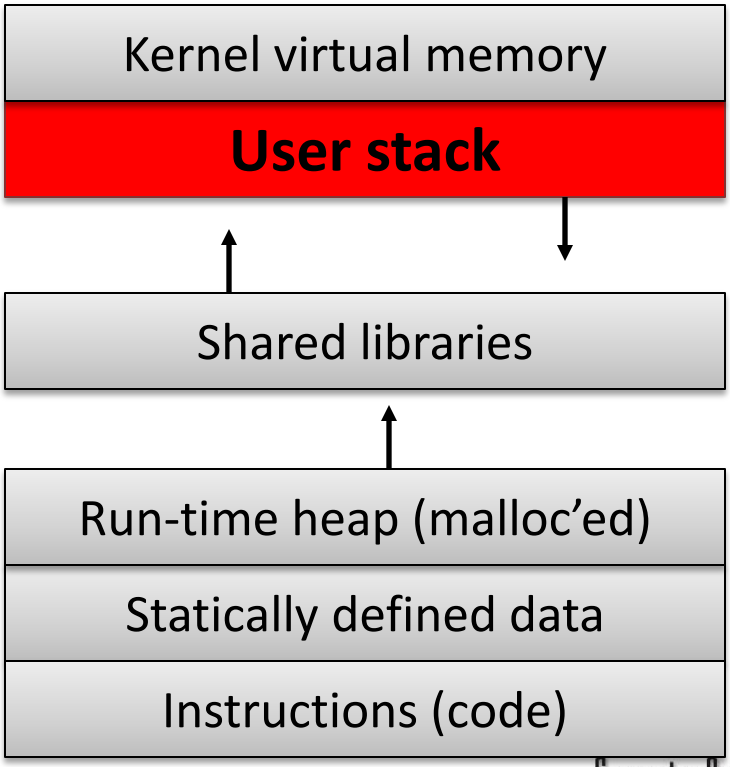
Lifetime (Storage Class) of Variables

- Memory space for a global variable is statically-allocated at compile and load time
  - this is called the ***static*** storage class



Lifetime… (cont'd)

- Memory space for a variable declared inside a block is automatically-allocated at run time
  - entry into the block triggers automatic memory allocation and exit triggers automatic deallocation
  - this is called the ***`auto`*** *storage class*



```
...
char c = 'a';
int i = 15;
int j = 0;

int main (void)
{
   char c = 'b';
   int i = 25;
   int sum = 0;
   for (int k = 1; k < 4; k++)
      sum += k;
   (void) printf("c=%c, i=%d, sum=%d\n", c, i, sum);
   {
      int i = 35;
      j = i + 13;
      (void) printf("c=%c, i=%d, j=%d\n", c, i--, j);
   }
   (void) printf("c=%c, i=%d, j=%d\n", c, i, j);
   …
}
```

For each i variable, how is the memory allocated (statically or dynamically) and what is the storage class?

Lifetime… (cont'd)

- In C, you can manually force variables declared inside a block to be static storage class using the **`static`** keyword
  - memory space is allocated only once, in the Static area of memory

```
...
char c = 'a';
int i = 15;
int j = 0;

int f(void)
{
    char c = 'b';
    int i = 25;
    int sum = 0;
    for (int k = 1; k < 4; k++)
        sum += k;
    (void) printf("c=%c, i=%d, sum=%d\n", c, i, sum);
    {
        static int i = 35;
        j = i + 13;
        (void) printf("c=%c, i=%d, j=%d\n", c, i--, j);
    }
    (void) printf("c=%c, i=%d, j=%d\n", c, i, j);
    …
}
```

Initialization of Variables

- **`static`**, **`auto`**, … - what does it matter?
- 1. Space on the stack is limited (remember problems allocating **`bigarray[]`** as an **`auto`** variable?)
- **`2. static`** variables with global scope can be initialized only with constant expressions

```
char c = 'a';
int i = 15 + (39 % 3);
int j = 0;
```

Initialization … (cont'd)

- **auto** class variables can be initialized using any valid expression at the point at which they are declared

```
{…
      int i = 15 + (39 % 3) + f();
      int j = getchar() * 6 + i;
…}
```

- 3. default value of static variables (if not explicitly initialized) is 0 Don't rely on this!
  - There is no default initial value for auto variables

```
{   int i;   static int j;
     printf("%d %d\n", i, j);   }
```

Output?

☠ common source of bugs ☠
failure to explicitly initialize variables

Initialization … (cont'd)

- 4. Static class variables are initialized only once!

  auto variables are (re-)initialized every time the block is entered

☠ *common source of bugs* ☠
expecting static behavior from auto variables

Initialization Example

```
void f(void);

main(void) {
    …
       f();
       f();
       f();

}

void f( void ) {
    int k = 0;
    static int j = 0;
    printf (" %d %d\n", ++j, ++k );
}
```

Output?

The `register` Storage Class

- A recommendation to the compiler to consider storing the variable in a register instead of memory

```
int main (void)
{
    …
    int i = 25;
    double sum = 0.0;
    for ( register int k  = 1; k < 1000000; k++)
        sum += k;
    …
}
```

What difference does that make?

The `register` … (cont'd)

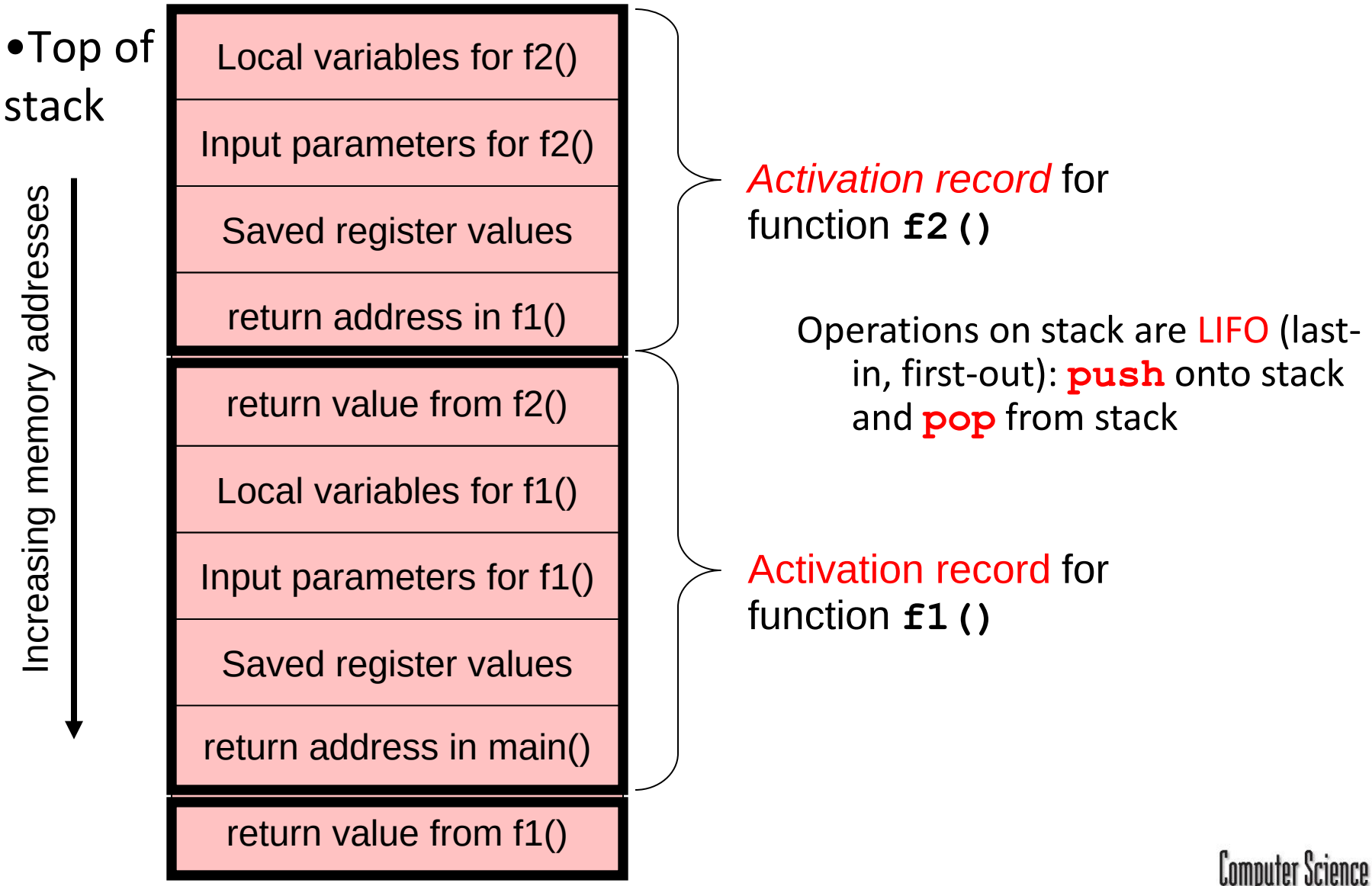
- Can only be specified for **`auto`** variables (i.e., not for global variables)
  - some restrictions on what types of variables can be specified as **`register`** class *(see reference manual for details)*
- Optimizing compilers may be able to do a better job than you can at identifying candidates for register storage

Seriously – I have never seen "register" used by itself in a C program. It implies that the programmer is "trusting" C to do something, which C programmers never do.

The Stack

- Area of memory reserved for dynamic allocation of auto variables, and function parameters
  - input parameter values
  - return address of caller
  - auto variables local to the block
  - saved register values
  - result returned by function
- All of this is called the *activation record* or *stack frame* of the called function (i.e., the callee)

Example of Stack Contents



Another Storage Class: `extern`

- *discussed later along with linking…*

Exercise 10a

Variable storage

- For each numbered printf, indicate:
  - What is printed? Put a **?** If it could be anything
  - Where the variable in question is allocated (stack or static region)?

```
int x = 15, y = 25;
int main (void) {
   printf("%d\n", x); //1
   int x;
   printf("%d\n", x); //2
   x = y;
   printf("%d\n", y); //3
   for (int j = 0; j < 3; j++) {
      int y = 32;
      static int x = 35;
      x = 2 * x;
      printf("%d\n", x); //4
      y = y / 2;
      printf("%d\n", y); //5
   }
   int y = 100;
   printf("%d\n", y); //6
}
```


Reminder: Go to course web page for link to exercise form. Paste code into ideone.com and submit the link.