CS 33

Introduction to C
Part 4

LGBTQ+ Mentorship Program

An initiative to build LGBTQ+ community in CS

Mentorship

1-on-1 or peer group mentoring for LGBTQ+ students - TGNC folks, femmes, and POC to especially welcome!

Sign up now!

form closes Sept 24

Community Events

- LGBTQ+ Peer Connections
- Industry Panelists
- Game Nights
- + Submit your own ideas!

More to Come

Join our mailing list! We plan to expand this fall

Questions? Feedback?

contact us at evan_dong@brown.edu

***we welcome closeted & questioning folks - participation is confidential!**

Encoding Byte Values

- Byte = 8 bits
  - binary 00000000_2 to 11111111_2
  - decimal: 0_{10} to 255_{10}
  - hexadecimal 00_{16} to FF_{16}
    - » base 16 number representation
    - » use characters ‘0’ to ‘9’ and ‘A’ to ‘F’
    - » write $FA1D37B_{16}$ in C as
      - 0xFA1D37B
      - 0xfa1d37b

Hex	Decimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
A	10	1010
B	11	1011
C	12	1100
D	13	1101
E	14	1110
F	15	1111

Unsigned 32-Bit Integers

b_{31}	b_{30}	b_{29}	…	b_2	b_1	b_0

value = $\sum_{i=0}^{31} b_i \cdot 2^i$

(we ignore negative integers for now)

Storing and Viewing Ints

```
int main() {
    unsigned int n = 57;
    printf("binary: %b, decimal: %u, "
           "hex: %x\n", n, n, n);
    return 0;
}
```

```
$ ./a.out
binary: 111001, decimal: 57, hex: 39
$
```

Boolean Algebra

- **Developed by George Boole in 19th Century**
  - **algebraic representation of logic**
    - » **encode “true” as 1 and “false” as 0**

And

- A&B = 1 when both A=1 and B=1

&	0	1
0	0	0
1	0	1

Or

- A|B = 1 when either A=1 or B=1

|	0	1
0	0	1
1	1	1

Not

- ~A = 1 when A=0

~	
0	1
1	0

Exclusive-Or (Xor)

- A^B = 1 when either A=1 or B=1, but not both

^	0	1
0	0	1
1	1	0

General Boolean Algebras

- Operate on bit vectors
  - operations applied bitwise

```
  01101001      01101001      01101001
& 01010101    | 01010101    ^ 01010101    ~ 01010101
  --------      --------      --------      --------
  01000001      01111101      00111100      10101010
```

- All of the properties of boolean algebra apply

Example: Representing & Manipulating Sets

- Representation
  - width-w bit vector represents subsets of {0, …, w–1}
  - $a_j = 1$ iff $j \in A$

01101001	{ 0, 3, 5, 6 }
76543210	
01010101	{ 0, 2, 4, 6 }
76543210	

- Operations

&	intersection	01000001	{ 0, 6 }
|	union	01111101	{ 0, 2, 3, 4, 5, 6 }
^	symmetric difference	00111100	{ 2, 3, 4, 5 }
~	complement	10101010	{ 1, 3, 5, 7 }

Bit-Level Operations in C

- Operations &, |, ~, ^ available in C
  - apply to any “integral” data type
    - » `long, int, short, char`
  - view arguments as bit vectors
  - arguments applied bit-wise
- Examples (char datatype)

```
~0x41 → 0xBE
   ~01000001₂ → 10111110₂
~0x00 → 0xFF
   ~00000000₂ → 11111111₂
0x69 & 0x55 → 0x41
   01101001₂ & 01010101₂ → 01000001₂
0x69 | 0x55 → 0x7D
   01101001₂ | 01010101₂ → 01111101₂
```

Contrast: Logic Operations in C

- **Contrast to Logical Operators**
  - `&&`, `||`, `!`
    - » view 0 as “false”
    - » anything nonzero as “true”
    - » always return 0 or 1
    - » early termination/short-circuited execution
- **Examples (char datatype)**

```
!0x41 → 0x00
!0x00 → 0x01
!!0x41 → 0x01

0x69 && 0x55 → 0x01
0x69 || 0x55 → 0x01
p && complicated_function(x)
```

Contrast: Logic Operations in C

- Contrast to Logical Operators
  - &&, ||, !
    - » vie "false"

Watch out for && vs. & (and || vs. |)… One of the more common oopsies in C programming

- E

```
!0x41 → 0x00
!0x00 → 0x01
!!0x41 → 0x01

0x69 && 0x55 → 0x01
0x69 || 0x55 → 0x01
p && complicated_function(x)
```

Quiz 1

- Which of the following would determine whether the next-to-the-rightmost bit of Y (declared as a char) is 1? (I.e., the expression evaluates to true if and only if that bit of Y is 1.)
  a) Y & 0x02
  b) !((~Y) & 0x02)
  c) none of the above
  d) both a and b

Shift Operations

- Left Shift: `x << y`
  - shift bit-vector x left y positions
    - throw away extra bits on left
    - » fill with 0's on right
- Right Shift: `x >> y`
  - shift bit-vector x right y positions
    - » throw away extra bits on right
  - logical shift
    - » fill with 0's on left
  - arithmetic shift
    - » replicate most significant bit on left
- Undefined Behavior
  - shift amount < 0 or ≥ word size

Argument `x`	`01100010`
`<< 3`	`00010`*`000`*
Log. `>> 2`	*`00`*`011000`
Arith. `>> 2`	*`00`*`011000`

Argument `x`	`10100010`
`<< 3`	`00010`*`000`*
Log. `>> 2`	*`00`*`101000`
Arith. `>> 2`	*`11`*`101000`

Digression

- **Pre-increment**
  - ***++b*** **means add one to *b;* the result of the expression is this new value of *b***
- **Post-increment**
  - ***b++*** **means the value of the expression is the current value of *b*, then add one to *b***
- **Example**

```
int b=1;
printf("%d\n", (++b)*b);
```

output:

```
4
```

```
int b=1;
printf("%d\n", (b++)*b);
```

output:

```
2
```

Global Variables

```
#define NUM_ROWS 3
#define NUM_COLS 4
int m[NUM_ROWS][NUM_COLS];

int main() {
   int row, col;
   for(row=0; row<NUM_ROWS; row++)
     for(col=0; col<NUM_COLS; col++)
          m[row][col] = row*NUM_COLS+col;
   return 0;
}
```

The scope is global;
***m* can be used**
by all functions

Global Variables

```
#define NUM_ROWS 3
#define NUM_COLS 4
int m[NUM_ROWS][NUM_COLS];

int main() {
   int row, col;
   printf("%u\n", m);
   printf("%u\n", &row);
   return 0;
}
```

```
$ ./a.out
8384
3221224352
```

Global Variables are Initialized!

```
#define NUM_ROWS 3
#define NUM_COLS 4
int m[NUM_ROWS][NUM_COLS];

int main() {
   printf("%d\n", m[0][0]);
   return 0;
}
```

```
$ ./a.out
0
```

Scope

```
int a;   // global variable

int main() {
   int a;   // local variable
   a = 0;
   proc();
   printf("a = %d\n", a); // what's printed?
   return 0;
}

int proc() {
   a = 1;
   return a;
}
```

```
$ ./a.out
0
```

Scope (continued)

```
int a;    // global variable

int main() {
   a = 2;
   proc(1);
   return 0;
}

int proc(int a) {
   printf("a = %d\n", a); // what's printed?
   return a;
}
```

```
$ ./a.out
1
```

Scope (still continued)

```
int a;   // global variable

int main() {
   a = 2;
   proc(1);
   return 0;
}

int proc(int a) {
   int a;
   printf("a = %d\n", a); // what’s printed?
   return a;
}
```

```
$ gcc prog.c
prog.c:12:8: error: redefinition of 'a'
   int a;
       ^
```

Scope (more ...)

```
int a;   // global variable

int proc() {
    {
        // the brackets define a new scope
        int a;
        a = 6;
    }
    printf("a = %d\n", a); // what's printed?
    return 0;
}
```

```
$ ./a.out
0
```

Quiz 2

```
int a;

int proc(int b) {
   {int b=6;}
   a = b;
   return a+2;
}

int main() {
   {int a = proc(4);}
   printf("a = %d\n", a);
   return 0;
}
```

- **What's printed?**
  a) 0
  b) 4
  c) 6
  d) 8
  e) nothing; there's a syntax error

Scope and For Loops (1)

```
int A[100];
for (int i=0; i<100; i++) {
  // i is defined in this scope
  A[i] = i;
}
```

Scope and For Loops (2)

```
int A[100];
initializeA(A);
for (int i=0; i<100; i++) {
  // i is defined in this scope
  if (A[i] < 0)
    break;
}
if (i != 100)
  printf("A[%d] is negative\n", i);
```

syntax error: reference to *i* is out of scope.

Lifetime

```
int count;

int main() {
    func();
    ...
    func(); // what's printed by func?
    return 0;
}

int func() {
    int a;
    if (count == 0) a = 1;
    count = count + 1;
    printf("%d\n", a);
    return 0;
}
```

```
% ./a.out
1
-38762173
```

Lifetime (continued)

```
int main() {
   func(1); // what's printed by func?
   return 0;
}
int a;
int func(int x) {
   if (x == 1) {
      a = 1;
      func(2);
      printf("%d\n", a);
   } else
      a = 2;
   return 0;
}
```

```
% ./a.out
2
```

Lifetime (still continued)

```
int main() {
    func(1); // what's printed by func?
    return 0;
}

int func(int x) {
    int a;
    if (x == 1) {
        a = 1;
        func(2);
        printf("a = %d\n", a);
    } else
        a = 2;
    return 0;
}
```

```
% ./a.out
1
```

Lifetime (more ...)

```
int main() {
    int *a;
    a = func();
    printf("%d\n", *a); // what's printed?
    return 0;
}

int *func() {
    int x;
    x = 1;
    return &x;
}
```

```
% ./a.out
23095689
```

Lifetime (and still more ...)

```
int main() {
   int *a;
   a = func(1);
   printf("%d\n", *a); // what's printed?
   return 0;
}

int *func(int x) {
   return &x;
}
```

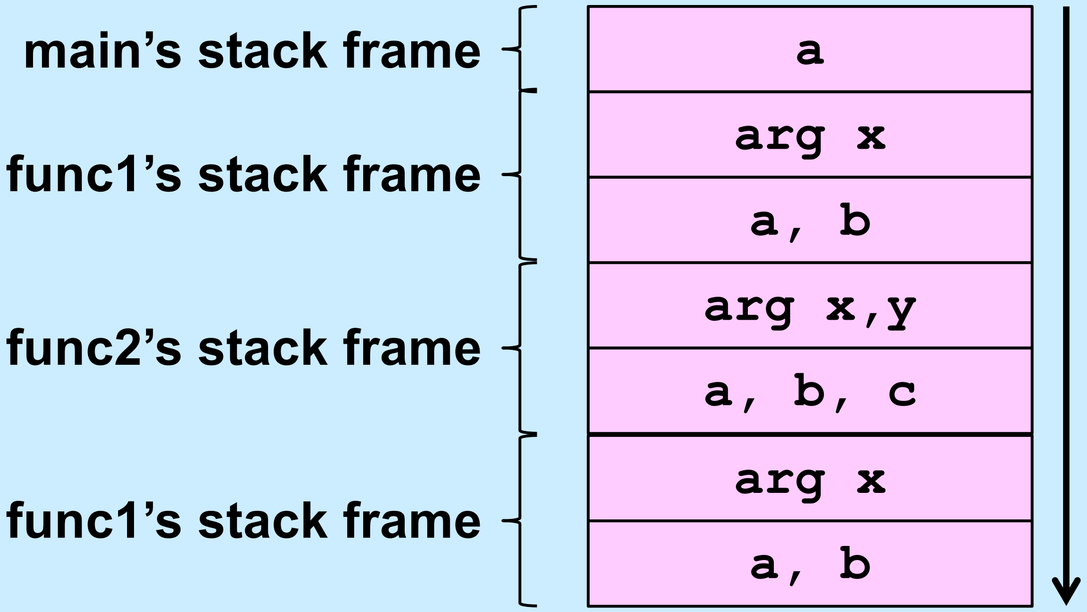
```
% ./a.out
98378932
```

Rules

- Global variables exist for the duration of program's lifetime
- Local variables and arguments exist for the duration of the execution of the function
  - from call to return
  - each execution of a function results in a new instance of its arguments and local variables

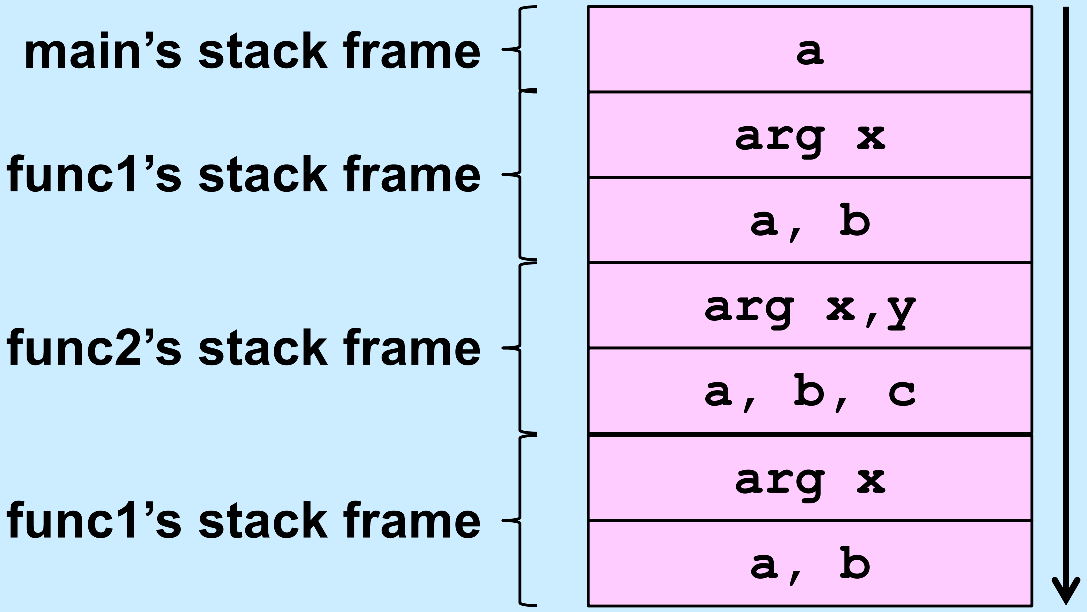
Implementation: Stacks

```
int main() {
   int a;
   func1(0);
   ...
}
int func1(int x) {
   int a,b;
   if (x==0) func2(a,2);
   ...
}
int func2(int x, int y) {
   int a,b,c;
   func1(1);
   ...
}
```



Implementation: Stacks

```
int main() {
   int a;
   func1(0);
   ...
}
int func1(int x) {
   int a,b;
   if (x==0) func2(a,2);
   ...
}
int func2(int x, int y) {
   int a,b,c;
   func1(1);
   ...
}
```



Quiz 3

```
void func(int a) {
   int b=2;
   if (a == 1) {
      func(2);
      printf("%d\n", b);
   } else {
      b = a*(b++)*b;
   }
}
int main() {
   func(1);
   return 0;
}
```

- What's printed?
  a) 0
  b) 1
  c) 2
  d) 4

Static Local Variables

```
int *sub1() {
  int var = 1;
  …
  return &var;
  /* amazingly illegal */
}
```

```
int *sub2() {
  static int var = 1;
  …
  return &var;
  /* (amazingly) legal */
}
```

- Scope
  - like local variables
- Lifetime
  - like global variables
- Initialized just once
  - when program begins
  - implicit initialization to 0

Quiz 4

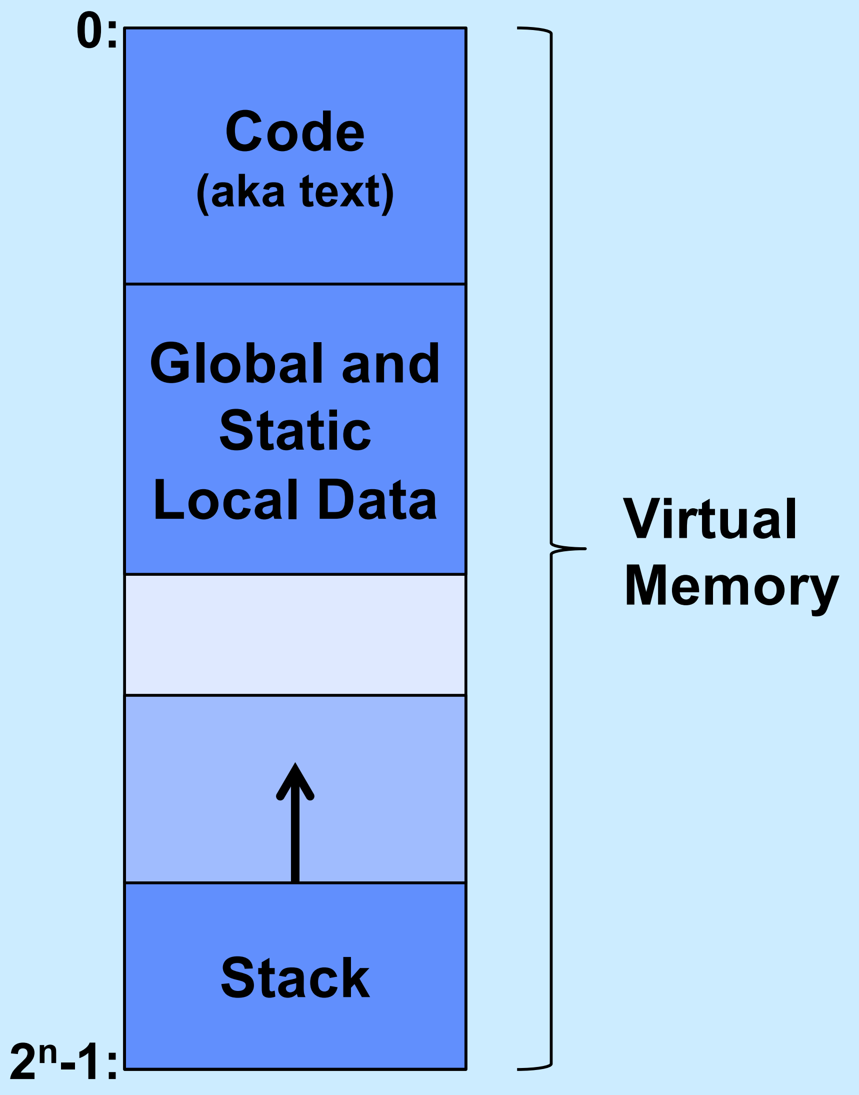
```
int sub() {
  static int svar = 2;
  int lvar = 1;
  svar += lvar;
  lvar++;
  return svar;
}

int main() {
  sub();
  printf("%d\n", sub());
  return 0;
}
```

What is printed?

a) 2
b) 3
c) 4
d) 5

Digression: Where Stuff Is
(Roughly)



scanf: Reading Data

```c
int main() {
   int i, j;
   scanf("%d %d", &i, &j);
   printf("%d, %d", i, j);
}
```

```
$ ./a.out
   3         12
3, 12
```

Two parts

- formatting instructions
  - whitespace in format string matches any amount of white space in input
    - » whitespace is space, tab, newline (‘\n’)
- arguments: must be addresses
  - why?

#define (again)

```
#define CtoF(cel) (9.0*cel)/5.0 + 32.0
```

Simple textual substitution:

```
float tempc = 20.0;
float tempf = CtoF(tempc);
// same as tempf = (9.0*tempc)/5.0 + 32.0;
```

Careful ...

```
#define CtoF(cel) (9.0*cel)/5.0 + 32.0
```

```
float tempc = 20.0;
float tempf = CtoF(tempc+10);
// same as tempf = (9.0*tempc+10)/5.0 + 32.0;
```

```
#define CtoF(cel) (9.0*(cel))/5.0 + 32.0
```

```
float tempc = 20.0;
float tempf = CtoF(tempc+10);
// same as tempf = (9.0*(tempc+10))/5.0 + 32.0;
```

Conditional Compilation

```
#ifdef DEBUG
  #define DEBUG_PRINT(a1, a2) printf(a1,a2)
#else
  #define DEBUG_PRINT(a1, a2)
#endif
```

```
int buggy_func(int x) {
   DEBUG_PRINT("x = %d\n", x);
     // printed only if DEBUG is defined
   ...
}
```