CSE 451: Operating Systems
Spring 2003

Lecture 2
C and Pointers

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Today's agenda

- Administrivia
  - programming assignment
    - get started early…
    - tomorrow's lab sections are a good opportunity to get help
  - office hours
    - Doug: Thursday at 11am in the TA offices (226a)
    - Valentin: Friday at 2pm, in 232
- Continuing through the trickier aspects of C

Typecasting

- A mistake from last time:

```
int x = 0x87654321;
char y;

y = (char) x;    printf(“%d\n”, (int) y);
```

- ANSI C defines:
  - if converting an integer to a signed type, the result is implementation-defined if the value cannot be represented in the new type
  - if converting an integer to an unsigned type, a complicated rule basically gives left-truncation of the bits
  - **regardless, don’t do this…!**

Memory management in Java

- the Java runtime manages memory on your behalf
  - you never allocate memory directly
    - instead, you instantiate objects using “new”

```
String x = new String(“hello world”);
```

  - the garbage collector frees memory for you
    - figures out when an object can be reclaimed (i.e., no more references exist to that object)

Memory management in C

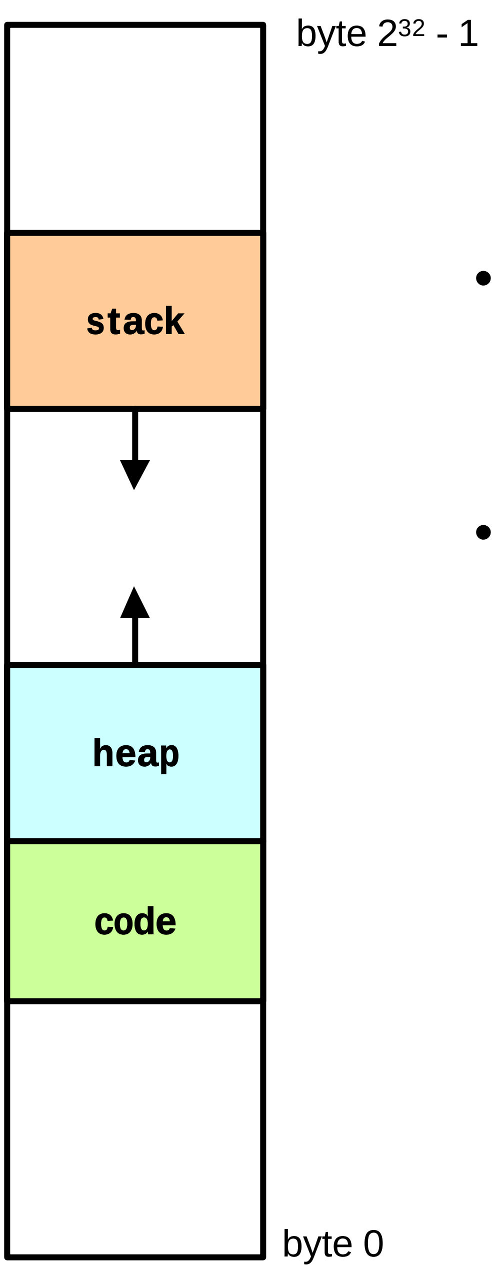
- some memory is managed on your behalf
  - the instructions which implement your functions
    - compiler, linker, and OS collude to allocate memory for this
  - the memory that backs global and "static" variables
    - compiler, linker, and OS collude to allocate memory for this
  - the memory that backs local variables within functions
    - compiler allocates this out of the "stack" when function is called
    - compiler frees this from the stack when function exits

Memory management in C

- you need to manage some memory on your own
  - allocate memory to hold your data structures
    - hash tables, linked lists, …etc.
    - allocated out of the "heap"
  - you must free this memory when you are done with it!
    - this is hard: elaborate bookkeeping to keep track of what memory you have allocated and when it is safe to free

```
char *x;     // a pointer – we'll cover this soon

x = (char *) malloc(12);  // allocate 12 bytes
if (x == NULL) exit(-1);  // out of memory?
free(x);                  // free the allocated memory
```



Memory

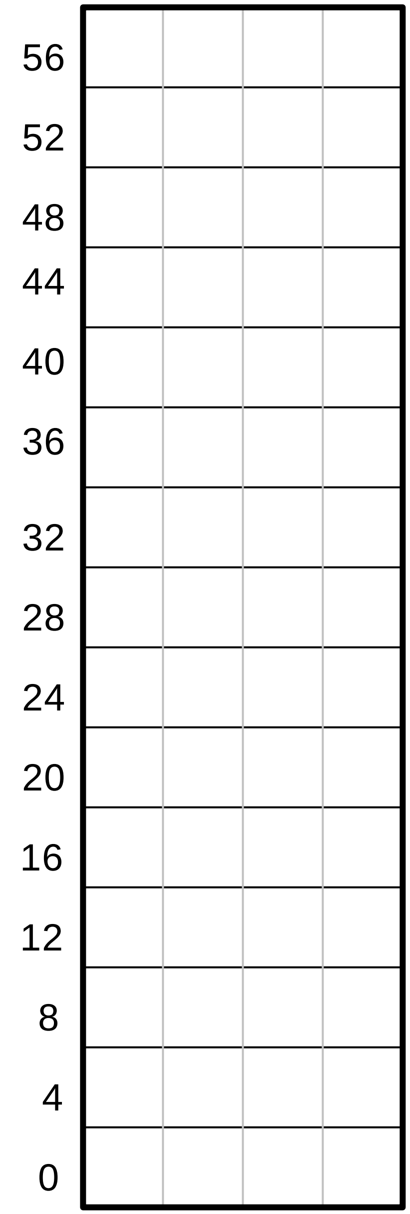
- memory is an array of bytes
  - potential addresses from 0 to 2^N-1
  - for Intel x86, N=32 (32-bit architecture)
- each Unix program uses three memory zones
  - the heap
    - things you allocate with malloc
  - the stack
    - local variables within functions, and other bookkeeping in “stack frames”
    - done automatically for you
  - the ‘text segment’
    - code, global and static variables
    - OS sets this up for you when program is loaded
      - “linker” provides the loader a recipe to fill in values

Pointers

- a pointer contains a memory address
  - a pointer “points” to a location in memory

```
unsigned short    x;
unsigned short   *y;
unsigned short  **z;

x = 1;
y = 4;  *y = 100;   y++;
z = 0;  **z = 101;  z++;
```



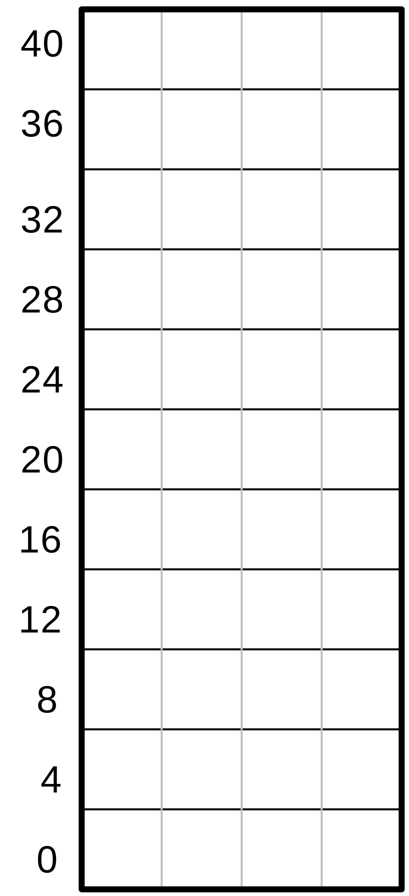
A brain-teaser: what gets printed out?

```
unsigned char *p;
unsigned char  y = 0x4E;

p = (unsigned char *) 0x00000002;
*p = 0x05;
*(p + 1) = 0x11;
*(p - 1) = 0x3F;
*(p - 2) = y;

printf(“%08x\n”,(unsigned int) *(p-2));

printf(“%08x\n”,
       *((unsigned int *) (p-2)));
```



Strings: arrays of characters

- Strings in C are just NULL-terminated arrays of chars

```
char *my_string = “Hi!”;
char another_string[4] = {‘H’, ‘i’, ‘!’, ‘\0’};
char *final_string;

final_string = (char *) malloc(4*sizeof(char));
if (final_string == NULL)  exit(-1);
final_string[0] = ‘H’;
final_string[1] = ‘i’;
final_string[2] = ‘!’;
final_string[3] = ‘\0’;

printf(“%s %s %s\n”, my_string, another_string,
       final_string);
```

Pointers and addresses

- & = “ address of ”

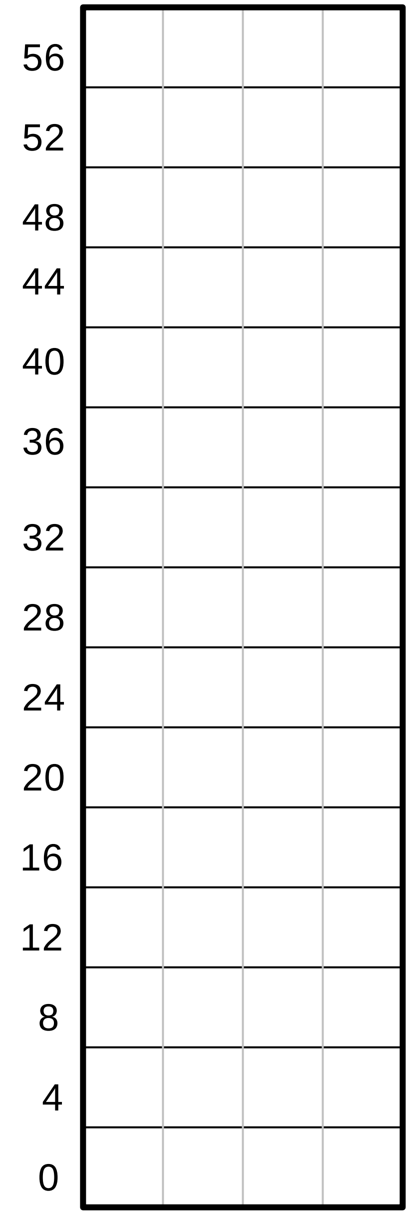
```
int main(void) {
  int x=1, *z;

  z = &x;
  printf(“%d %08x %08x\n”, *z, z, &z);

  z = (int *)
     malloc(2 * sizeof(int));

  *z = 100;
  *(z+1) = 101;
  *(z+2) = 102;   // whoops!

  return 0;       // same as exit(0)
}
```



Brain teasers…

#1: predict the printout

```
#include <stdio.h>

void main(void) {

     int i = 6, j = 3;

    *(int *) ( (i<j) ? &i : &j ) = 2;

     printf("%d", i+j);

}
```

#2: spot the bug

```
typedef struct ll_st {
  struct ll_st  *next;
  int            value;
} linked_list_element;

  ...

void free_linked_list(linked_list_element *head) {

  free(head);
  free_linked_list(head->next);

}

  ...
```

#3: spot the bug

```
typedef struct {
   char test_string[5];
} embedded_string;

char *extract_string(embedded_string extract_from_me) {
  return extract_from_me.test_string;
}

void main() {
   char *x;
   embedded_string y;

   …
   x = extract_string(y);
   *x = “hi!”;
   …
}
```

#4: predict the output

```
#include <stdio.h>

void main(void) {
  char input[256];

  gets(input);
  printf(“User inputted: ‘%s’\n”, input);

  return;
}
```

#5: spot the bugs

```
void foo(int print, int value) {
  char *string;

  string = (char *) malloc(10*sizeof(char));

  if (input > 1) {
    sprintf(string, “value: %d”, value);
    printf(string);
    free(string);
  }

  return;
}
```

#6: spot the bug (subtle)

```
unsigned short  x, *x_ptr;
unsigned int    y;
unsigned char  *c_ptr;

// assign some values
y = 0; x=0xFFFF;

// point x_ptr into the “middle” of y
c_ptr = (char *) (&y);
x_ptr = (unsigned short *) (c_ptr+1);
*y_ptr = x;
```