Memory, Data, & Addressing II
CSE 351 Autumn 2023

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http://xkcd.com/138/
 Relevant Course Information

❖ Lab 0 due today @ 11:59 pm
  ▪ *You will revisit the concepts from this program in future labs!*

❖ hw2 due Wednesday, hw3 due Friday
  ▪ Autograded, unlimited tries, no late submissions

❖ Lab 1a released today, due next Monday (10/9)
  ▪ Pointers in C (requires course material through bit shifting in Lesson 5)
  ▪ Last submission graded, can optionally work with a partner
    • One student submits, then add their partner to the submission
  ▪ Short answer “synthesis questions” for after the lab
Late Days

❖ You are given 5 late day tokens for the whole quarter
  ▪ Tokens can only apply to Labs
  ▪ No benefit to having leftover tokens

❖ Count lateness in days (even if just by a second)
  ▪ **Special:** weekends count as one day
  ▪ No submissions accepted more than two days late

❖ Late penalty is 10% deduction of your score per day
  ▪ Only late labs are eligible for penalties
  ▪ Penalties applied at end of quarter to maximize your grade

❖ Use at own risk – don’t want to fall too far behind
  ▪ Intended to allow for unexpected circumstances
Lesson Summary (1/2)

❖ Pointers are data objects that hold addresses
  ▪ Type of pointer determines size of thing being pointed at, which could be another pointer
  ▪ & = “address of” operator
  ▪ * = “value at address” or “dereference” operator

❖ Pointer arithmetic scales by size of target type
  ▪ Convenient when accessing array-like structures in memory
  ▪ Be careful when using – particularly when casting variables

❖ Arrays are adjacent locations in memory storing the same type of data object
  ▪ Strings are null-terminated arrays of characters (ASCII)
Lesson Summary (2/2)

❖ Terminology:
  ▪ pointer, address-of operator (&), dereference operator (⋆), NULL
  ▪ box-and-arrow memory diagrams
  ▪ pointer arithmetic, arrays, C string, null character, string literal

❖ Learning Objectives:
  ▪ Define pointers and their significance in computer memory organization.
  ▪ Declare, initialize, and manipulate pointers in C using address-of, dereference, and arithmetic operators.
  ▪ Handle I/O operations with C strings, accounting for the null character.

❖ What lingering questions do you have from the lesson?
Memory & Data II — Context
Examining Data Representations

❖ Code to print byte representation of data
  ▪ Treat any data type as a byte array by casting its address to char*
  ▪ C has unchecked casts  !! DANGER !!

```c
void show_bytes(char* start, int len) {
    int i;
    for (i = 0; i < len; i++)
        printf("%p\t0x%.2hhX\n", start+i, *(start+i));
    printf("\n");
}
```

❖ printf legend:
  ▪ Special characters: \t = Tab, \n = newline
  ▪ Format specifiers:  %p = pointer,
                         %.2hhX = 1 byte (hh) in hex (X), padding to 2 digits ( . 2)
Examining Data Representations

- Code to print byte representation of data
  - Treat any data type as a `byte array` by casting its address to `char*`
  - C has unchecked casts!! DANGER!!

```c
void show_bytes(char* start, int len) {
    int i;
    for (i = 0; i < len; i++)
        printf("%p\t0x%.2hhX\n", start+i, *(start+i));
    printf("\n");
}

void show_int(int x) {
    show_bytes((char*) &x, sizeof(int));
}
```
**show_bytes Execution Example**

```c
int x = 123456; // 0x00 01 E2 40
printf("int x = %d;\n", x);
show_int(x); // show_bytes((char *) &x, sizeof(int));
```

- **Result (Linux x86-64):**
  - **Note:** The addresses will change on each run (try it!), but fall in same general range

```c
int x = 123456;
0x7fffb245549c 0x40
0x7fffb245549d 0xE2
0x7fffb245549e 0x01
0x7fffb245549f 0x00
```
Java References

❖ In Java, everything that is not a primitive data type is an object
  ▪ An object variable is actually a “reference” – a restricted pointer

```java
class Record { ... }  
Record x = new Record();
```

❖ Reference restrictions:
  ▪ No pointer arithmetic, just reassignment
    • Reassignment must adhere to rules set by typing system (e.g., inheritance)
  ▪ References can only be “dereferenced” in ways that match class definition
    • e.g., calling a method, accessing a field in object

❖ All higher-level languages use pointers/addresses under the hood, but likely abstracted away from the programmer
Discussion Question

❖ Discuss the following question(s) in groups of 3-4 students
  ▪ I will call on a few groups afterwards so please be prepared to share out
  ▪ Be respectful of others’ opinions and experiences

❖ Brainstorm some reasons why you think the designers of C gave its programmers access to “raw” pointers.
  ▪ What might these reasons say about the implicit *values* embedded in C?
Memory & Data II — Practice
Group Work Time

❖ During this time, you are encouraged to work on the following:
   1) If desired, continue your discussion
   2) Work on the lesson problems (solutions at the end of class)
   3) Work on the homework problems

❖ Resources:
   ▪ You can revisit the lesson material
   ▪ Work together in groups and help each other out
   ▪ Course staff will circle around to provide support
Practice Questions (1/2)

- int x = 351;
  char* p = &x;
  int ar[3];

- How much space does the variable p take up?
  A. 1 byte
  B. 2 bytes
  C. 4 bytes
  D. 8 bytes

- Which of the following expressions evaluate to an address?
  A. x + 10
  B. p + 10
  C. &x + 10
  D. *(&p)
  E. ar[1]
  F. &ar[2]
Practice Questions (2/2)

The variable values after Line 3 executes are shown on the right. What are they after Line 5?

```c
void main() {
    int a[] = {0x5, 0x10};
    int* p = a;
    p = p + 1;
    *p = *p + 1;
}
```

<table>
<thead>
<tr>
<th></th>
<th>Data (hex)</th>
<th>Address (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a[0]</td>
<td>5</td>
<td>0x100</td>
</tr>
<tr>
<td>a[1]</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>