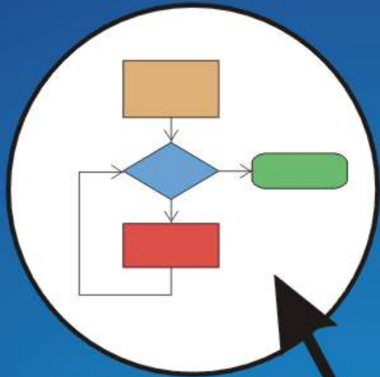
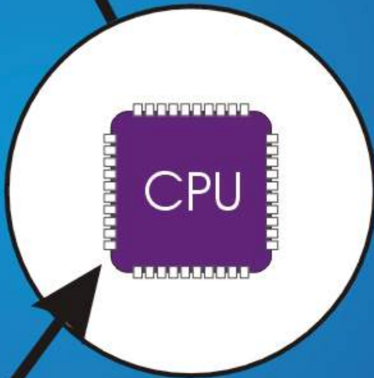
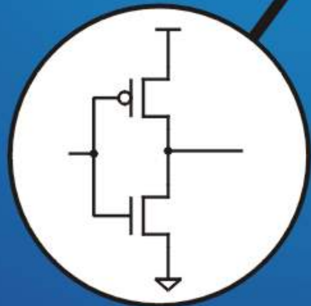






Chapter 16
Pointers and Arrays

Pointers and Arrays

We've seen examples of both of these in our C programs; now we'll see how they are implemented in LC-3.

Pointer

- **Address of a variable in memory**
- **Allows us to <u>indirectly</u> access variables**
  - **in other words, we can talk about its *address* rather than its *value***

Array

- **A list of values arranged sequentially in memory**
- **Example: a list of telephone numbers**
- **Expression `a[4]` refers to the 5th element of the array `a`**

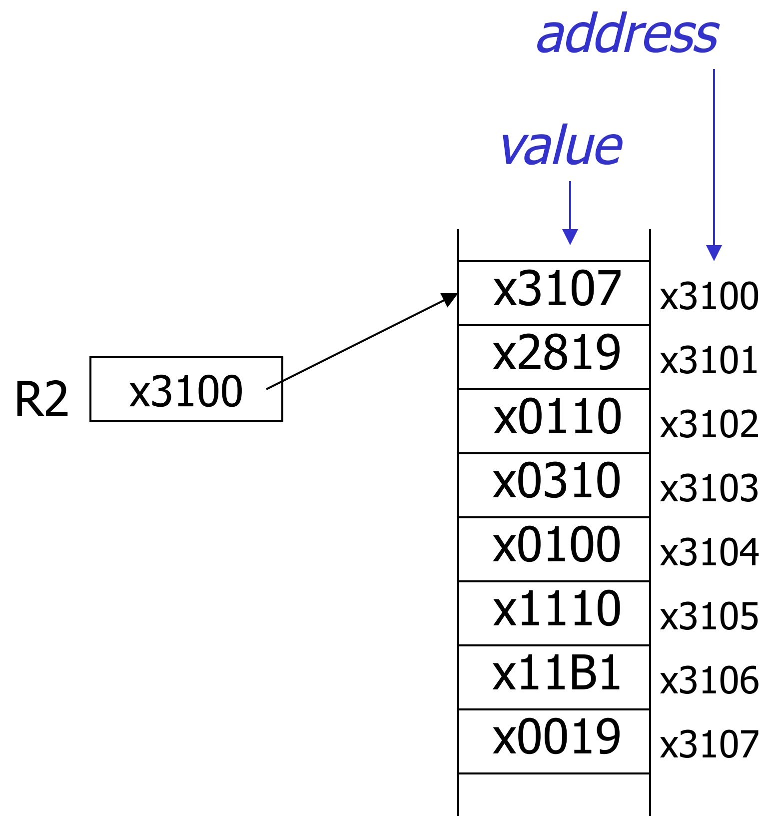
Address vs. Value

Sometimes we want to deal with the address of a memory location, rather than the value it contains.

Recall example from Chapter 6: adding a column of numbers.

- **R2 contains address of first location.**
- **Read value, add to sum, and increment R2 until all numbers have been processed.**

R2 is a pointer -- it contains the address of data we're interested in.



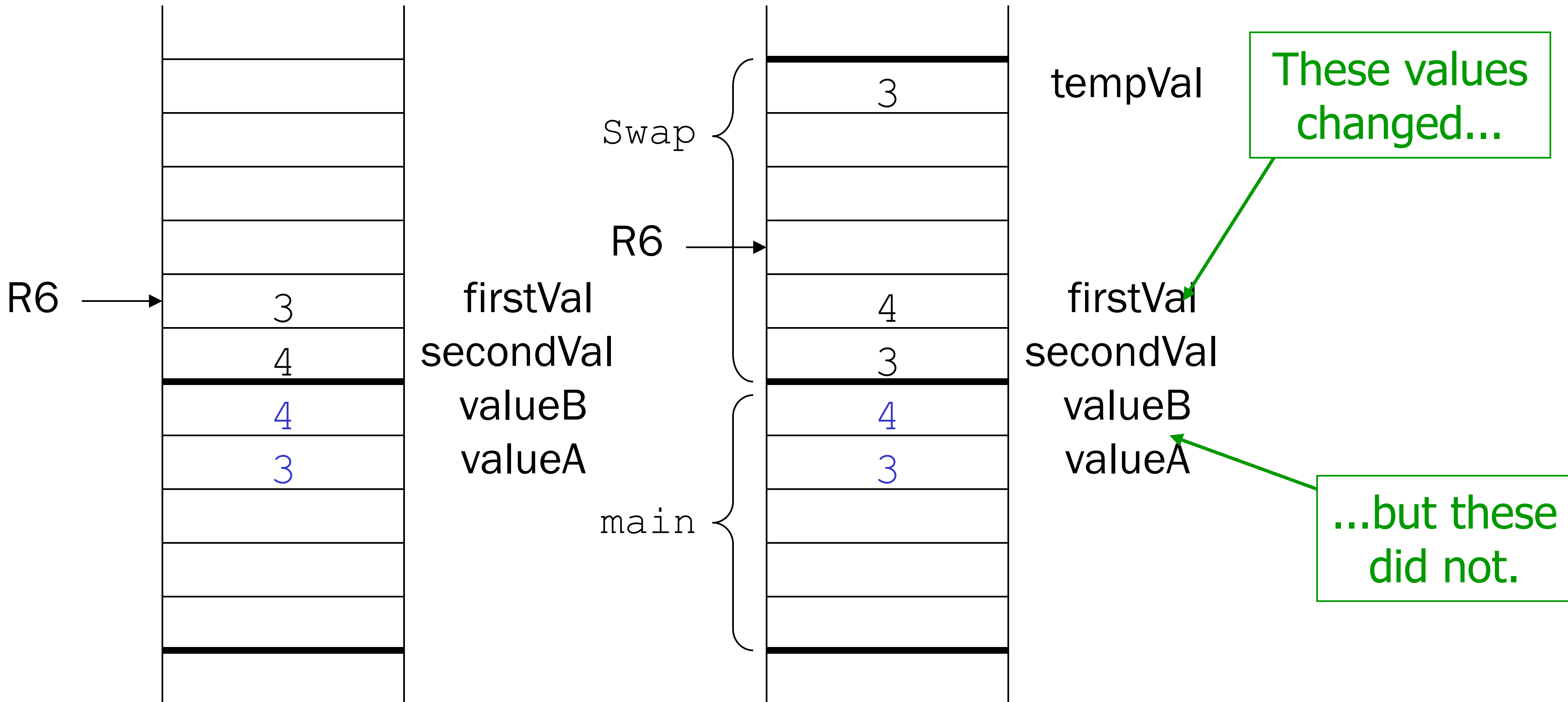
Another Need for Addresses

Consider the following function that's supposed to swap the values of its arguments.

```
void Swap(int firstVal, int secondVal)
{
  int tempVal = firstVal;
  firstVal = secondVal;
  secondVal = tempVal;
}
```

With LC-3 implementation, we see why this does not work as intended.

Executing the Swap Function



Swap needs addresses of variables outside its own activation record.

Example

```
int i;
int *ptr;

i = 4;
ptr = &i;
*ptr = *ptr + 1;
```

store the value 4 into the memory location associated with i

store the address of i into the memory location associated with ptr

read the contents of memory at the address stored in ptr

store the result into memory at the address stored in ptr

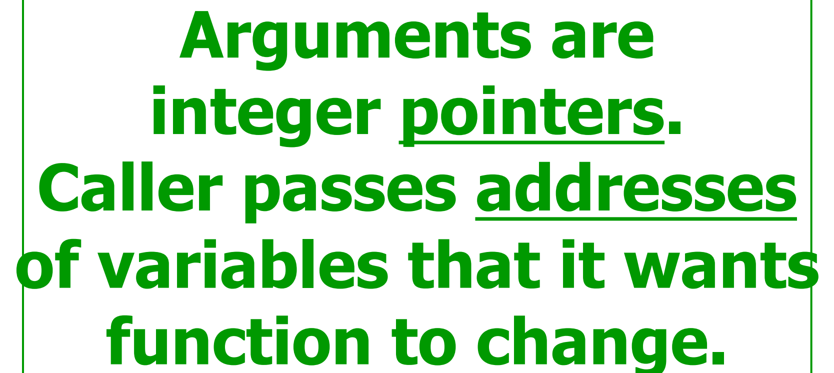
Example: LC-3 Code

```
; i is 1st local (offset 0), ptr is 2nd (offset -1)
; i = 4;
        AND   R0, R0, #0    ; clear R0
        ADD   R0, R0, #4    ; put 4 in R0
        STR   R0, R5, #0    ; store in i
; ptr = &i;
        ADD   R0, R5, #0    ; R0 = R5 + 0 (addr of i)
        STR   R0, R5, #-1   ; store in ptr
; *ptr = *ptr + 1;
        LDR   R0, R5, #-1   ; R0 = ptr
        LDR   R1, R0, #0    ; load contents (*ptr)
        ADD   R1, R1, #1    ; add one
        STR   R1, R0, #0    ; store result where R0 points
```

Pointers as Arguments

Passing a pointer into a function allows the function to read/change memory outside its activation record.

```
void NewSwap(int *firstVal, int *secondVal)
{
  int tempVal = *firstVal;
  *firstVal = *secondVal;
  *secondVal = tempVal;
}
```



Passing Pointers to a Function

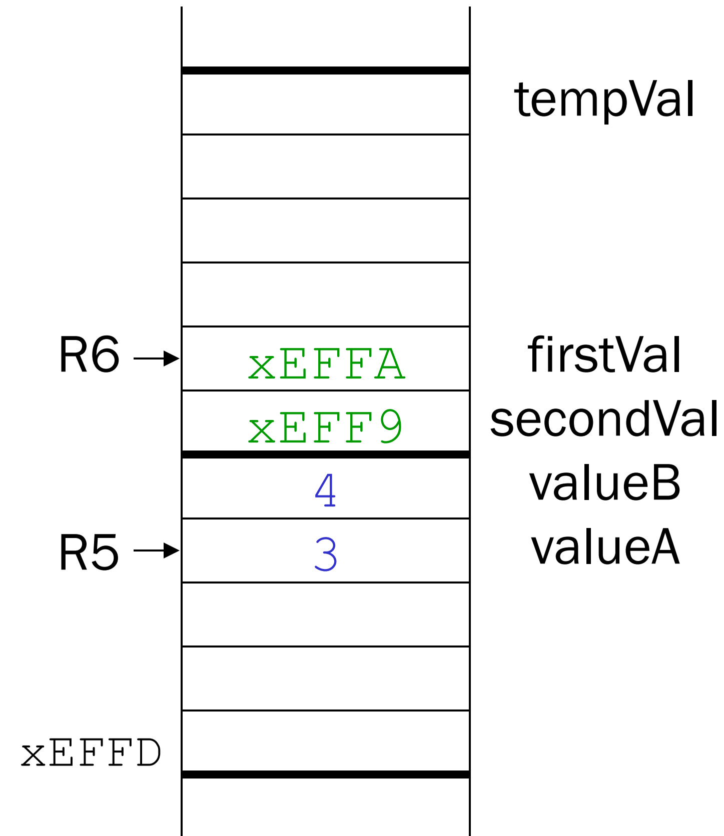
main() wants to swap the values of valueA and valueB

passes the addresses to NewSwap:

```
NewSwap(&valueA, &valueB);
```

Code for passing arguments:

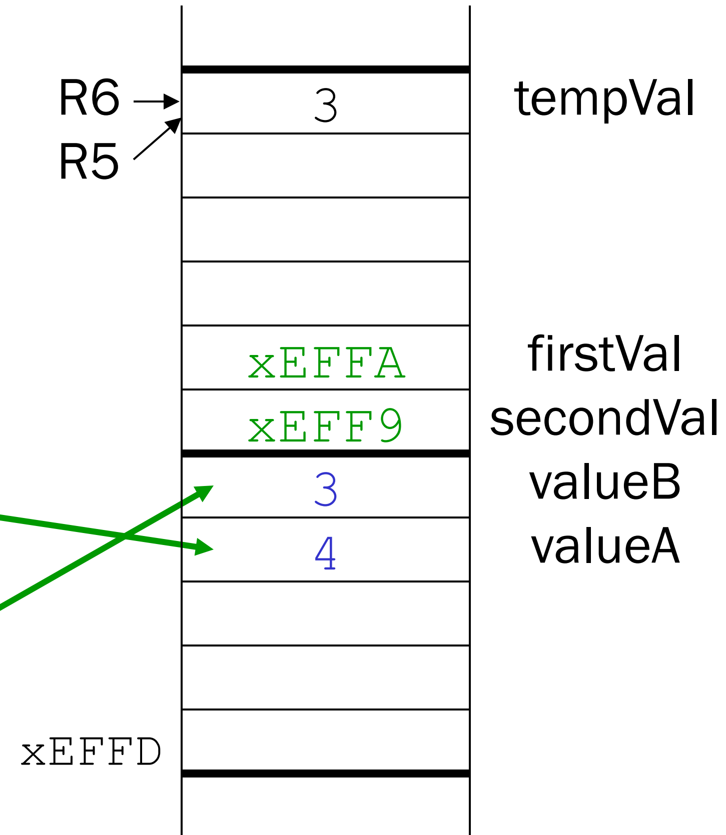
```
ADD R0, R5, #-1 ; addr of valueB
ADD R6, R6, #-1 ; push
STR R0, R6, #0
ADD R0, R5, #0  ; addr of valueA
ADD R6, R6, #-1 ; push
STR R0, R6, #0
```



Code Using Pointers

Inside the NewSwap routine

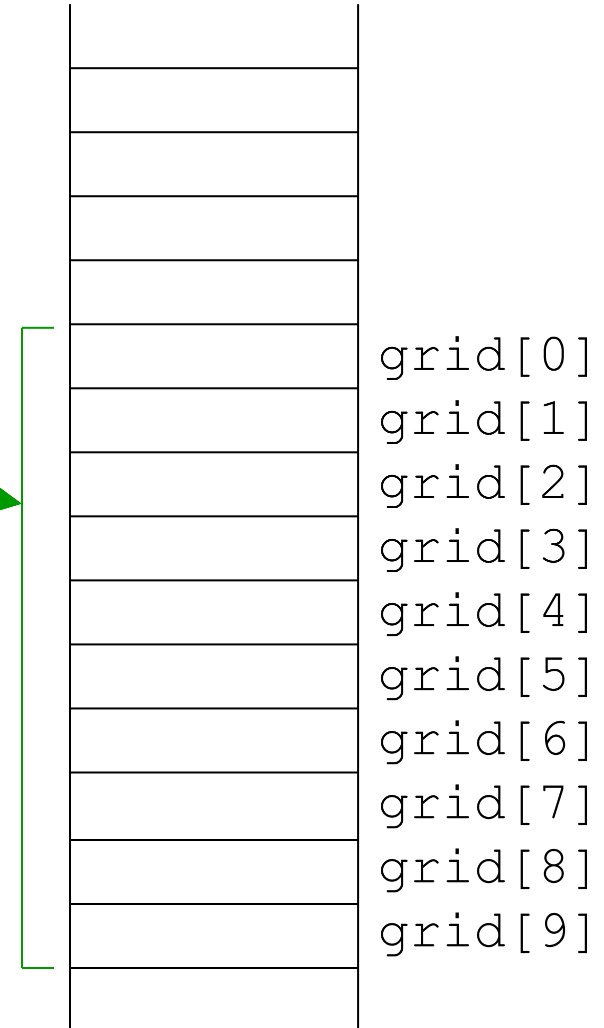
```
; int tempVal = *firstVal;
LDR   R0, R5, #4 ; R0=xEFFA
LDR   R1, R0, #0 ; R1=M[xEFFA]=3
STR   R1, R5, #4 ; tempVal=3
; *firstVal = *secondVal;
LDR   R1, R5, #5 ; R1=xEFF9
LDR   R2, R1, #0 ; R1=M[xEFF9]=4
STR   R2, R0, #0 ; M[xEFFA]=4
; *secondVal = tempVal;
LDR   R2, R5, #0 ; R2=3
STR   R2, R1, #0 ; M[xEFF9]=3
```



Array as a Local Variable

Array elements are allocated as part of the activation record.

```
int grid[10];
```

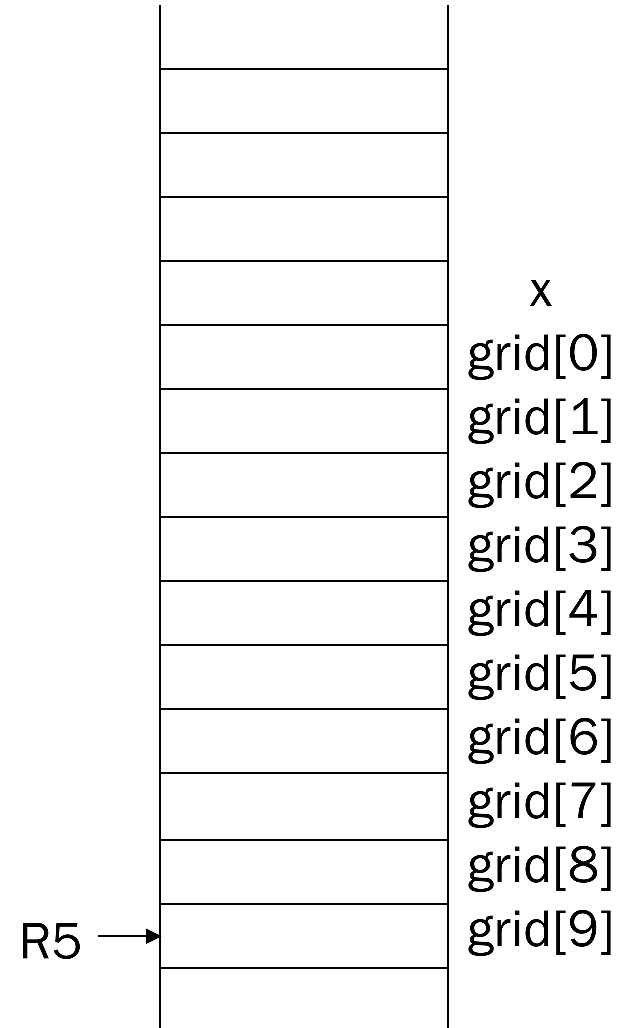


First element (`grid[0]`) is at lowest address of allocated space.

If `grid` is first variable allocated, then R5 will point to `grid[9]`.

LC-3 Code for Array References

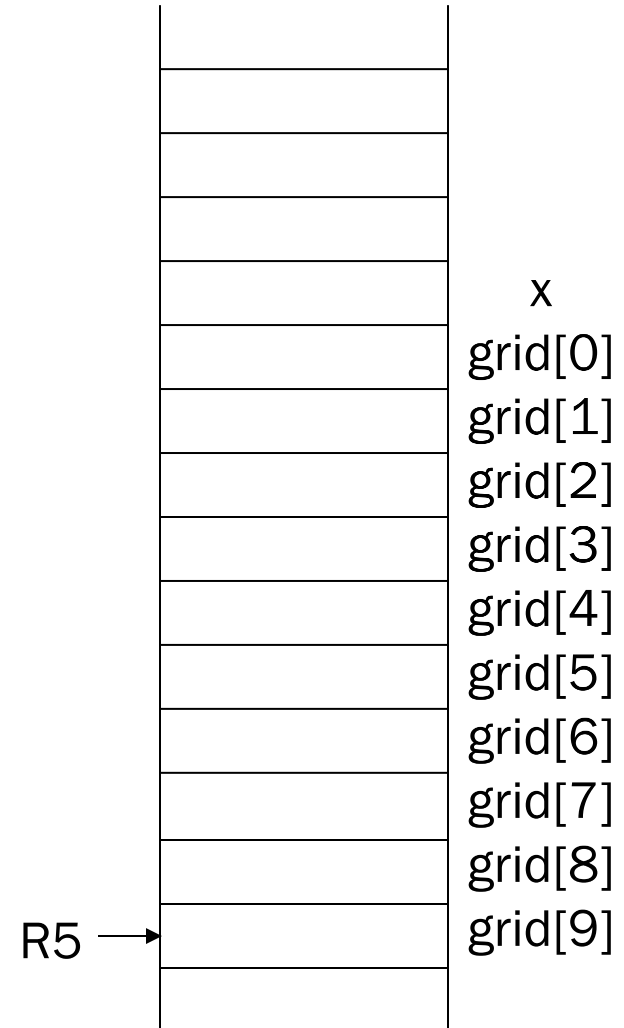
```
; x = grid[3] + 1
   ADD R0, R5, #-9   ; R0 = &grid[0]
   LDR R1, R0, #3    ; R1 = grid[3]
   ADD R1, R1, #1    ; plus 1
   STR R1, R5, #-10 ; x = R1
; grid[6] = 5;
   AND R0, R0, #0
   ADD R0, R0, #5   ; R0 = 5
   ADD R1, R5, #-9 ; R1 = &grid[0]
   STR R0, R1, #6   ; grid[6] = R0
```



More LC-3 Code

```
; grid[x+1] = grid[x] + 2
  LDR R0, R5, #-10   ; R0 = x
  ADD R1, R5, #-9    ; R1 = &grid[0]
  ADD R1, R0, R1     ; R1 = &grid[x]
  LDR R2, R1, #0     ; R2 = grid[x]
  ADD R2, R2, #2     ; add 2

  LDR R0, R5, #-10   ; R0 = x
  ADD R0, R0, #1     ; R0 = x+1
  ADD R1, R5, #-9    ; R1 = &grid[0]
  ADD R1, R0, R1     ; R1 = &grix[x+1]
  STR R2, R1, #0     ; grid[x+1] = R2
```



A String is an Array of Characters

Allocate space for a string just like any other array:

```
char outputString[16];
```

Space for string must contain room for terminating zero.

Special syntax for initializing a string:

```
char outputString[16] = "Result = ";
```

…which is the same as:

```
outputString[0] = 'R';
outputString[1] = 'e';
outputString[2] = 's';
...
```

Common Pitfalls with Arrays in C

Overrun array limits

- There is no checking at run-time or compile-time to see whether reference is within array bounds.

```
int array[10];
int i;
for (i = 0; i <= 10; i++) array[i] = 0;
```

Declaration with variable size

- Size of array must be known at compile time.

```
void SomeFunction(int num_elements) {
  int temp[num_elements];
  …
}
```

Pointer Arithmetic

Address calculations depend on size of elements

- In our LC-3 code, we've been assuming one word per element.
  - e.g., to find 4th element, we add 4 to base address
- It's ok, because we've only shown code for int and char, both of which take up one word.
- If double, we'd have to add 8 to find address of 4th element.

C does size calculations under the covers, depending on size of item being pointed to:

```
double x[10];
double *y = x;
*(y + 3) = 13;
```

allocates 20 words (2 per element)

same as x[3] -- base address plus 6