ECE 220

Lecture x0009 - 09/24

Slides based on material originally by: Yuting Chen & Thomas Moon

Reminders

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  - One debugging LC3
  - Conceptual questions (including C)

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  - `R7` - for `RET` instruction

Swap function

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- The declaration syntax for a pointer is:

```
type *ptr-name;
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Pointers in C

Example declarations

```
int *ptr; // ptr is a pointer to an int

char *cptr; // cptr is a pointer to _____

double *dptr; // dptr is a pointer to _____
```

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Usefulness well become clear in later lectures.

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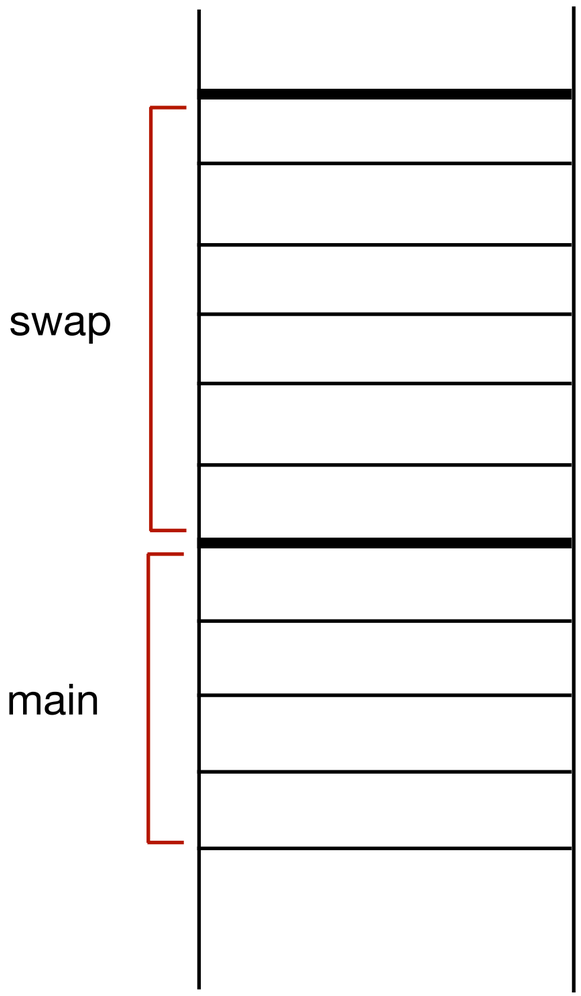

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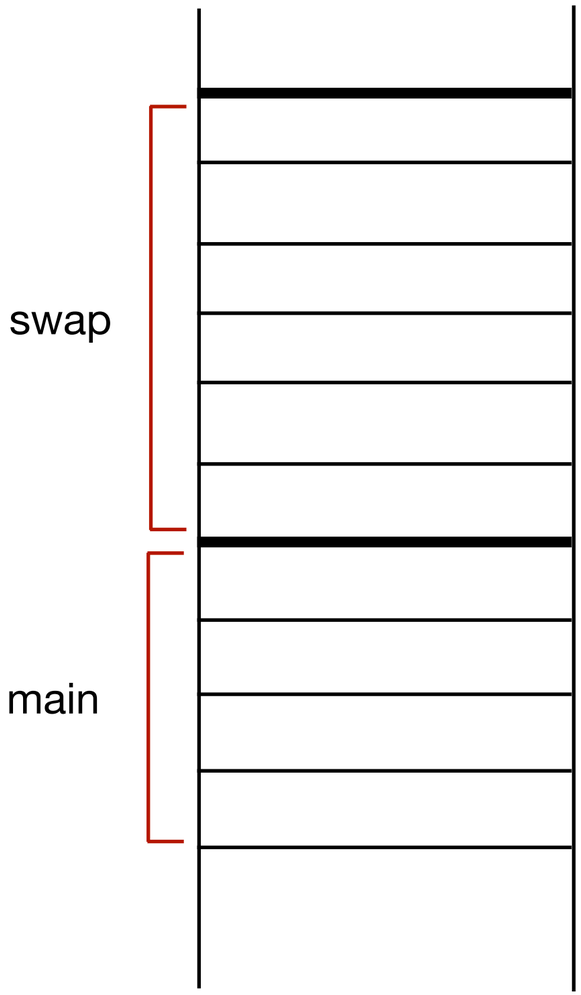


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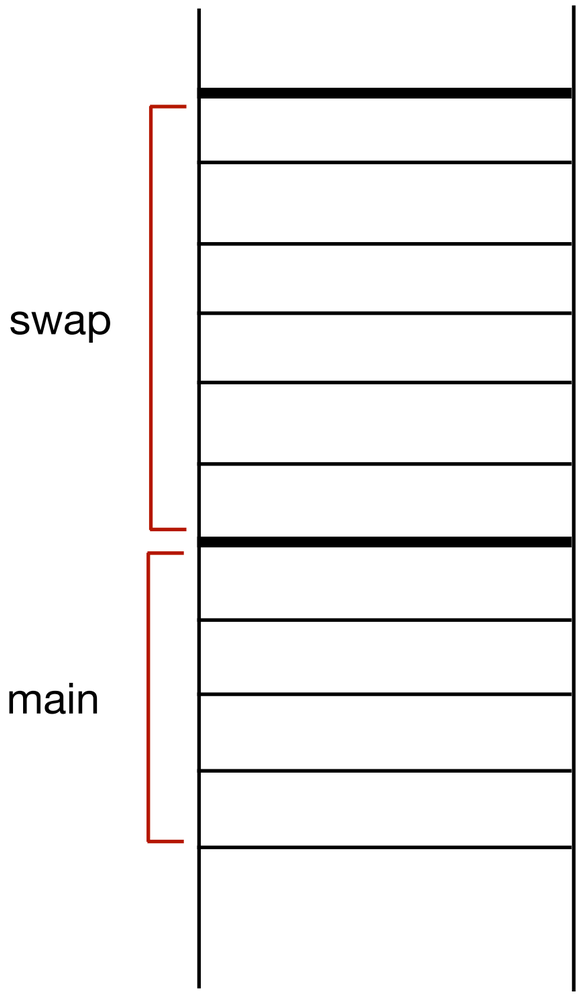


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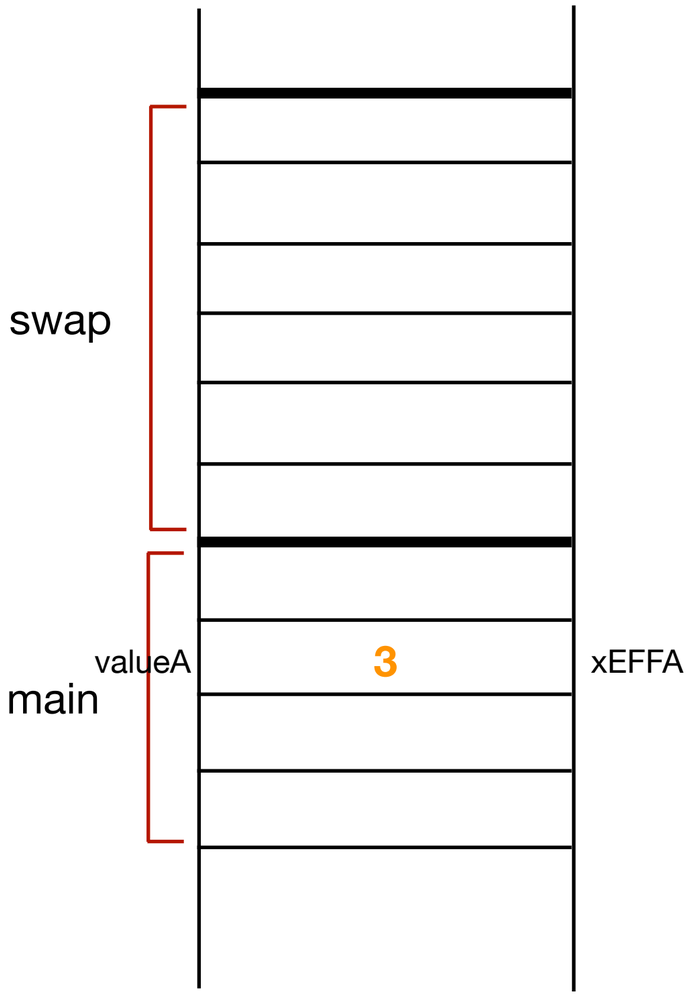


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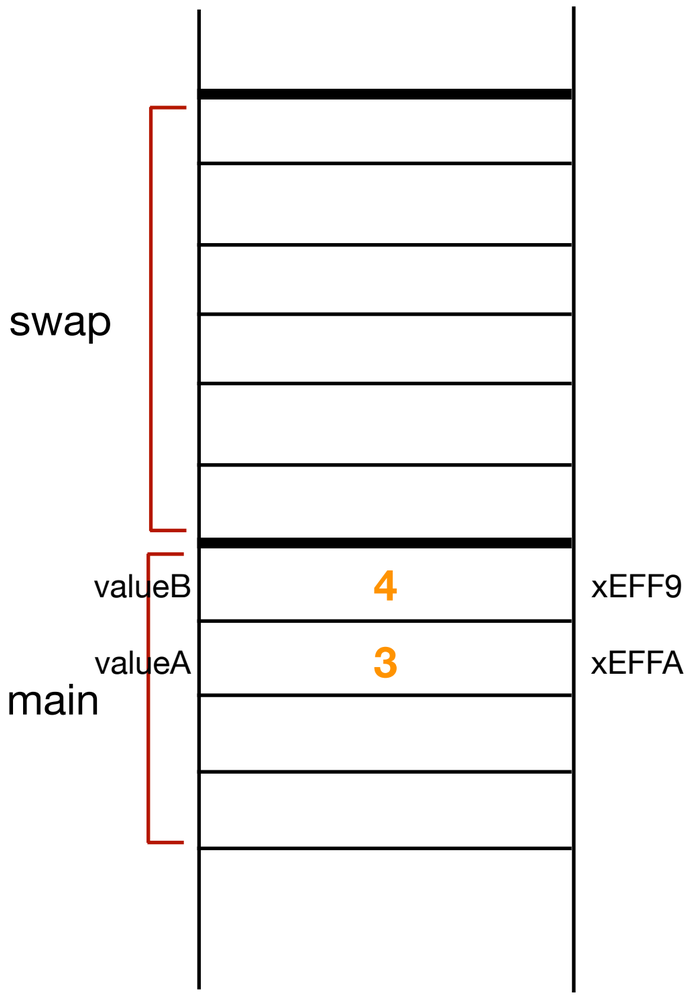


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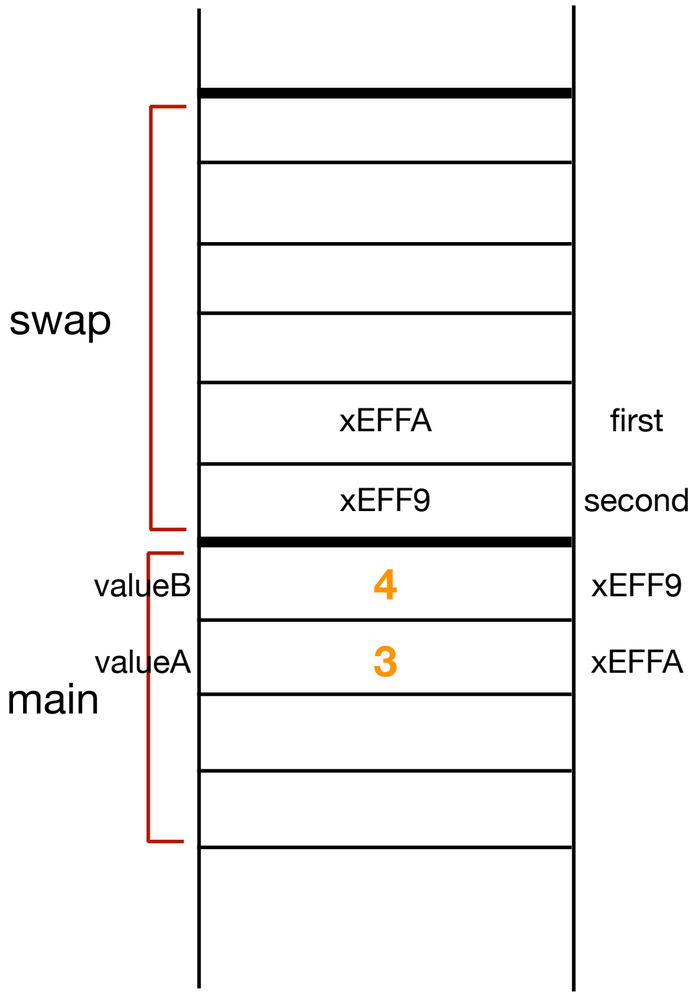


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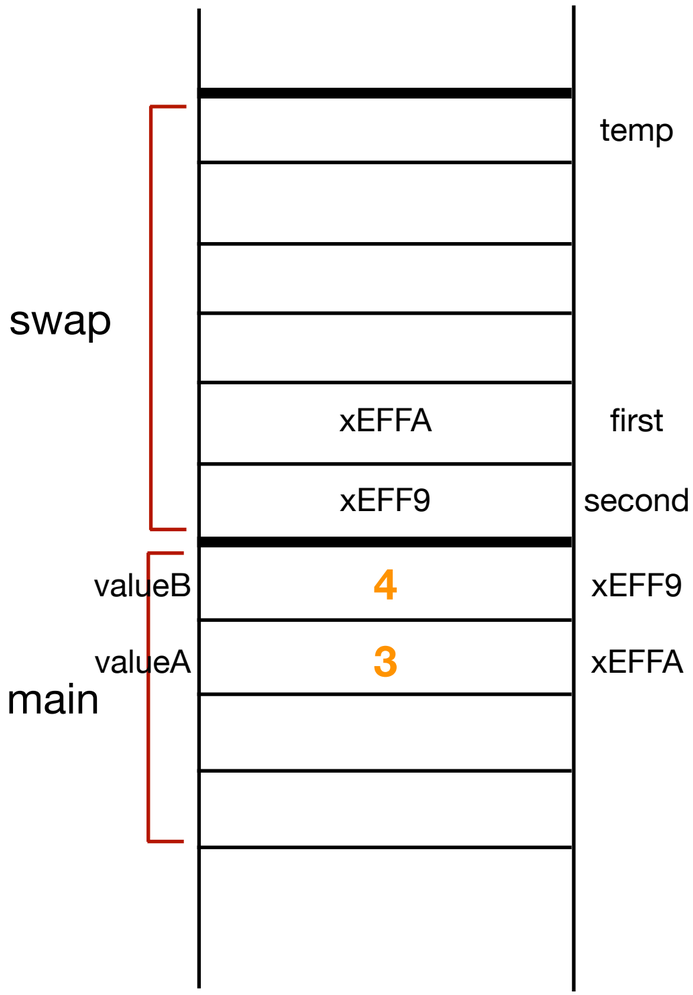


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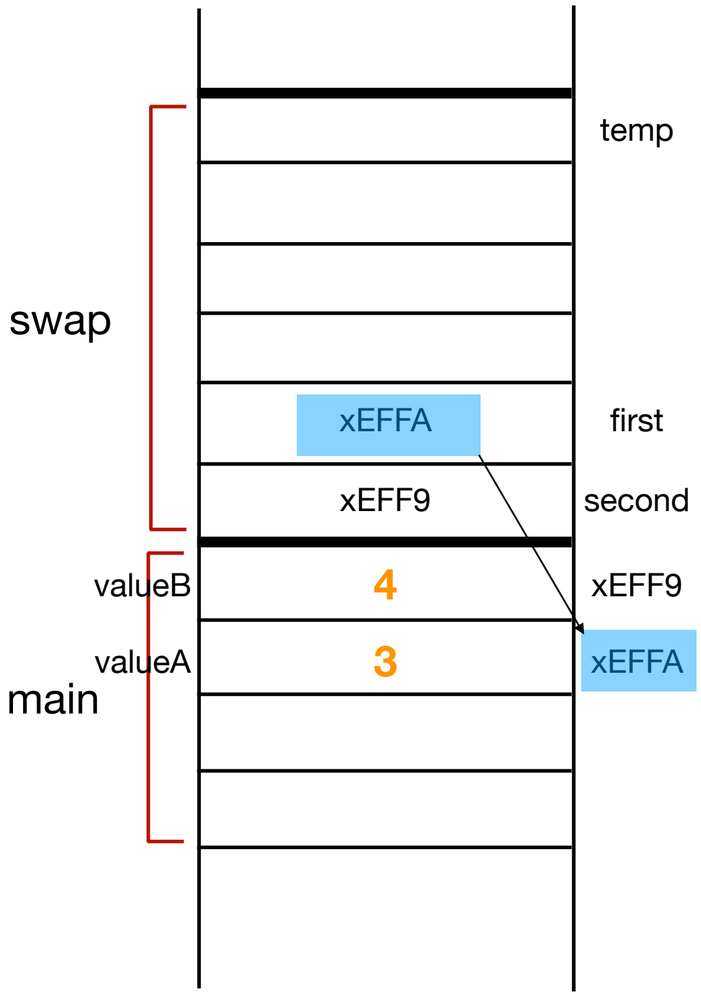


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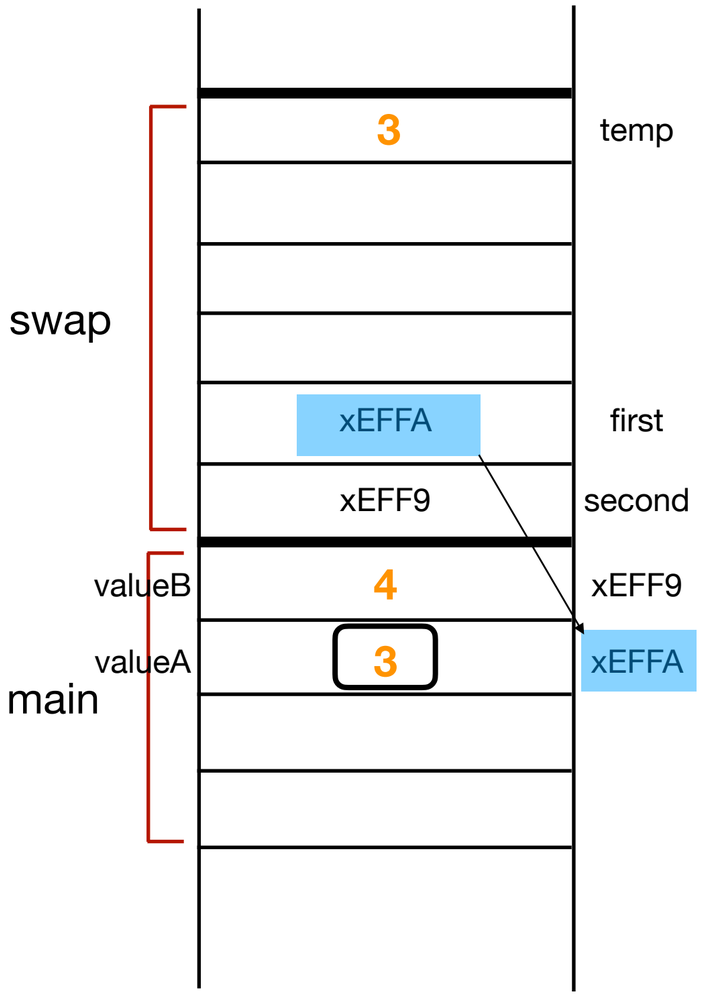


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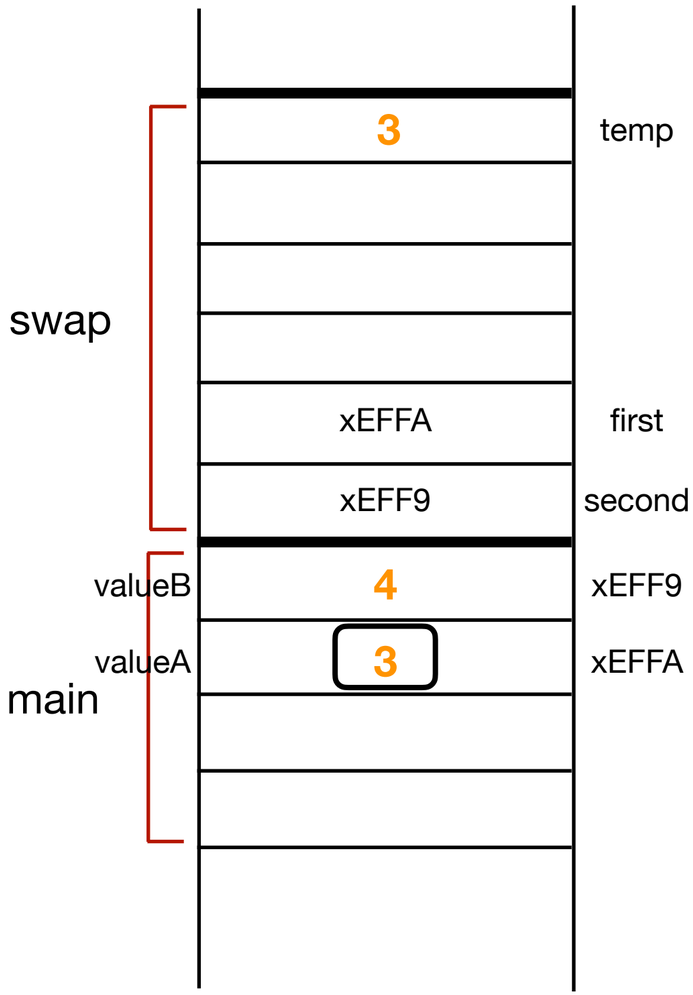


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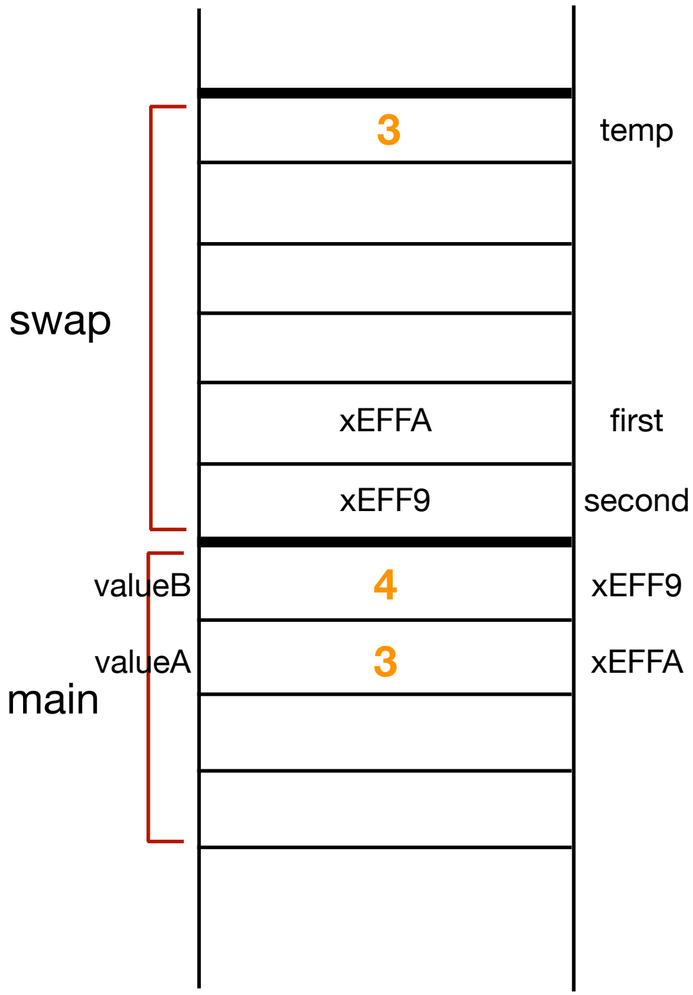


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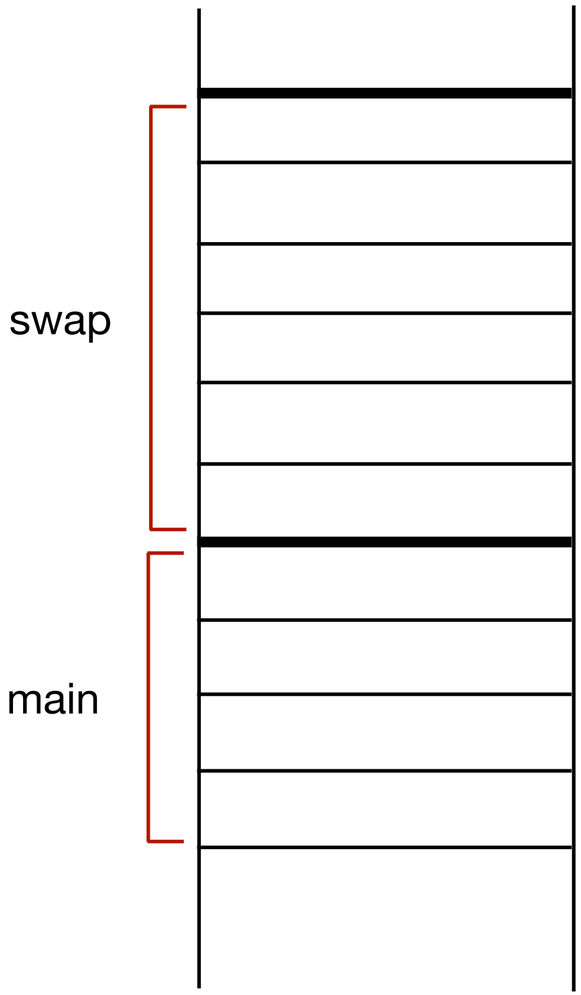

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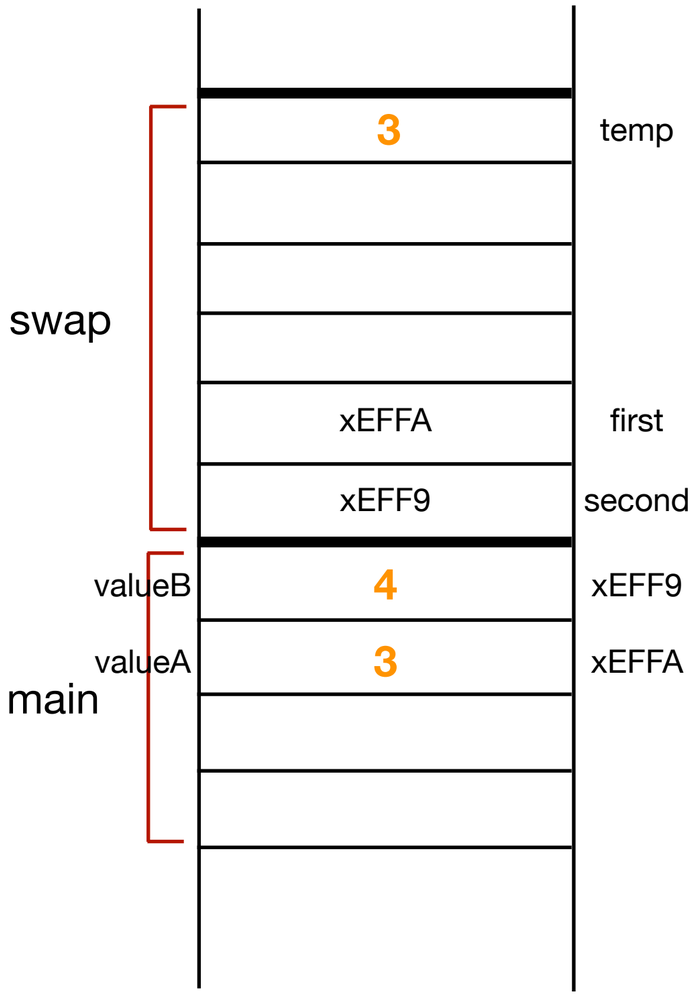
Using pointers in C



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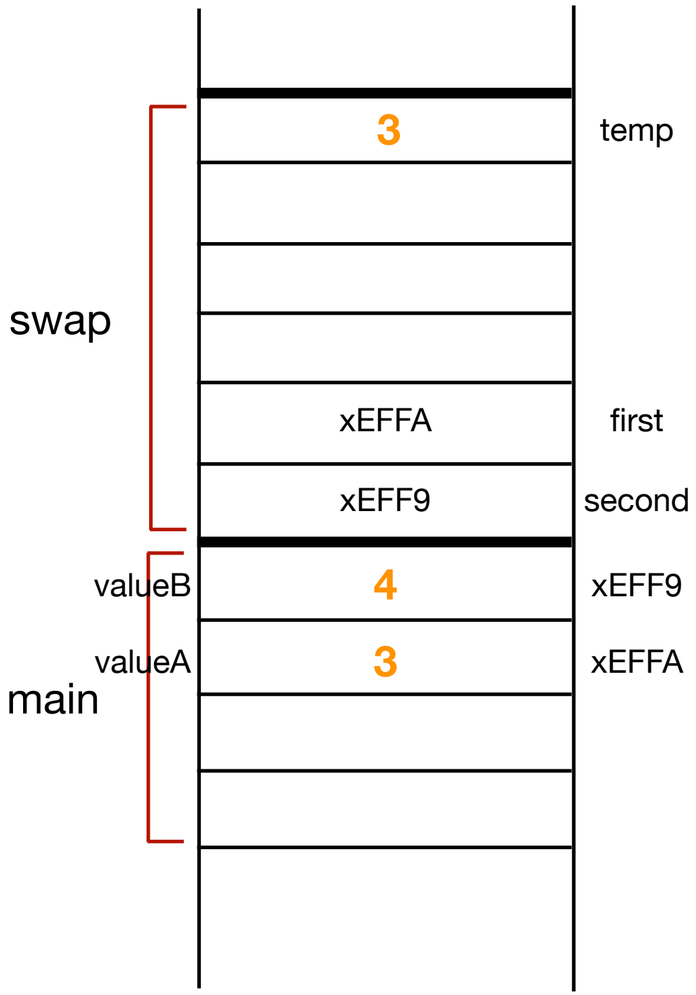


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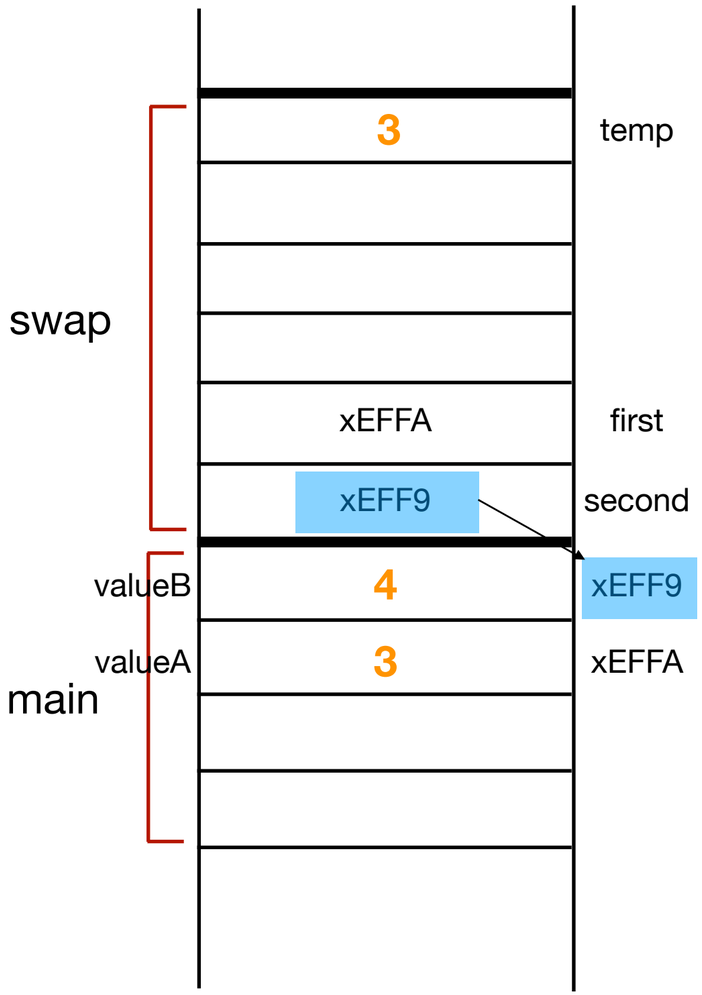


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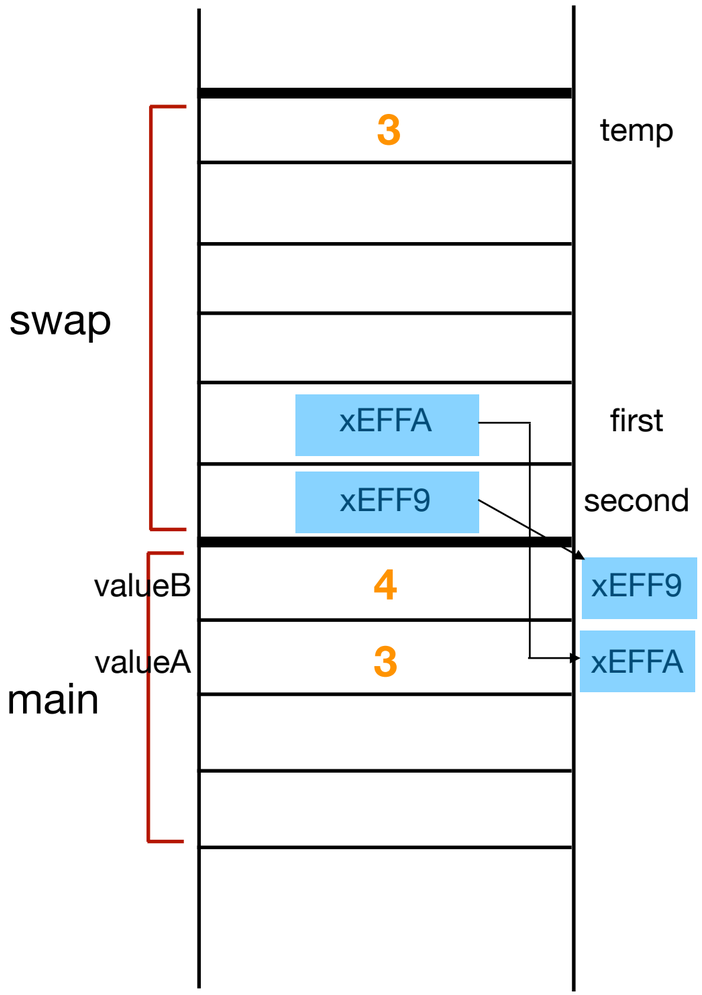


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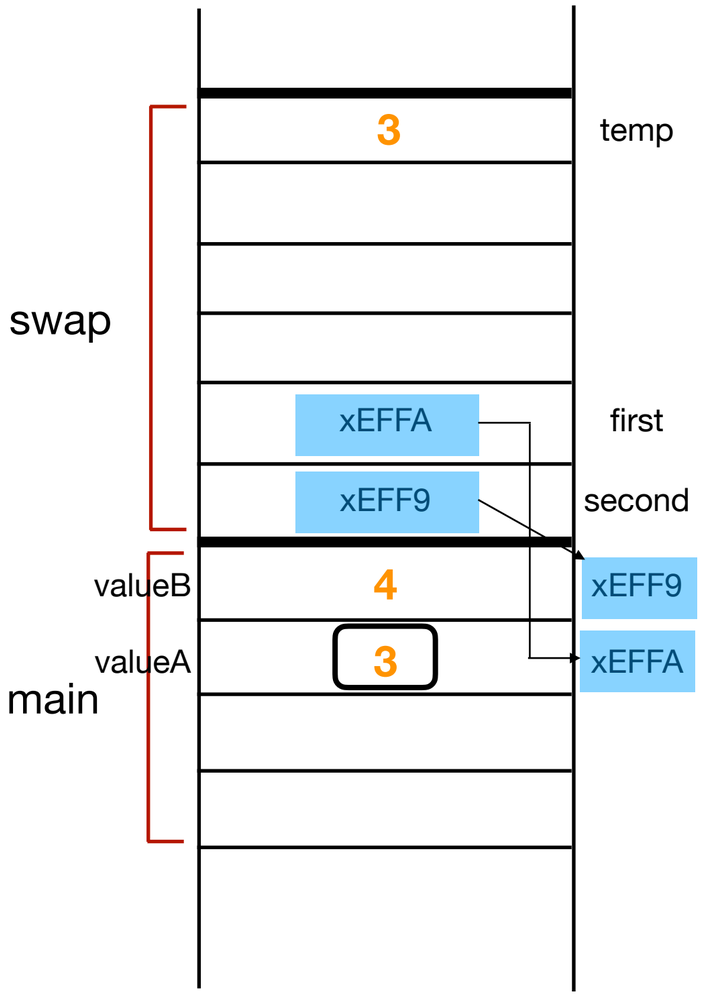


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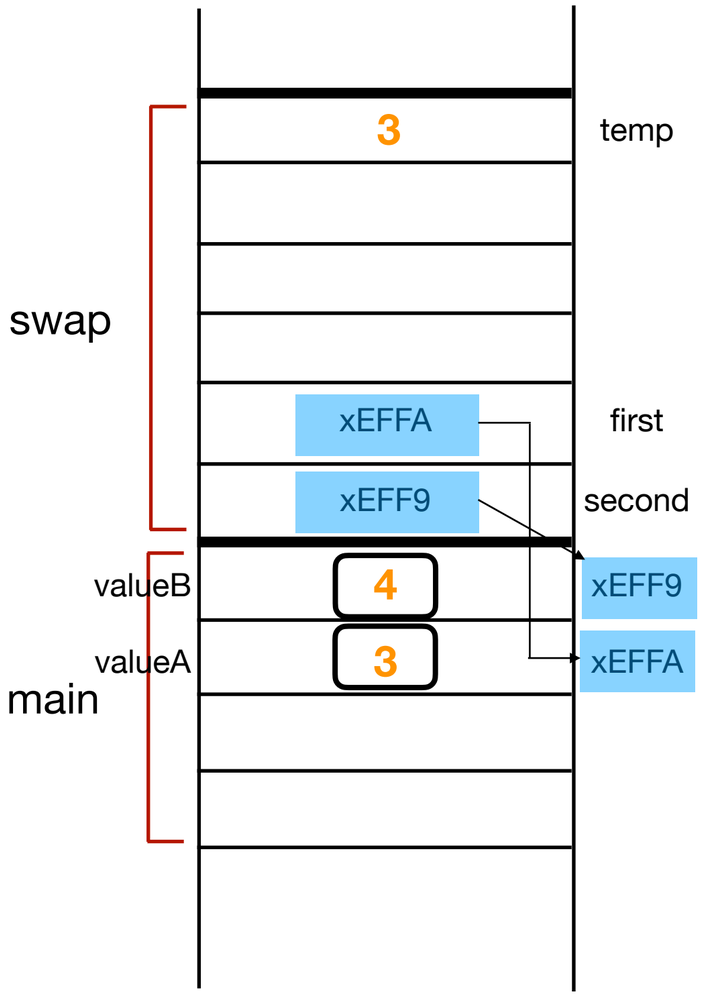


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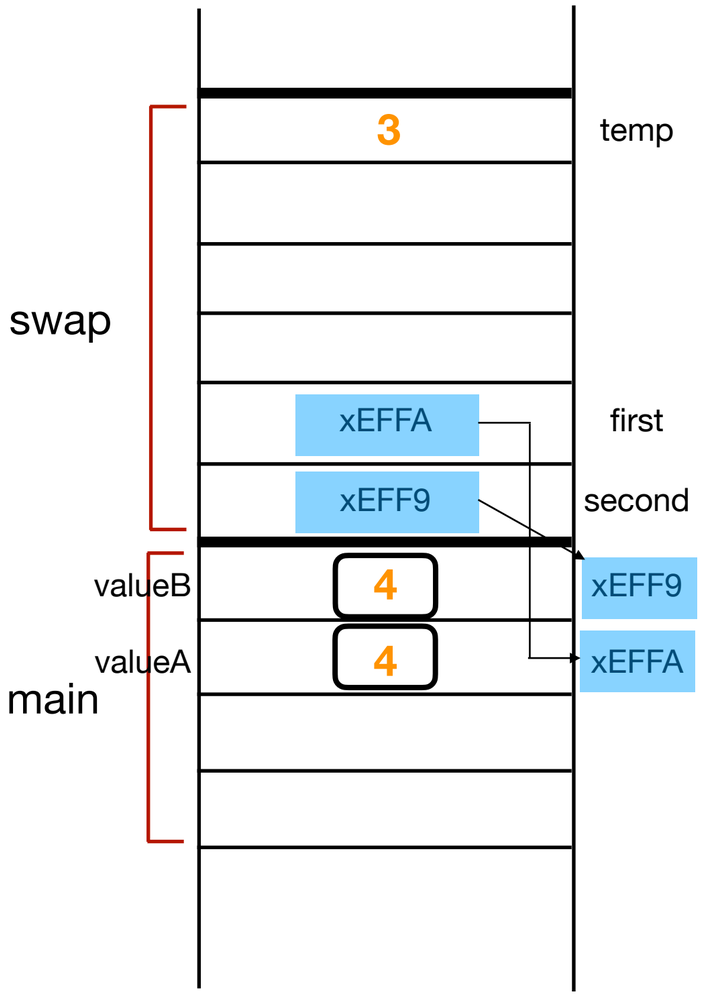


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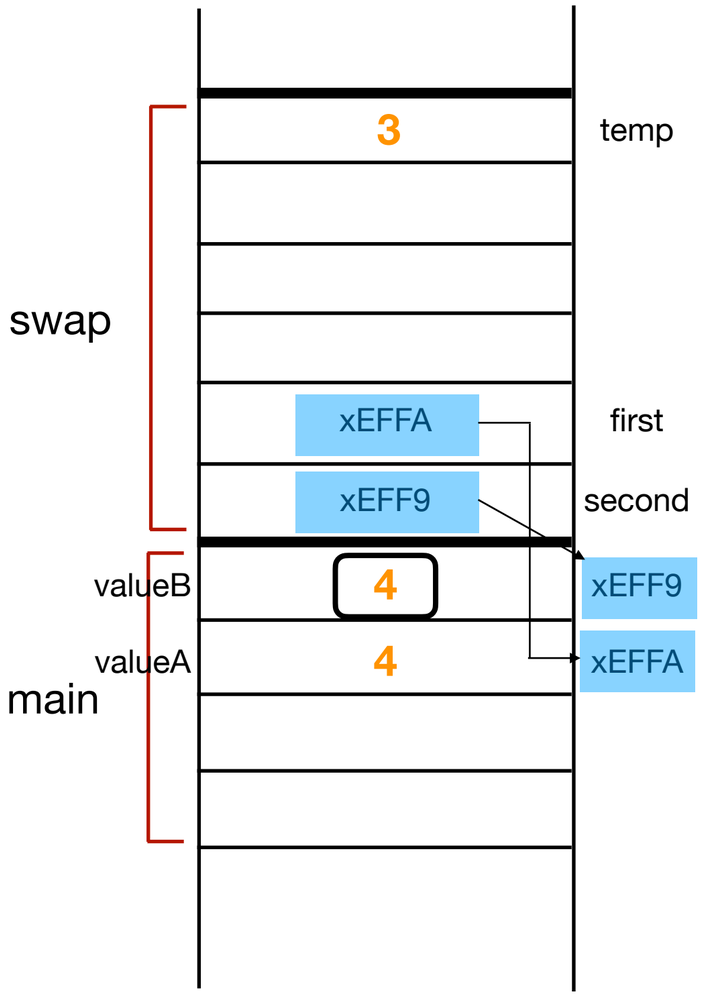


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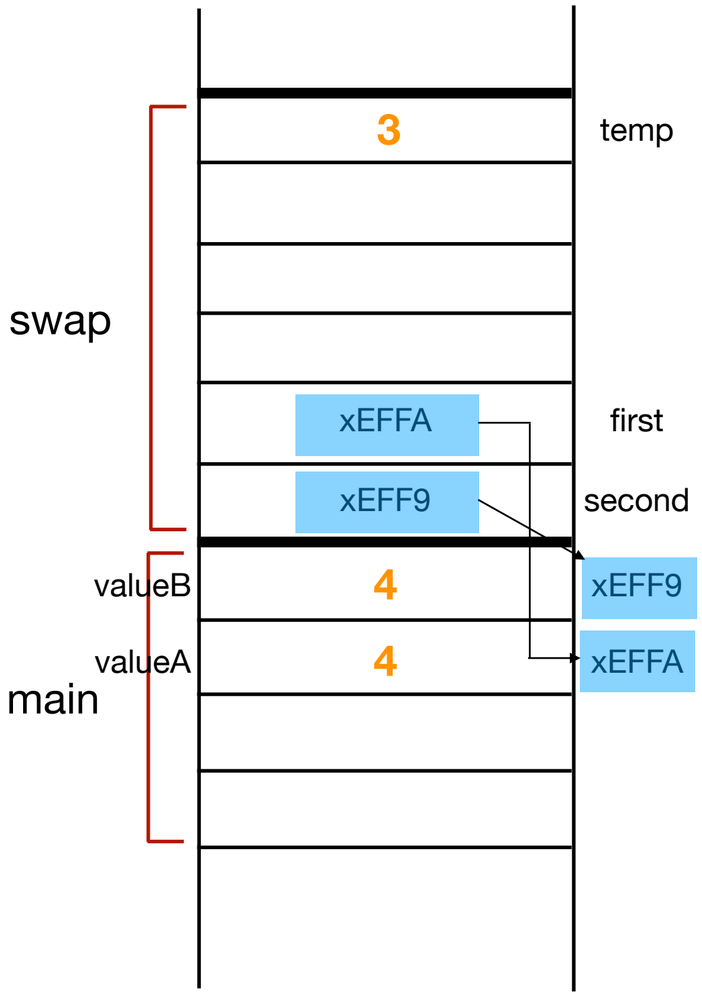


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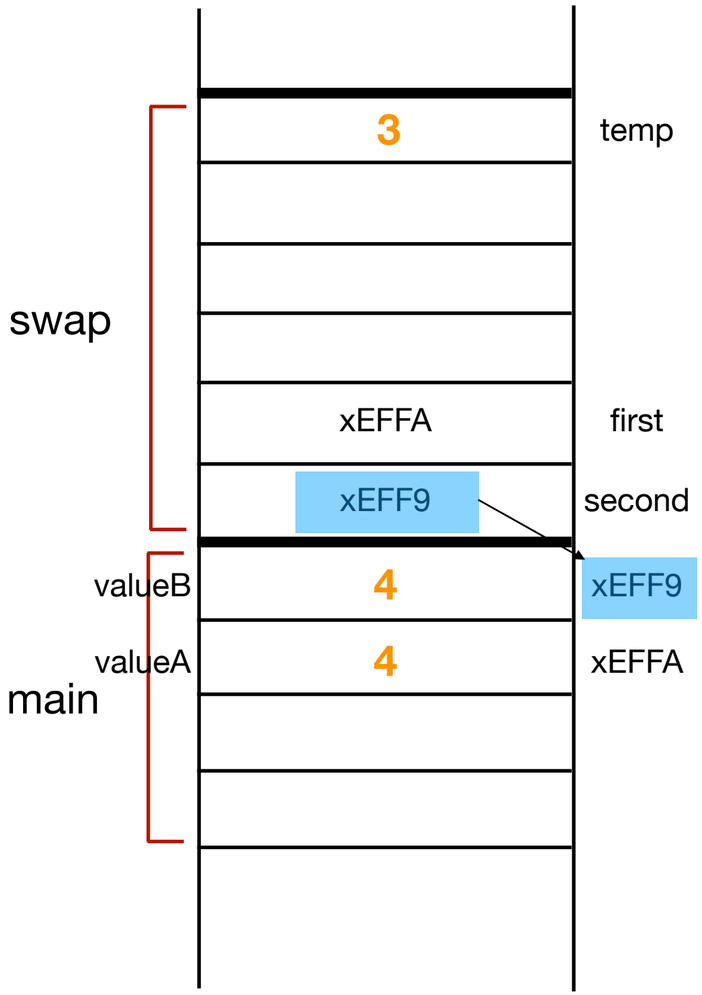


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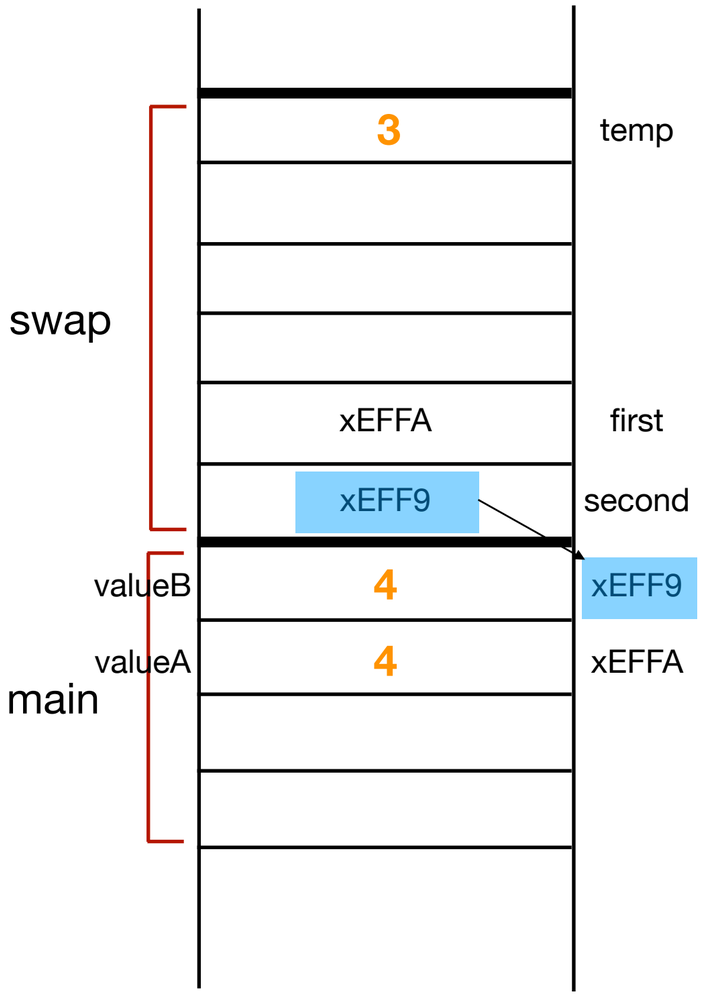


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int main(){
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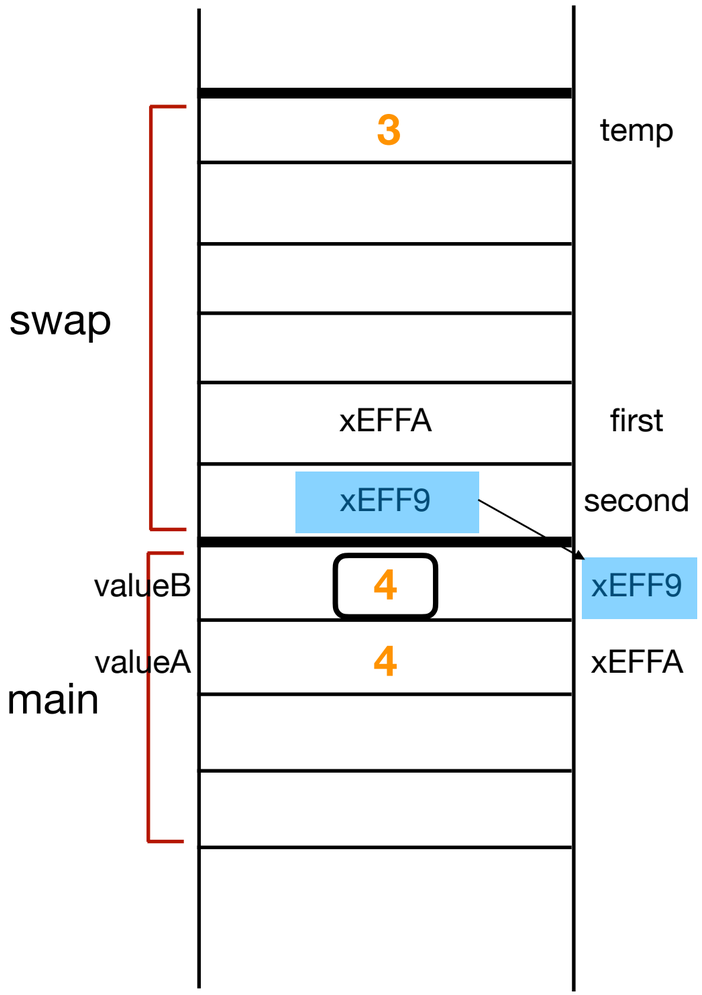
Using pointers in C

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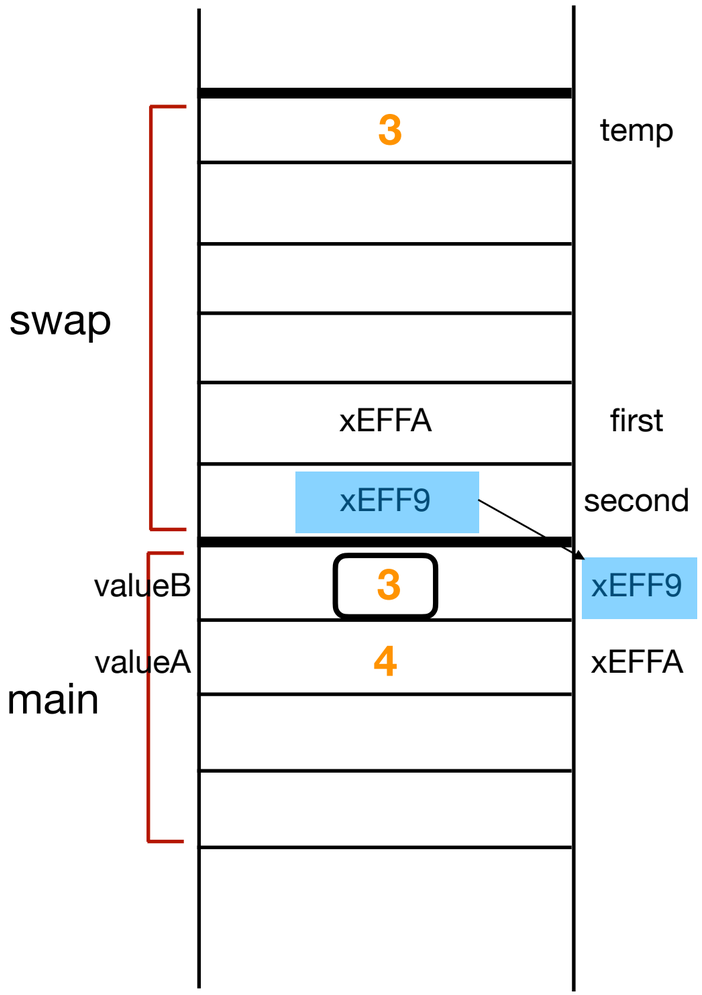


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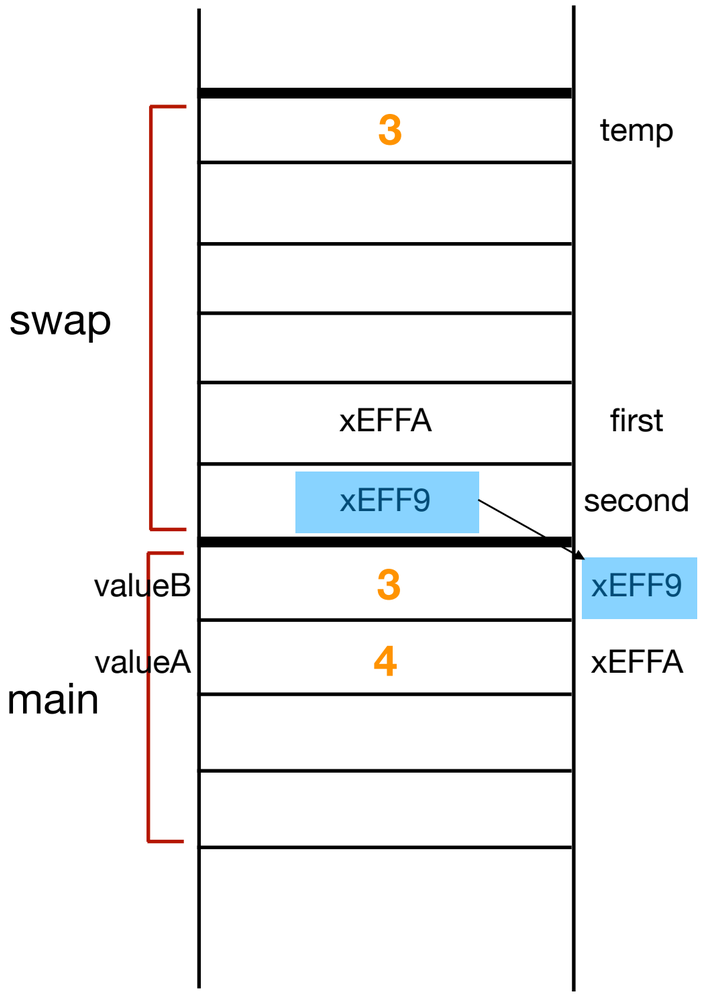


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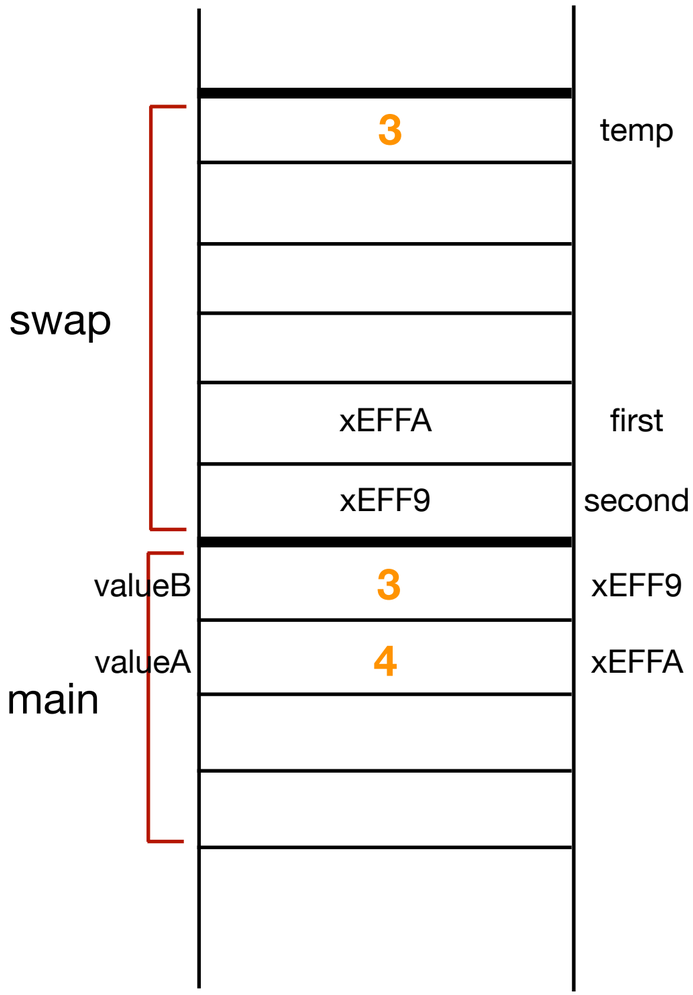


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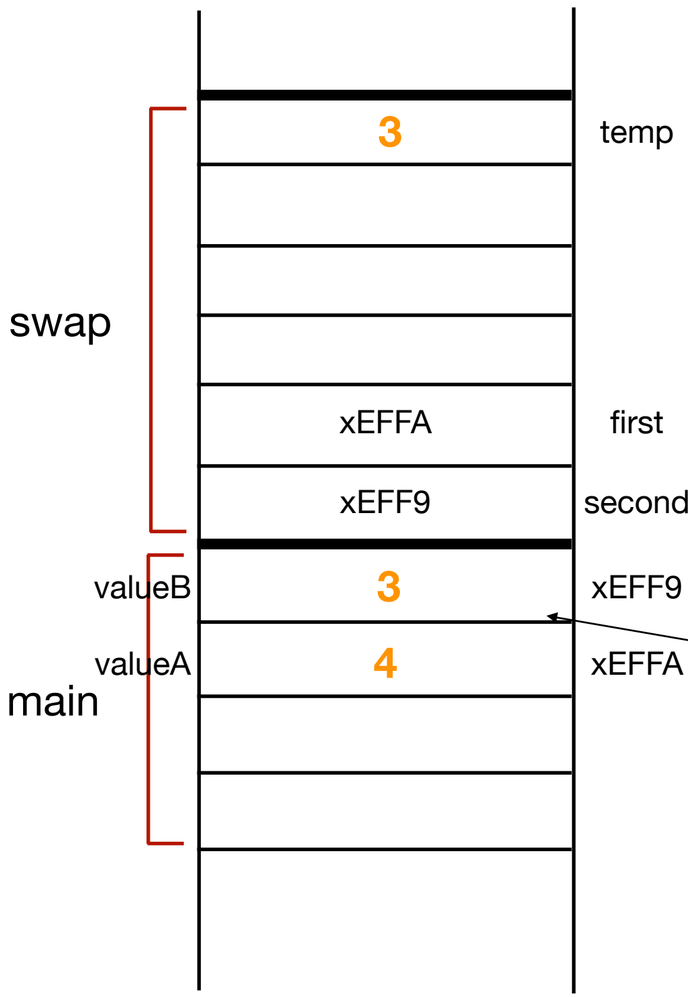
Using pointers in C



Compare

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Using pointers in C

- Pointers *need* to be indicated when making parameter declarations.

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- How did we use the value at memory location which pointer is pointing to?

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`*ptr` → ***dereference operator***: returns the value pointed to by `ptr`

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Using pointers in C

- Which uses of * are *dereferencing* (not declarations) ?

```
#include <stdio.h>

                    1              2
void Swap(int *first, int *second){
int temp;
temp = *first;3
4*first = *second;5
6*second = temp;
}

int main(){
  int valueA = 3;
  int valueB = 4;
  Swap(&valueA, &valueB);
}
```

Asides: … pointers *only* point to variables?

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```c
#include <stdio.h>

void fun(int a){
   printf("Value of a is %d\n", a);
}

int main(void){
   void (*fun_ptr)(int) = &fun;
   (*fun_ptr)(10);

   return 0;
}
```

Asides: … pointers *only* point to variables?

- No.
- They can point to functions, structs, *other pointers*, etc.
- Example on left shows a pointer to a function.
- We will learn about them on a **need-to-know** basis (definitely about pointers to structs).

```c
#include <stdio.h>

void fun(int a){
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Using pointers in C

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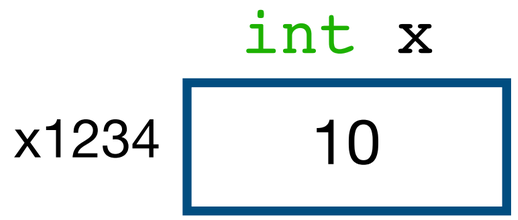

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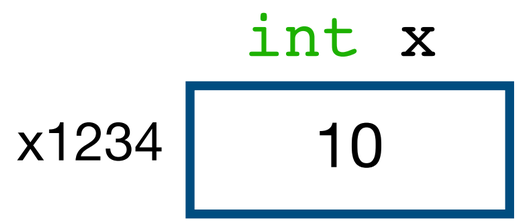

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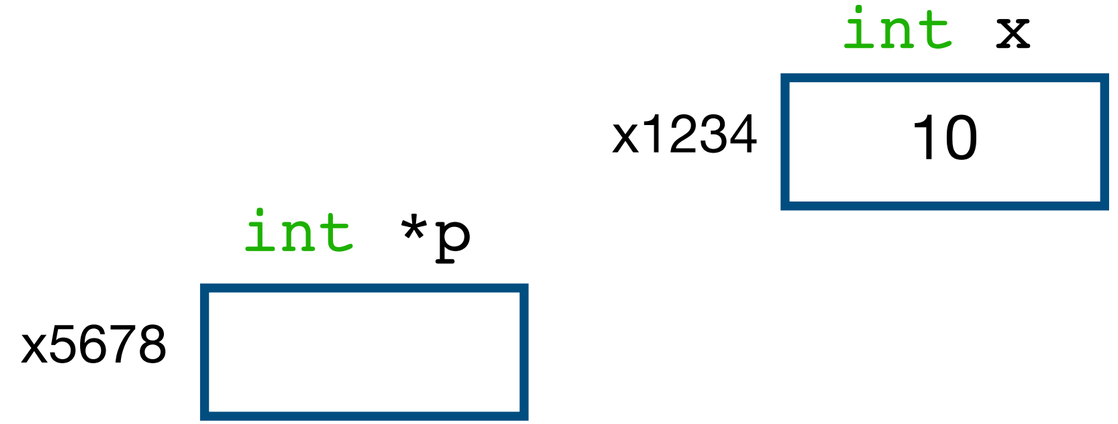

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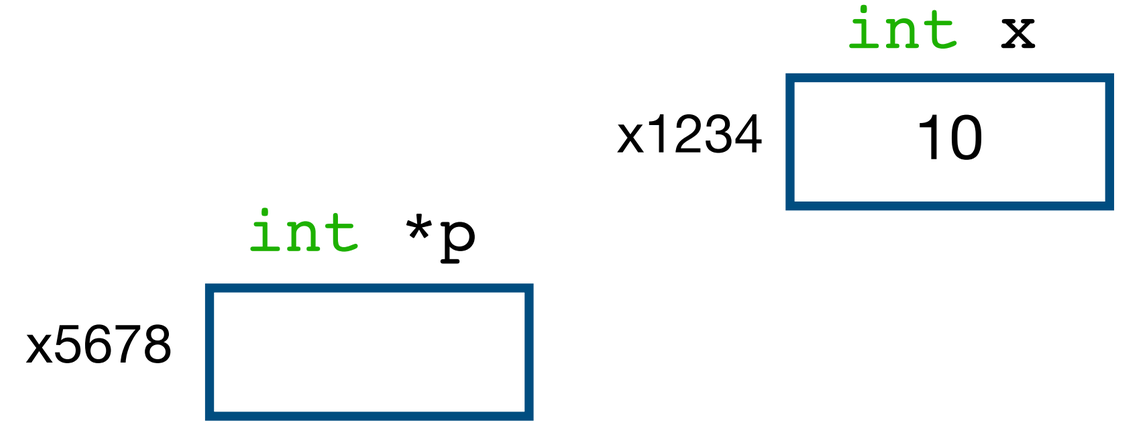

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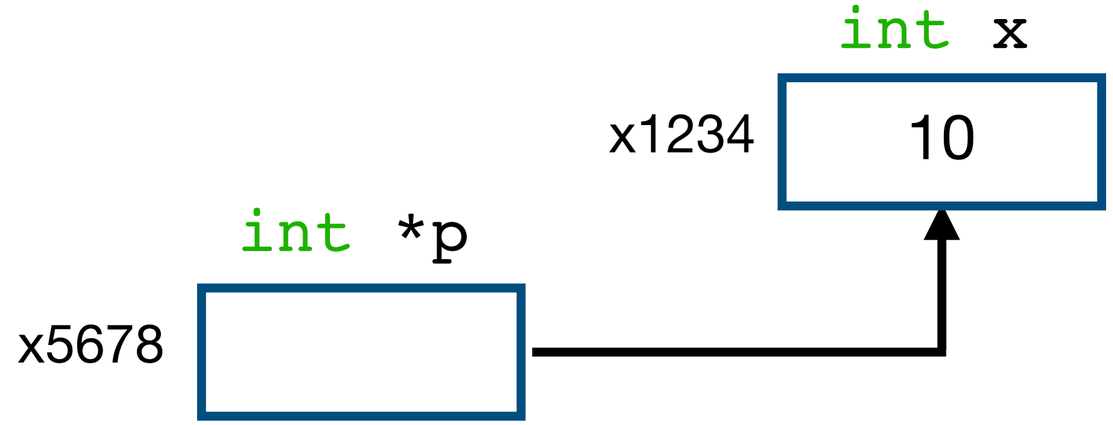

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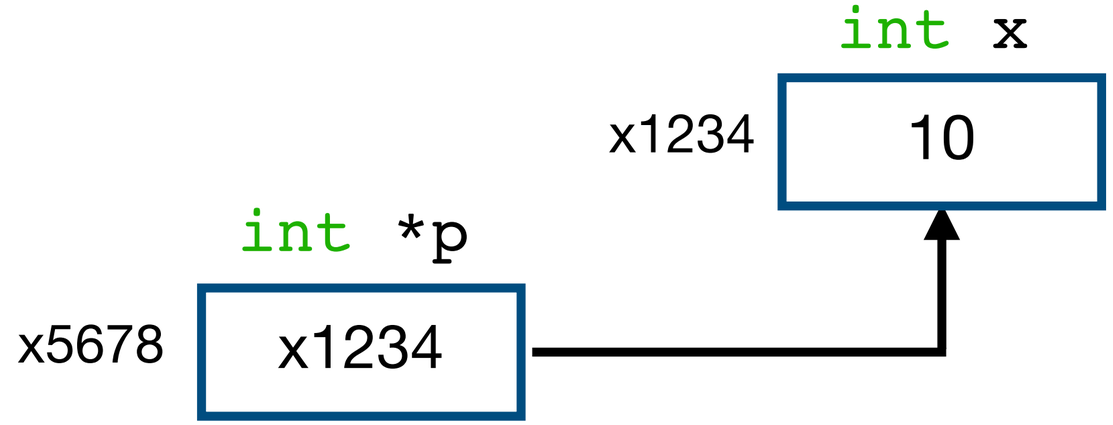
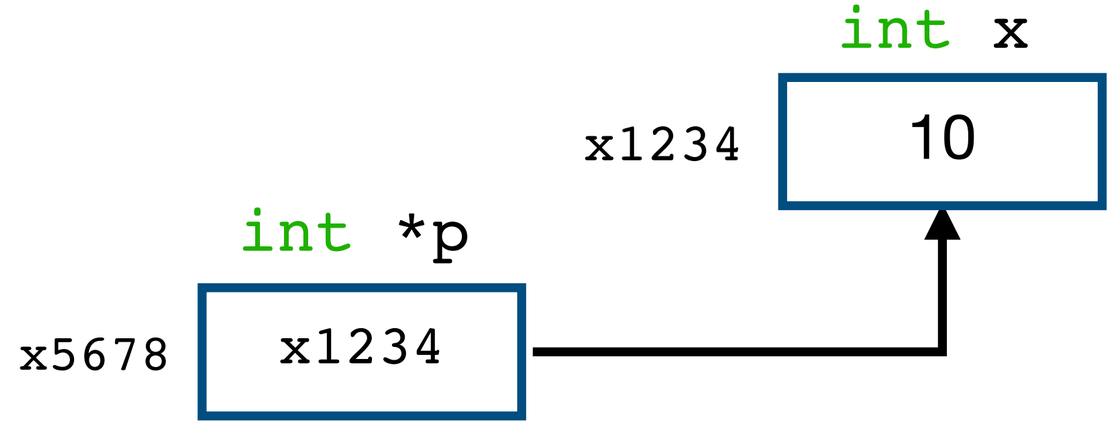


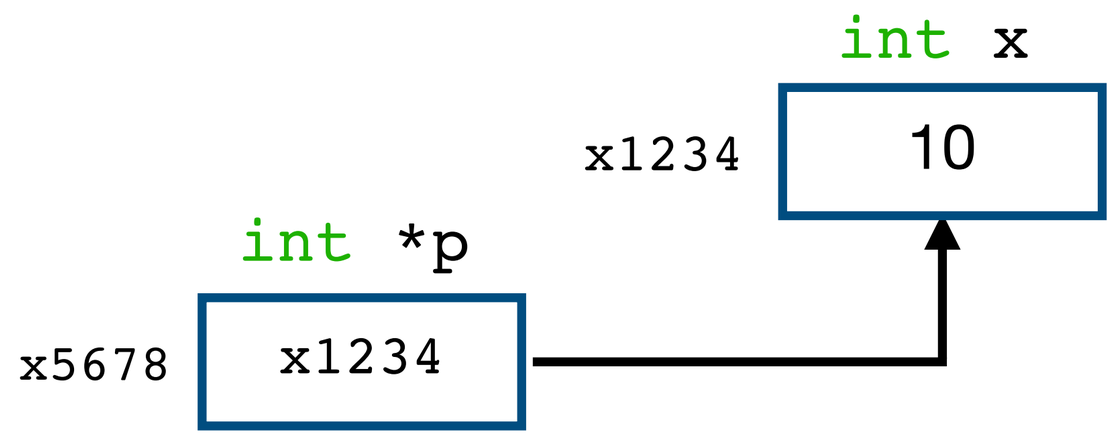
More pointers in C



More pointers in C

```
int x = 10;
int *p = &x;

/* Guess the outputs 1*/
```

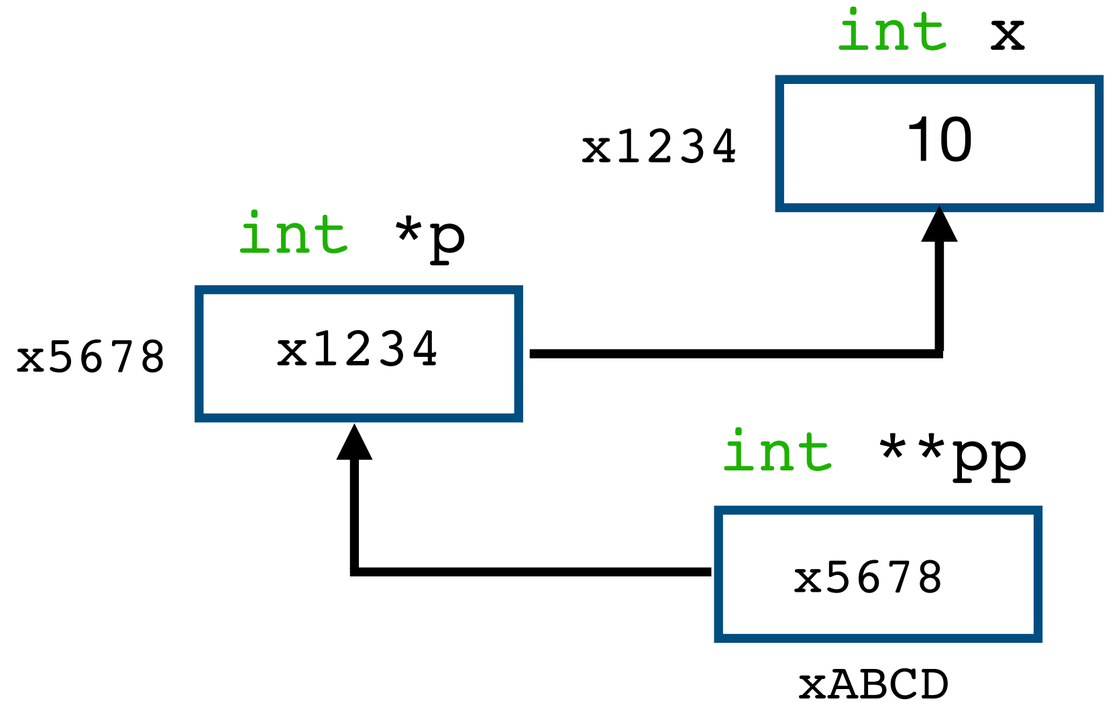



```
printf("x%X\n", &x);
printf("x%X\n", p);
printf("x%X\n", &p);
printf("%d\n", *p);

*p = *p + 10;

printf("%d\n", *p);
printf("%d\n", x);
```

Even more pointers in C

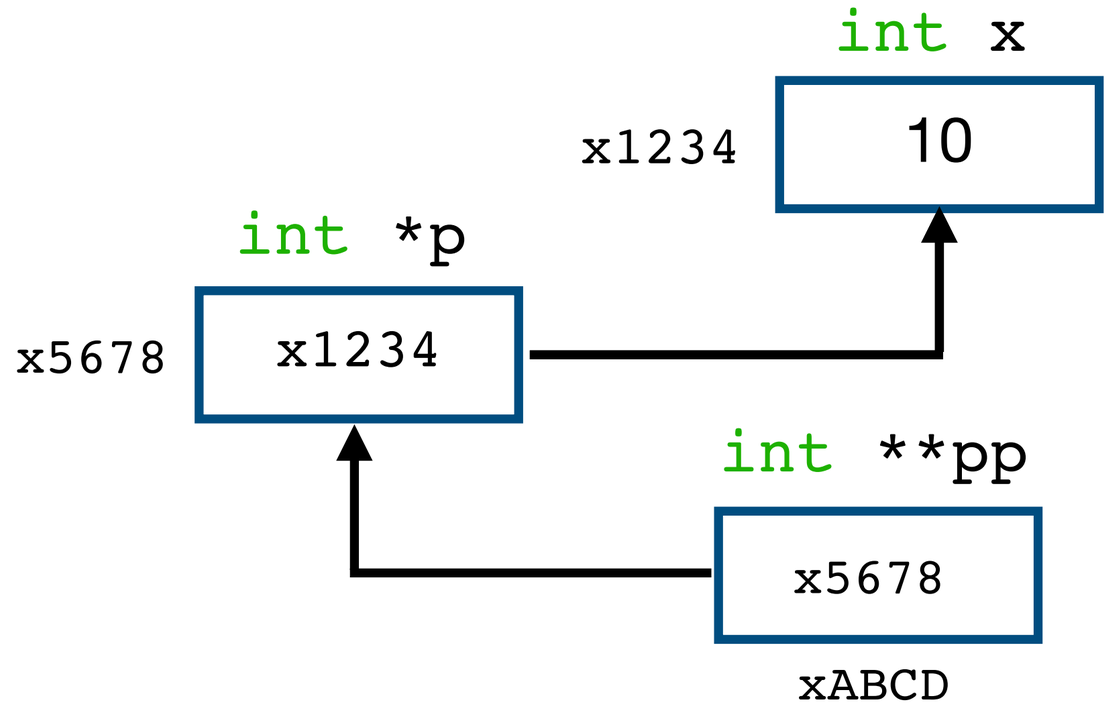


Even more pointers in C

```
int x = 10;
int *p = &x;
int **pp = &p;
```

```
/* Guess the outputs 2 */

printf("x%X\n", &pp);
printf("x%X\n", pp);
printf("x%X\n", *pp);
printf("%d\n", **pp);
```



Pointers in LC-3

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int *ptr;
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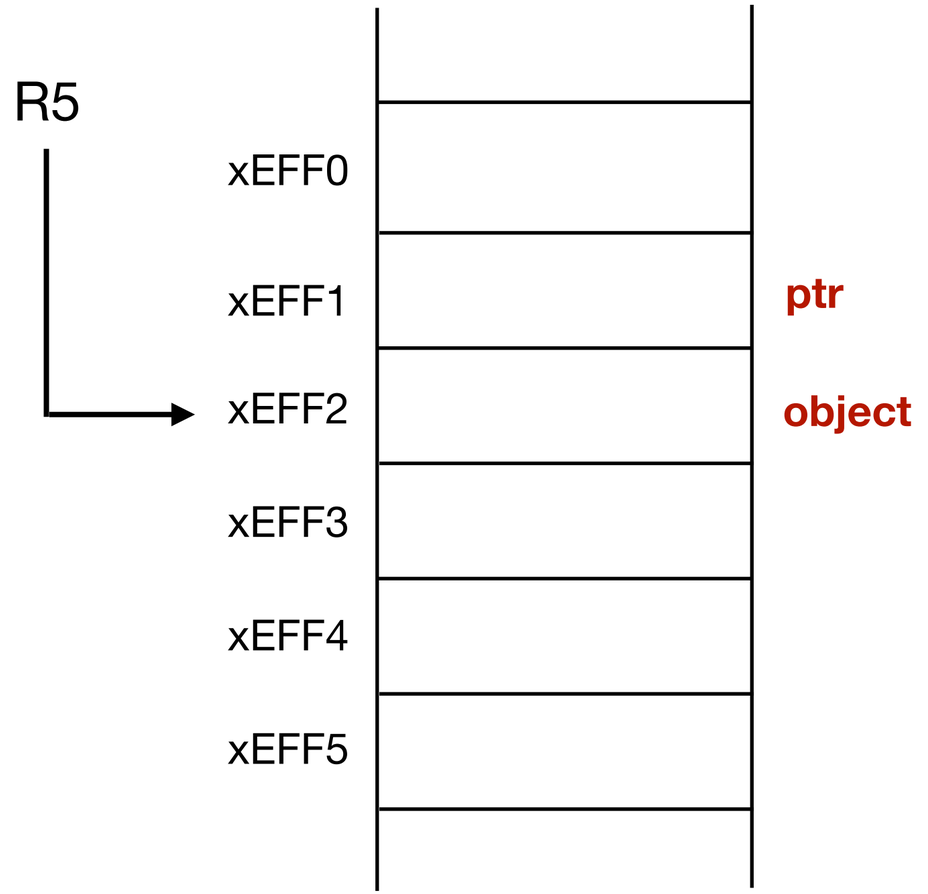
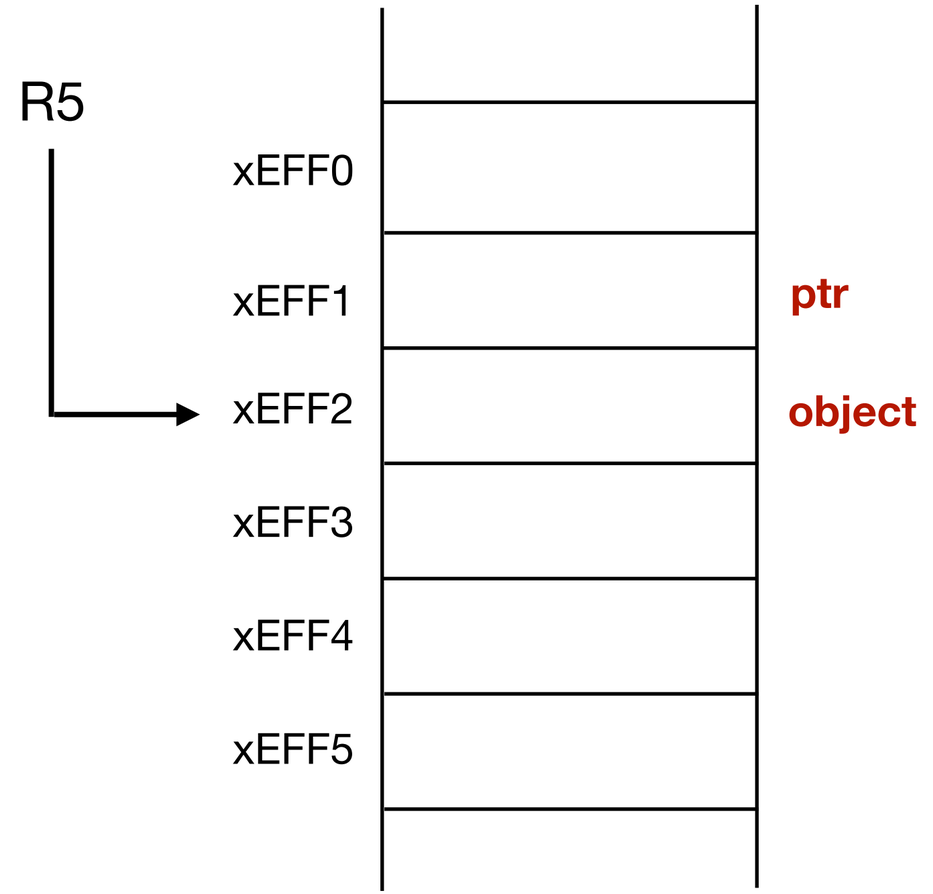


Pointers in LC-3

```
int object;
int *ptr;

object = 4;
ptr = &object;
```

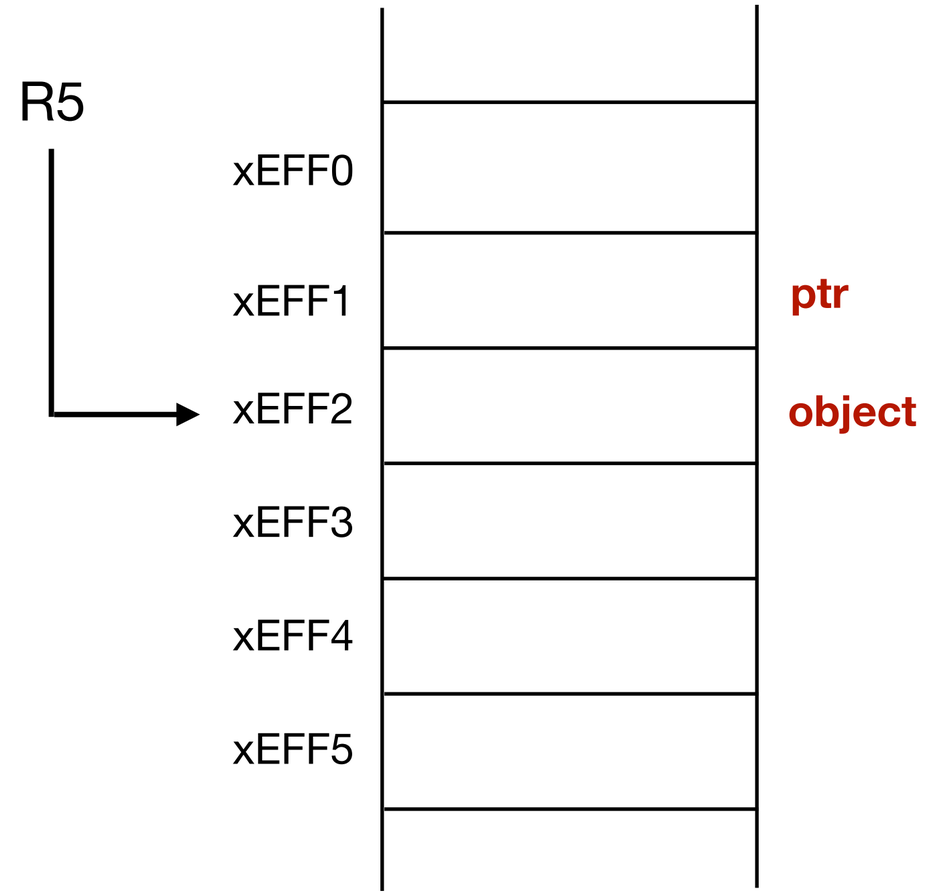


Pointers in LC-3

```
int object;
int *ptr;

object = 4;
ptr = &object;
```

```
AND R0, R0, #0    ; Clear R0
```



Pointers in LC-3

```
int object;
int *ptr;

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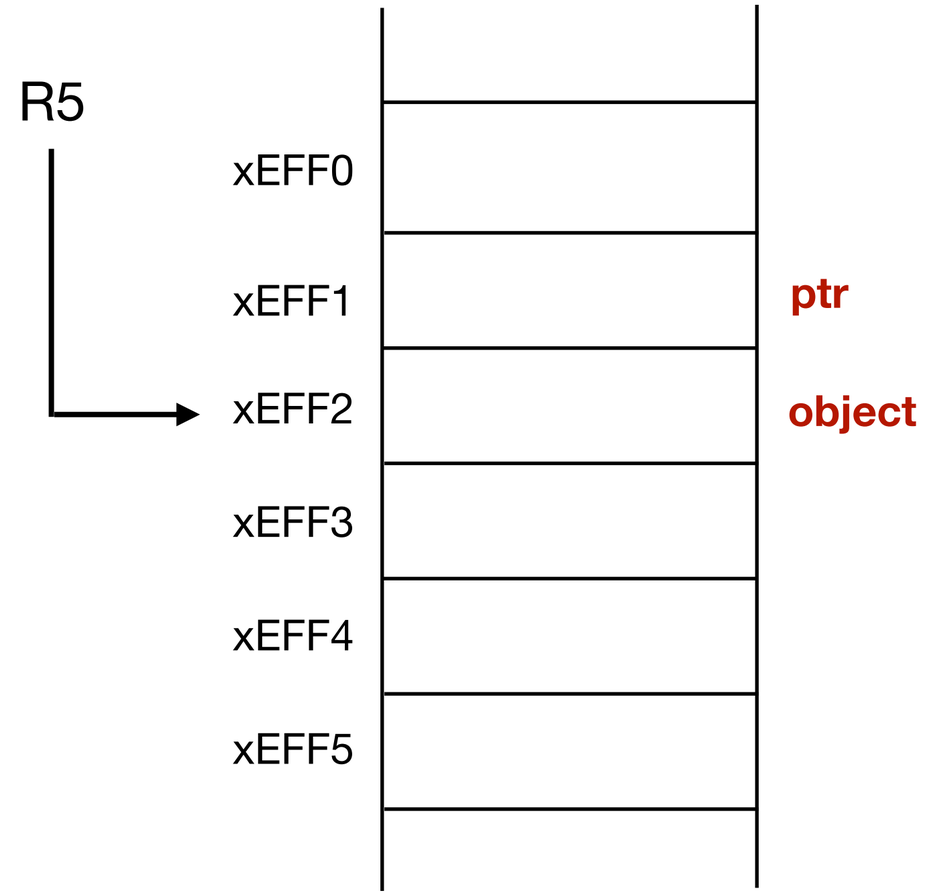
ptr = &object;
```

```
AND R0, R0, #0    ; Clear R0
ADD R0, R0, #4    ; R0 = 4
```



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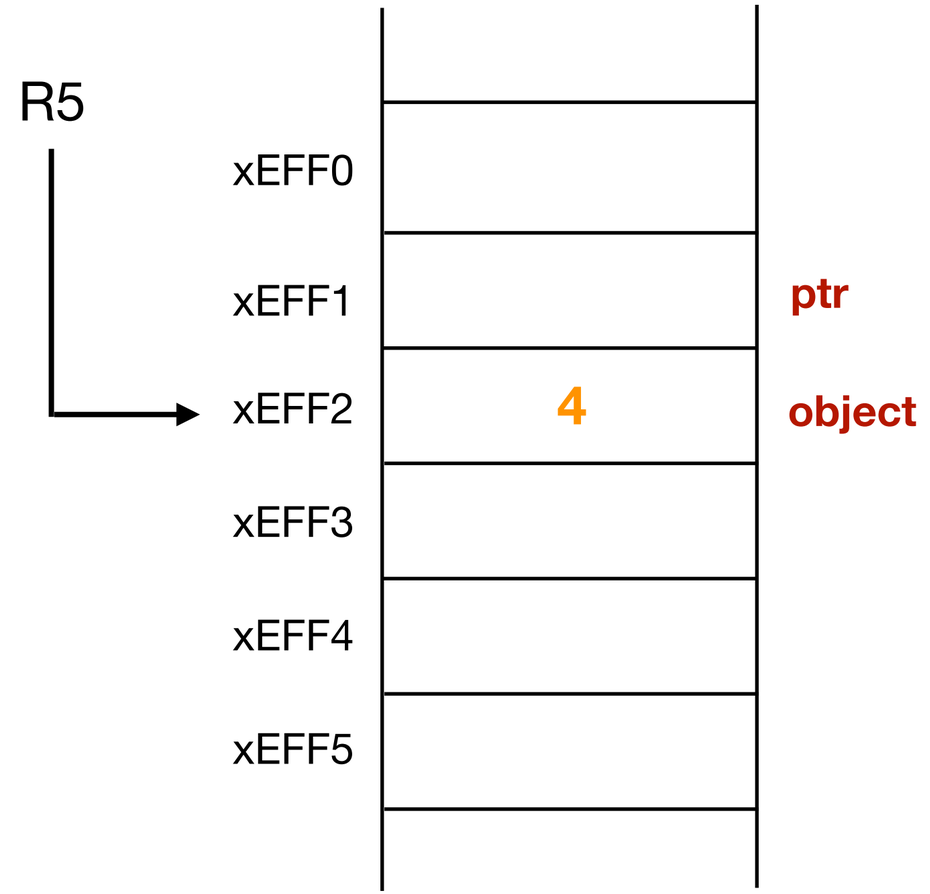


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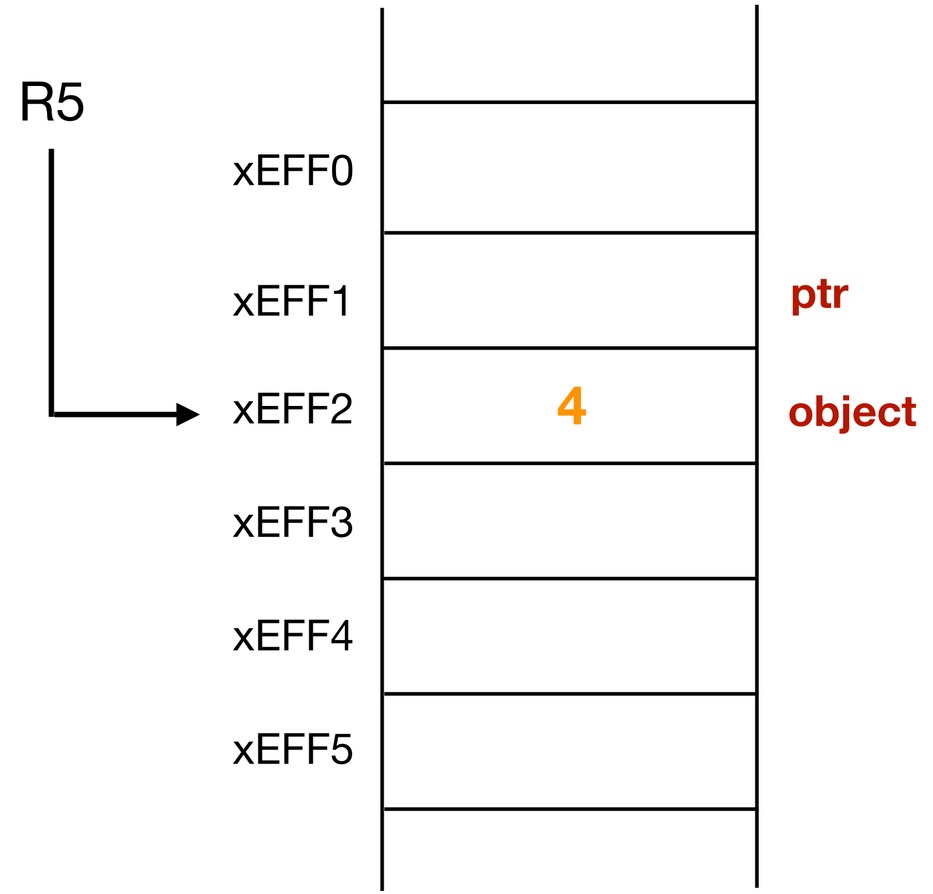


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AND R0, R0, #0    ; Clear R0
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STR R0, R5, #0    ; object = 4

ADD R0, R5, #0    ; Generate memory address of object
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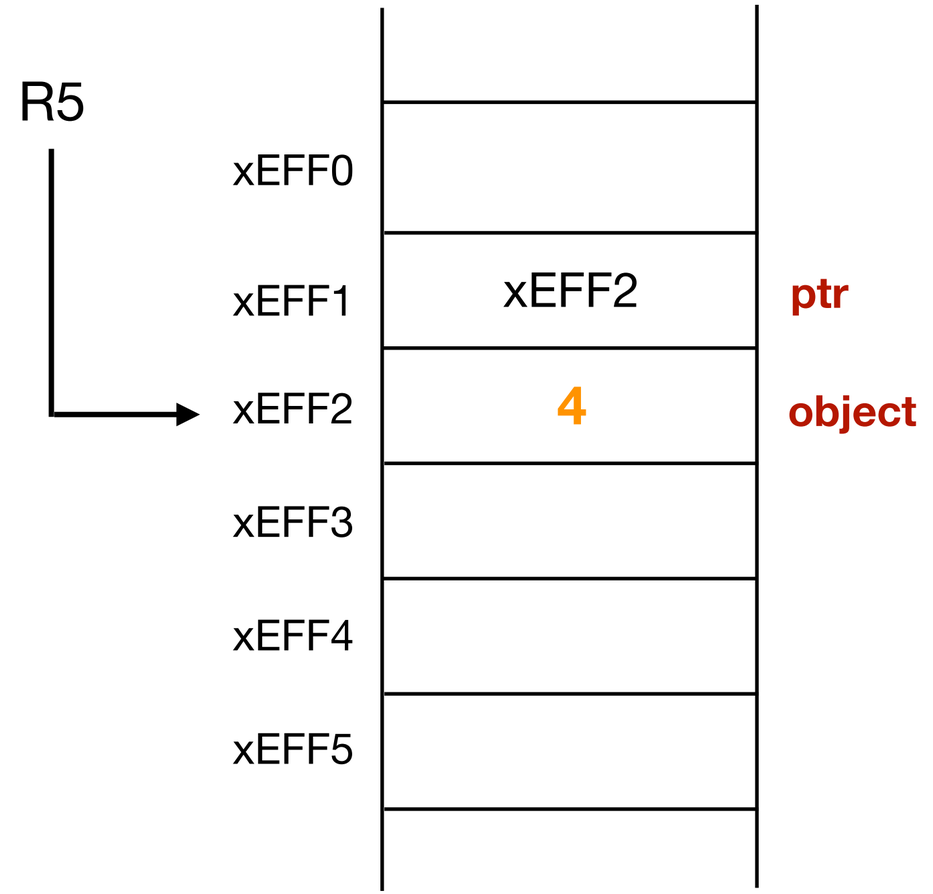


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ADD R0, R5, #0    ; Generate memory address of object
STR R0, R5, #-1   ; ptr = &object
```
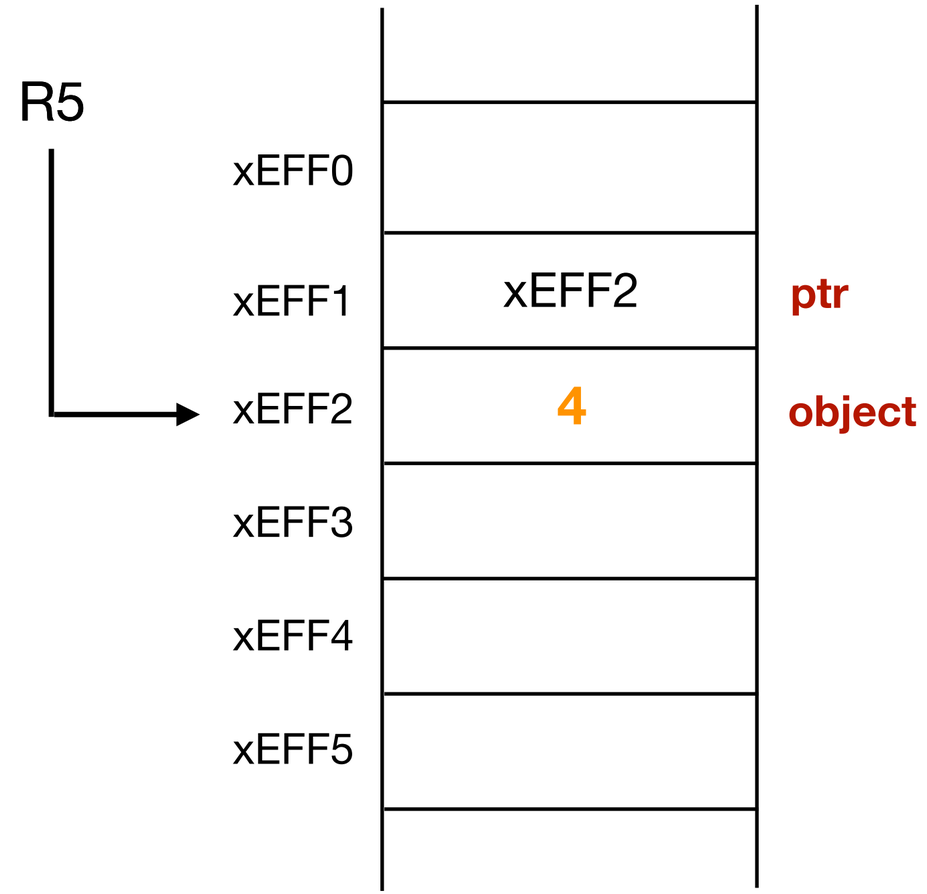
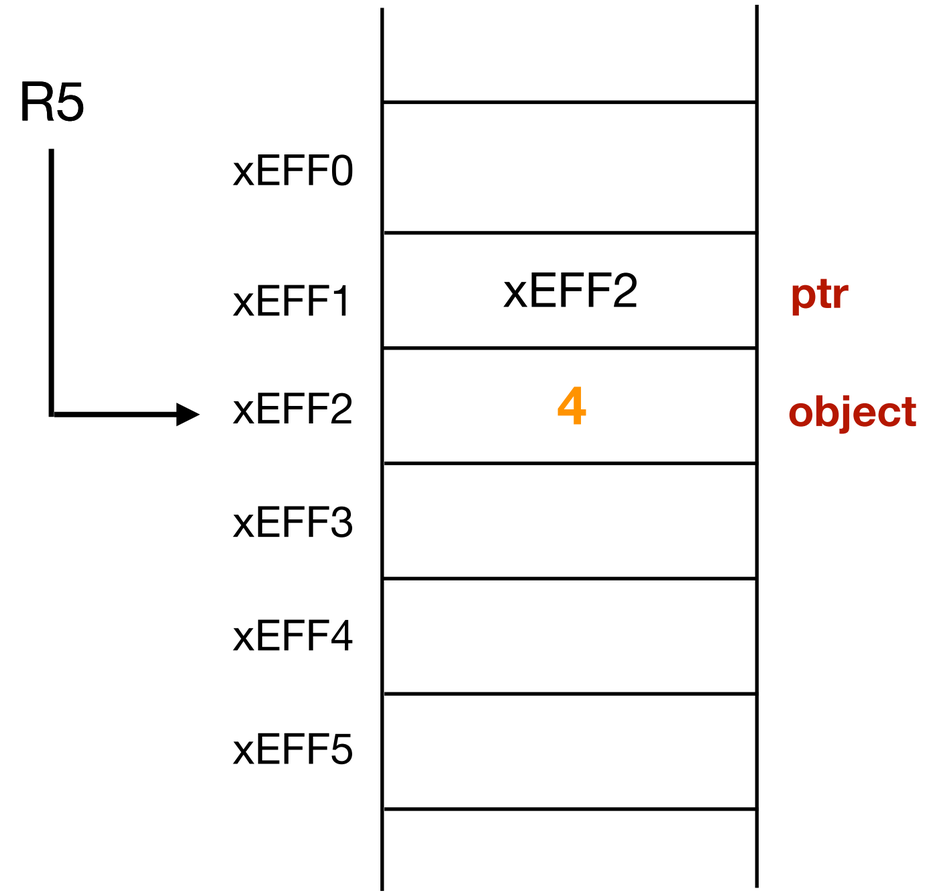

Pointers in LC-3



Pointers in LC-3

```
*ptr = *ptr + 1;
```



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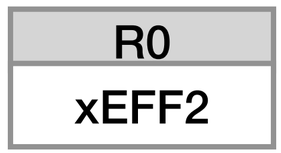

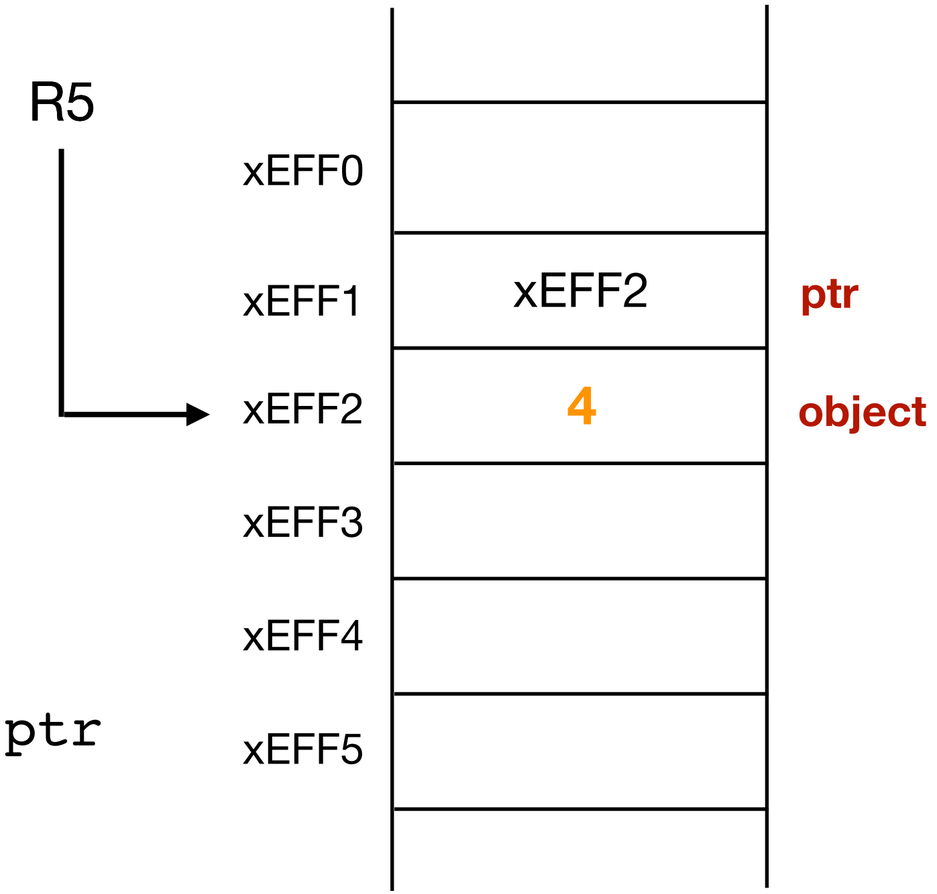


```
LDR R0, R5, #-1  ; R0 contains the value of ptr
```

Pointers in LC-3

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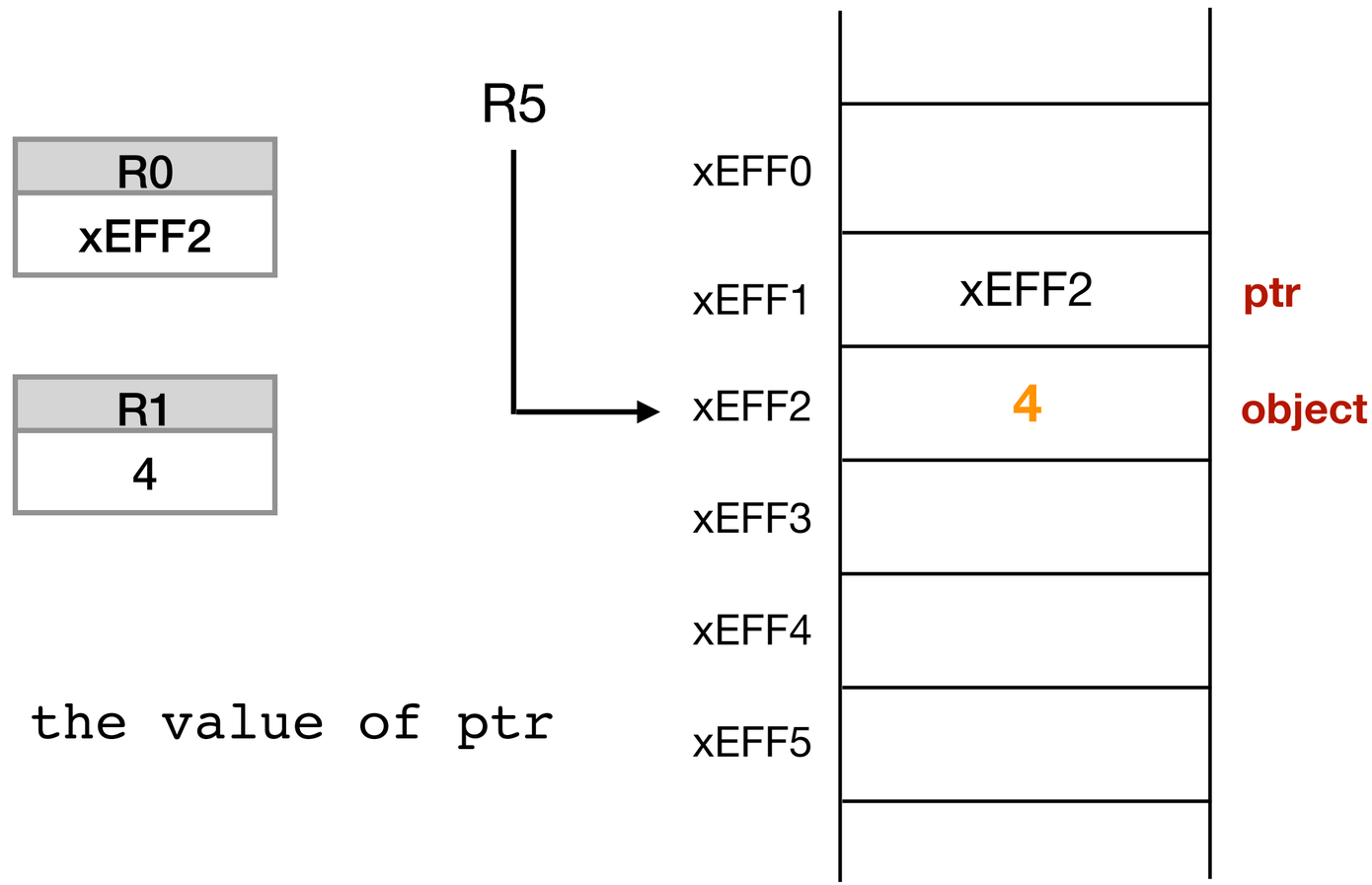


```
LDR R0, R5, #-1   ; R0 contains the value of ptr
LDR R1, R0, #0    ; R1 = *ptr
```

Pointers in LC-3

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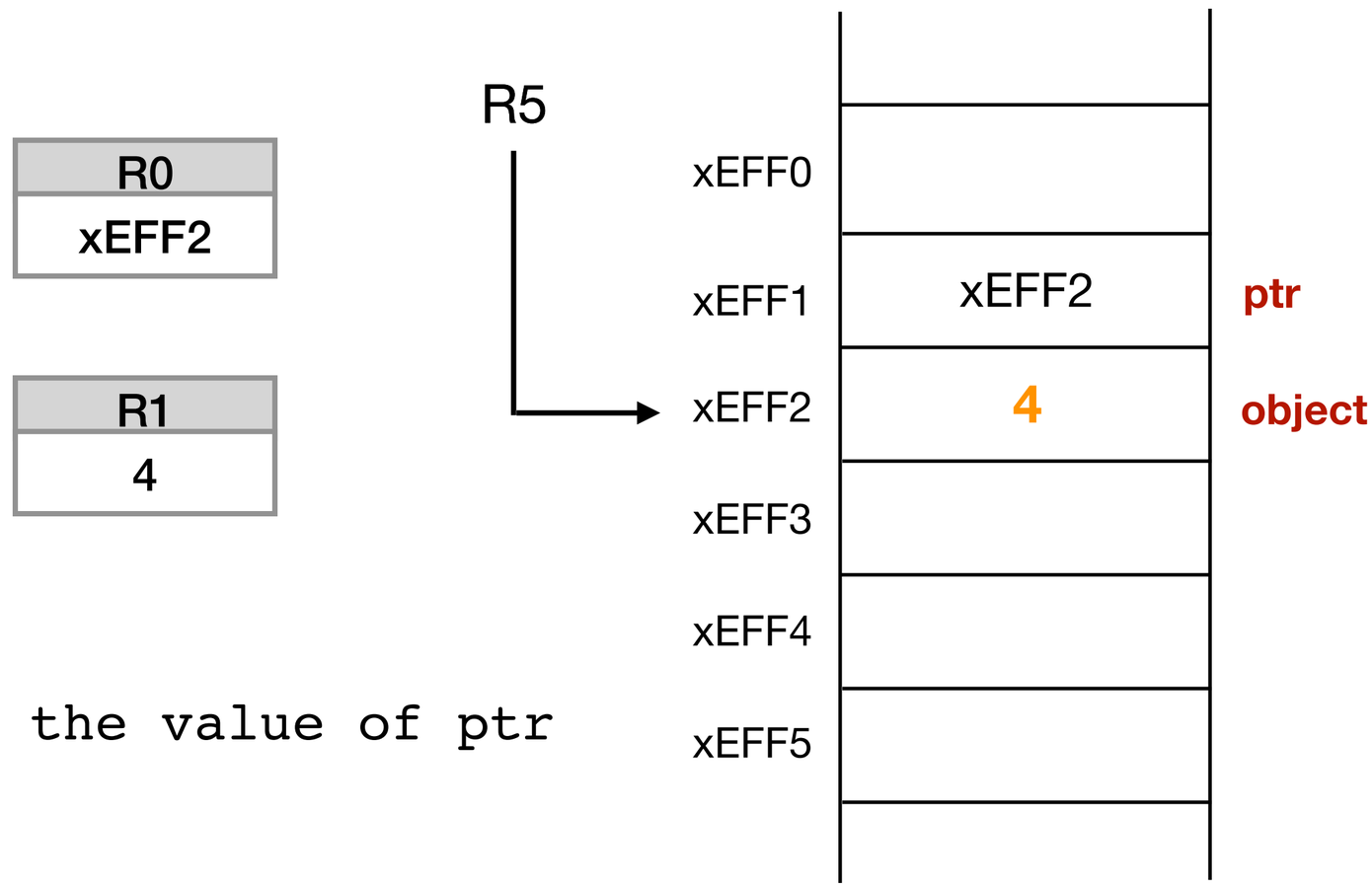


```
LDR R0, R5, #-1   ; R0 contains the value of ptr
LDR R1, R0, #0    ; R1 = *ptr


ADD R1, R1, #1    ; *ptr + 1
```

Pointers in LC-3

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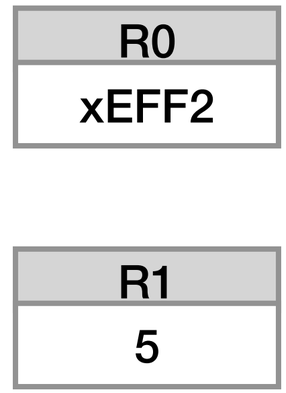

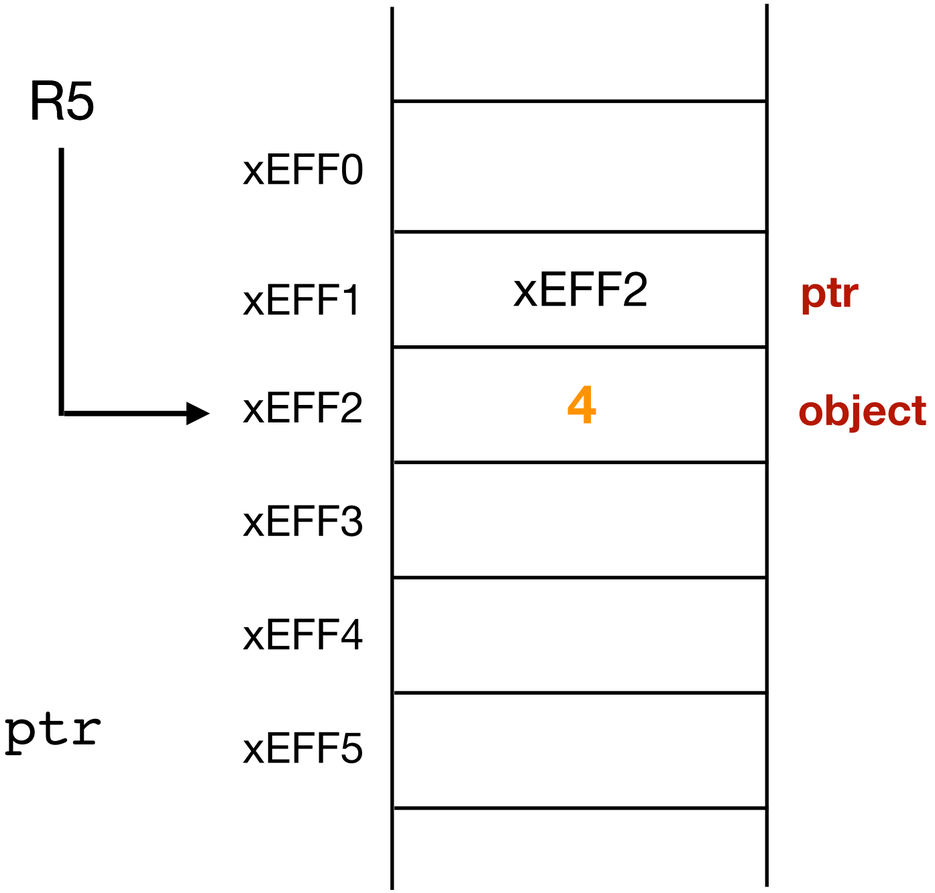


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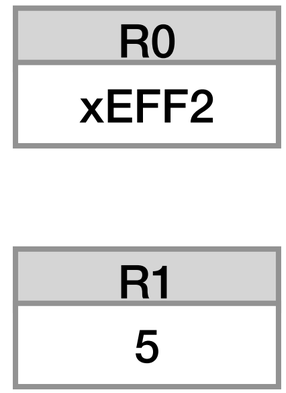

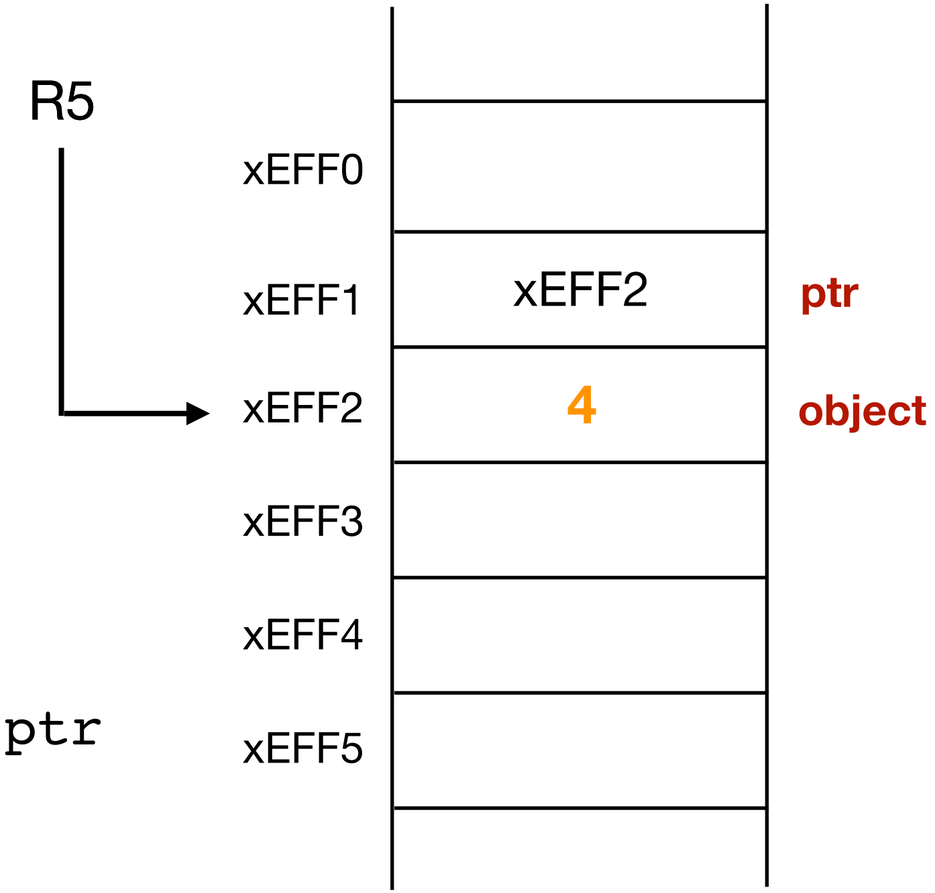


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ADD R1, R1, #1    ; *ptr + 1
STR R1, R0, #0    ; *ptr = *ptr +1
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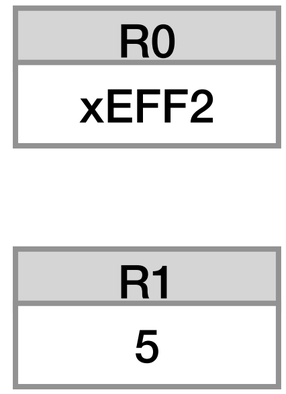
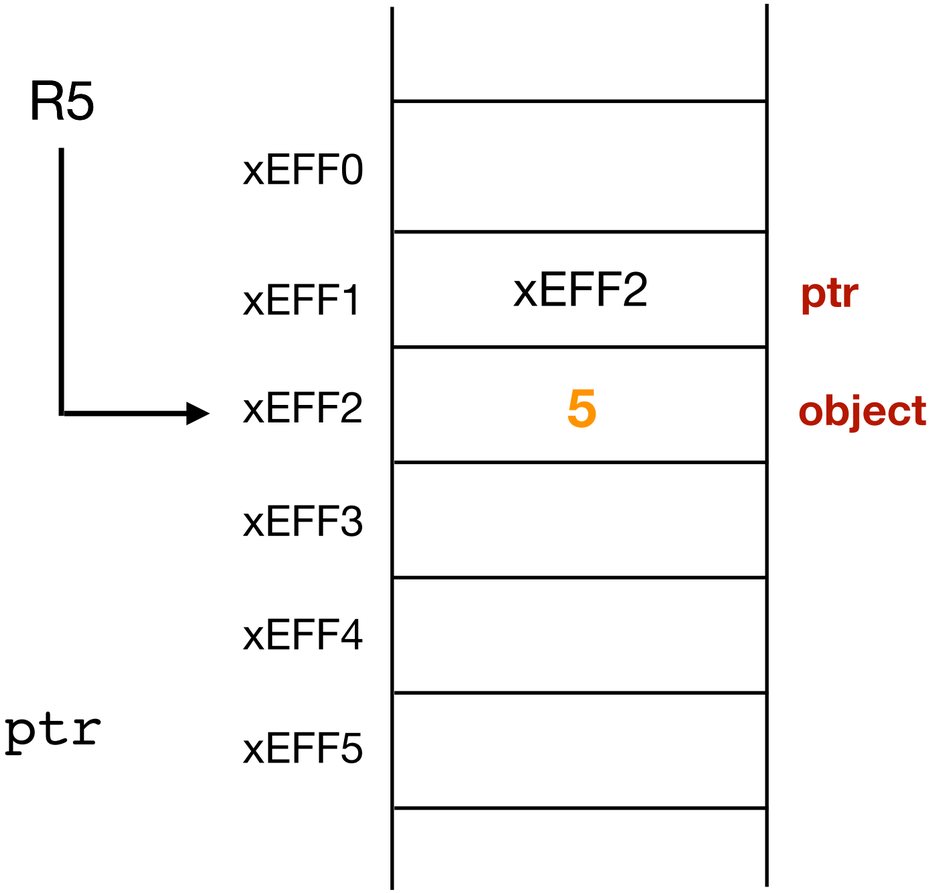
```



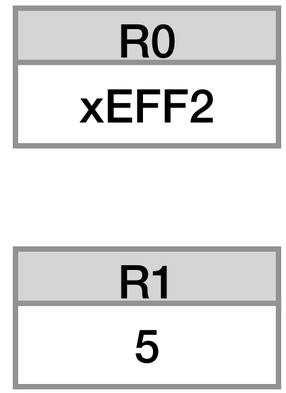


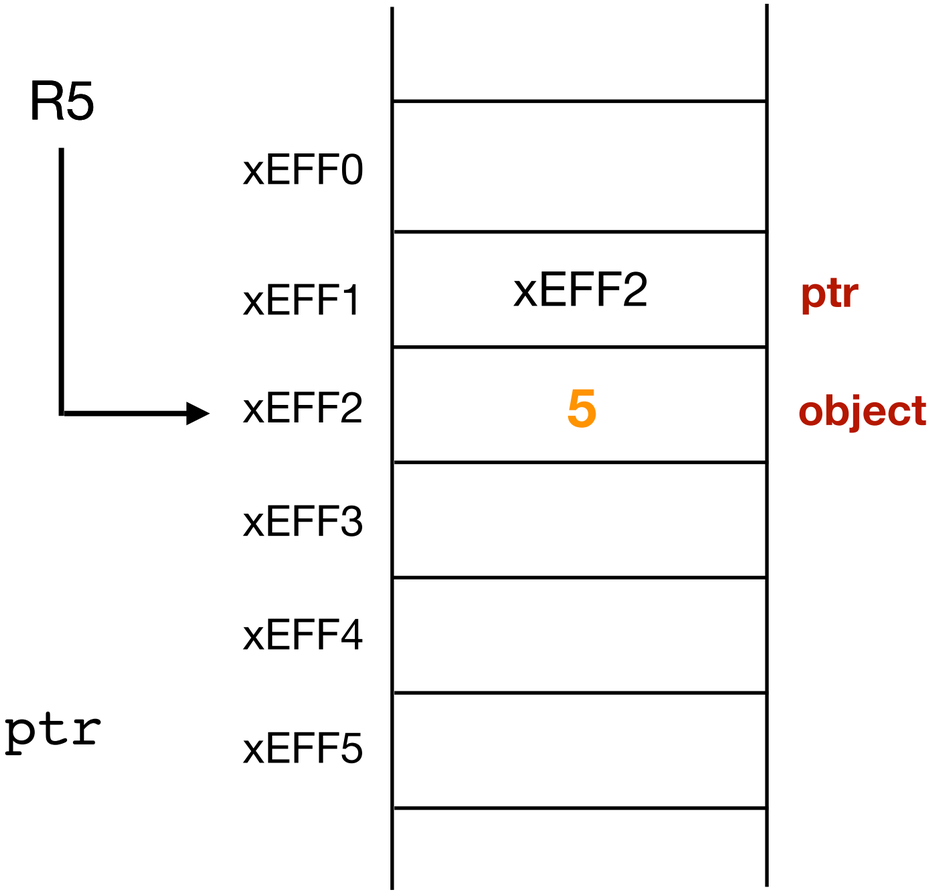

```
LDR R0, R5, #-1   ; R0 contains the value of ptr
LDR R1, R0, #0    ; R1 = *ptr


ADD R1, R1, #1    ; *ptr + 1
STR R1, R0, #0    ; *ptr = *ptr +1
```

Pointers in LC-3

```
*ptr = *ptr + 1;
```



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```

Why not?

```
STR R1, R5, #0
```

Arrays

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- `arraySize` has to be positive, nonzero and integer values
- `type` is any valid C type

Arrays

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double balance[5] = {1000.0, 2.0, 3.4, 7.0, 50.0};
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- Accessing elements?
  - Expression **`a[4]`** refers to the 5th element of the array **`a`** (index starts from 0)

Arrays

- How do we calculate the length of an array?

Arrays

- How do we calculate the length of an array? `sizeof` function

Arrays

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```c
#include <stdio.h>

int main() {
  //simple array
  int arr[] = {19, 25, 8,  22, 17, 7,  84, 9,  19, 25, 10, 3,  1,
               7,  84, 9,  19, 25, 10, 3,  1,  8,  22, 17, 19, 25,
               10, 3,  1,  8,  22, 17, 7,  84, 9,  33, 1,  8,  22,
               17, 7,  84, 9,  19, 25, 10, 22, 17, 7,  84, 9,  19,
               25, 10, 3,  1,  8,  84, 9,  11, 23, 45, 5,  3};

  // using sizeof() operator to get length of array
  int len = sizeof(arr) / sizeof(arr[0]);

  printf("The length of int array is : %d ", len);
}
```

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```

Gives memory occupied by all of `arr`

Gives memory occupied by `arr[0]`

Exercise

Using loops, write a C program that prompts the user for *five* integers one by one and stores them into an array `arr`. Then print out the five integers in a single line but in reverse order.

Exercise

Add a function `int my_first_sum` to the previous program which will take the list of five numbers and return their sum. Use this function to display the sum to the console instead of the numbers in reverse order.

Passing arrays

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```c
int my_first_sum(int array[]){
  int i, sum=0;
  for (i=0; i<5; i++)
    sum = sum + array[i];
  return sum;
}
```

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```
printf("Sum is: %d \n", my_sum(arr));
```

Passing arrays

- How did we let the compiler know `my_first_sum` takes an array of integers?

- How did we pass the parameter `arr` to the function `my_first_sum` ?

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int my_first_sum(int array[]){  printf("Sum is: %d \n", my_sum(arr));
  int i, sum=0;
  for (i=0; i<5; i++)
    sum = sum + array[i];
  return sum;
}
```

Fact: The name of the array is *pointer* to the array!

Not convinced?

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- Replace the previous function with this one instead and try it out!

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```
int my_second_sum(int *array){
  int i, sum=0;
  for (i=0; i<5; i++)
    sum = sum + array[i];
  return sum;
}
```

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- The parameter declaration `int array[]` in the function definition is *syntactic sugar* for `int *array`.

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- However, `int p[]` makes it clear we are passing an array of integers while `int *p` … not so much.

This is called pointer/array duality in C.

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- In fact `arr[3]` is syntactic sugar for `*(arr + 3)` !!

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```
int my_third_sum(int *arr){
  int i, sum=0;
  for (i=0; i<5; i++)
    sum = sum + *(arr + i);
  return sum;
}
```

would also work just fine!

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- So is there a difference between `cptr` and `arr` in the below?

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char arr[10];
char *cptr;
cptr = arr;
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- Try doing:

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cptr = cptr + 1;
arr = arr + 1;
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- Try doing:

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arr = arr + 1;
```

What gives?

Some tips for the debugging MP

- Pointer arithmetic implicitly uses size of each data type.
    - If an integer pointer that stores address x1000 is incremented, then it will increment by 4 (size of an int), and the new address will point to x1004.
    - If ptr is an integer pointer that stores x1000 as an address. If we add integer 5 to it using the expression ptr = ptr + 5, then, the final address stored in the ptr will be x1000 + sizeof(int) * 5.
- The addition and subtraction of pointers are only possible if they are of the same type.

Next time

- More pointer/array duality
- Arrays in LC3
- Variable length arrays
- Strings
- Multi-dimensional arrays

Good luck on the exam!