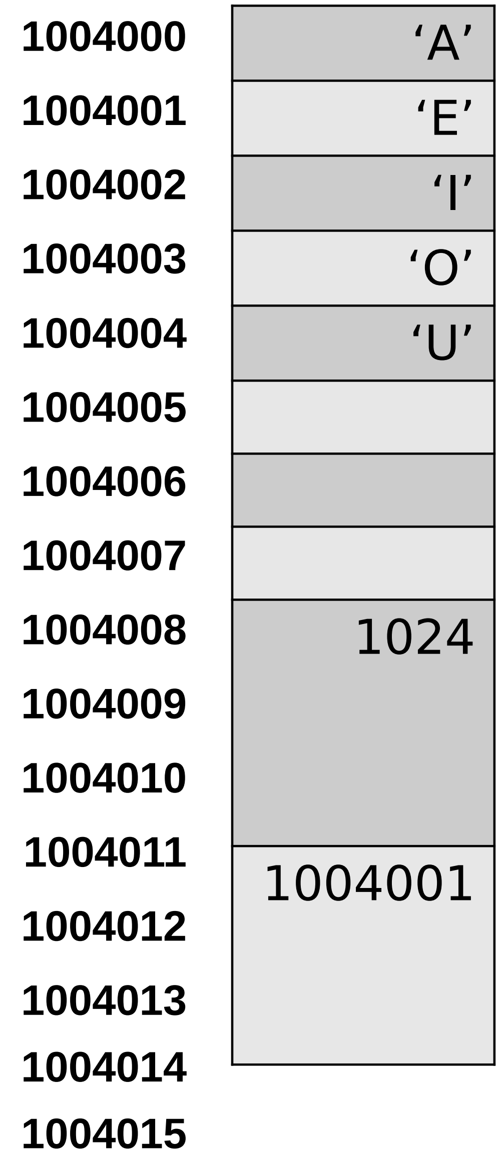
Pointers: the Prequel

IC-100
December, 2022

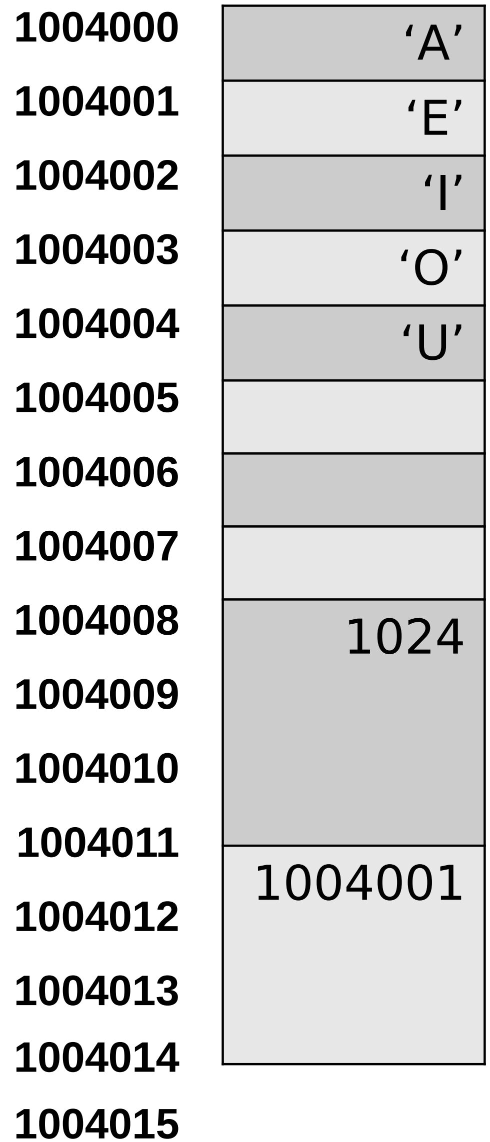
Simplified View of Memory



- "Array" of blocks
- Each block can hold a byte (8-bits)
- "char" stored in 1 block
- "int" (32-bit) stored in 4 consecutive blocks
- Finite number of blocks
  - Limited by the capacity of (Virtual) Memory

Simplified View of Memory

- Blocks are addressable.
- Address range: $[0...2^N-1]$
- N is the number of bits in address (number of digits in binary world)
- Any integer in the above range can be used as an index in the MEMORY ARRAY
- We call each index a memory address



Simplified View of Memory

- Content of the 4-blocks starting at address 1004012
  - ✓ 1004001
- Without knowing the context it is not possible to de
  significance of num
  1004001
  - ✓ It could be an integer value 1004001
  - ✓ It could be the “location” of the bl ‘E’

“Type” helps us disambiguate.

How do we decide what it is?

Address	Content
1004000	‘A’
1004001	‘E’
1004002	‘I’
1004003	‘O’
1004004	‘U’
1004005	
1004009	
1004010	
1004011	
1004012	1004001
1004013	
1004014	
1004015	

What is a Pointer

- **Pointer**: A **special type** of variable that contains an address of a memory location.
- Think of a pointer as a new data type (a new kind of box) that holds memory addresses.
- Pointers are almost always associated with the type of data that is contained in the memory location.
  - For example, an integer pointer is a memory location that contains an integer.
  - Character pointer, float pointer
  -

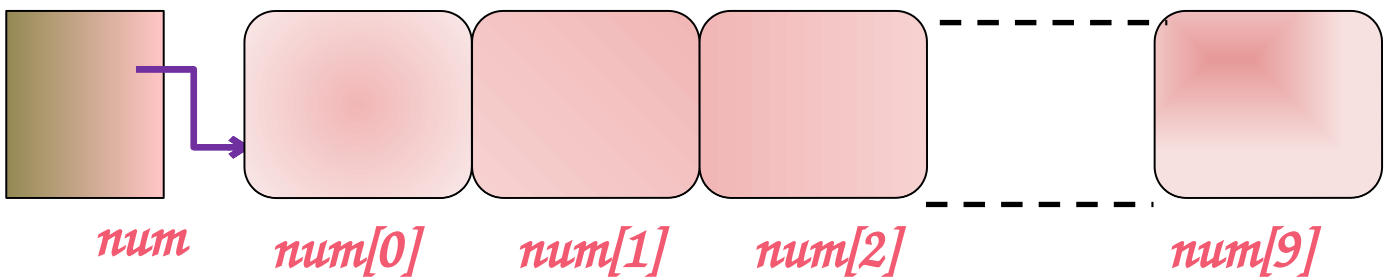
Remember Arrays?

The memory allocated to array has two components:

A consecutively allocated segment of memory boxes of the same type, and

A box with the same name as the array. This box holds the address of the base (i.e., first) element of the array.

int num[10];



This definition for num[10] gives 11 boxes, 10 of type int, and 1 of type address of an int box.

1. *We represent the address of a box x by an arrow to the box x. So addresses are referred to as pointers.*
2. *Contents of an address box: pointer to the box whose address it contains. e.g., num points to num[0] above.*

What can we do with a box? e.g., an integer box?

We can do operations supported for the data type of the box.

int num[10];

True!. But we can also take the address of a box. Like scanf for reading using the & operator.

For integers, we can do + - * / % etc. for each of num[0] through num[9].

ptr = &num[1];

But what is the type of ptr? And how do i define ptr?

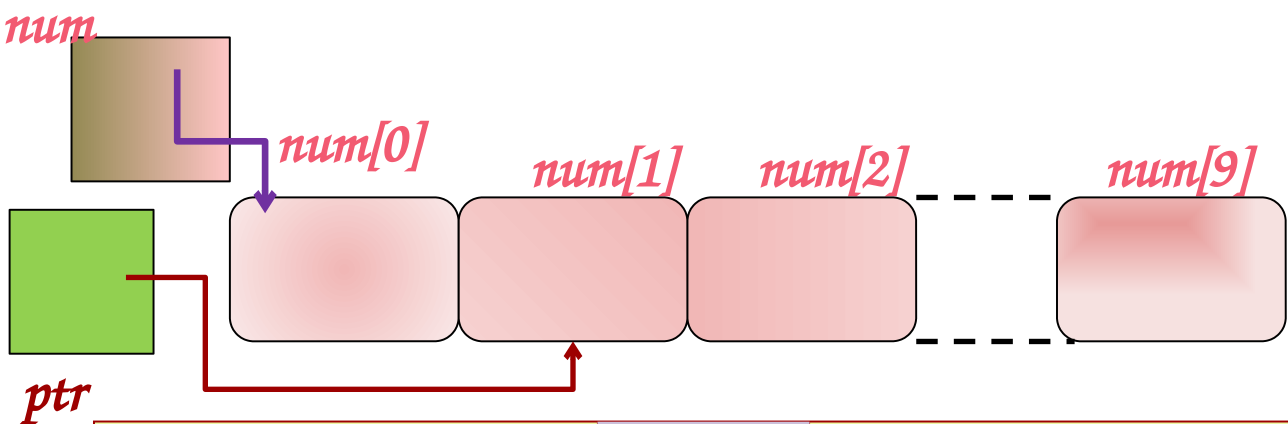
ptr would be of type address of int. In C this type is int *.

```
int * ptr;
ptr= &num[1];
```

ptr =&num[1]
let's look at the memory

int num[10];
int * ptr;
ptr = &num[1];

state after num[10] gets defined.

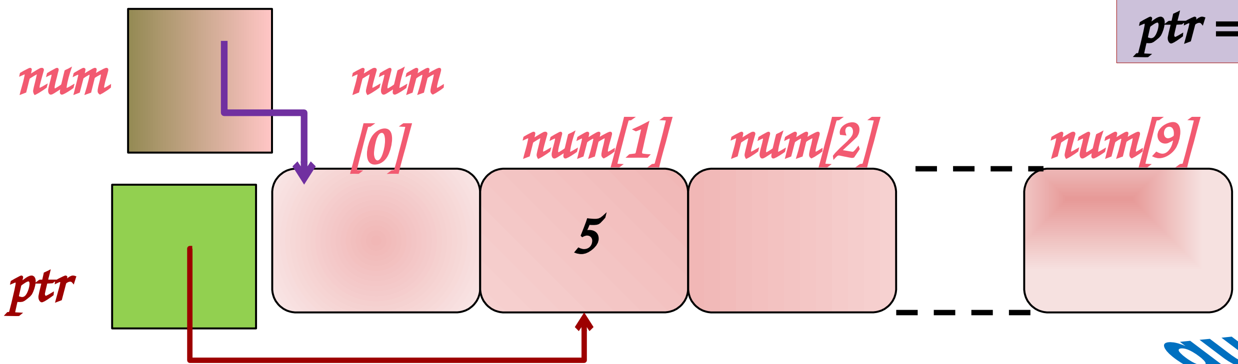


The statement c int *ptr; w box of type "address of an int box", more commonly referred to as, of type "pointer to integer".

The statement ptr = &num[1]; address of the box num[1]. Commonly referred to as: ptr now points to num[1].

The program fragment below results in this memory state.

```
int num[10];
int * ptr;
ptr = &num[1];
```



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1. *Yes! scanf("%d",ptr) reads input integer into the box pointed to by the corresponding argument.*
2. *The box pointed to by ptr is num[1].*
3. *So num[1] becomes 5.*

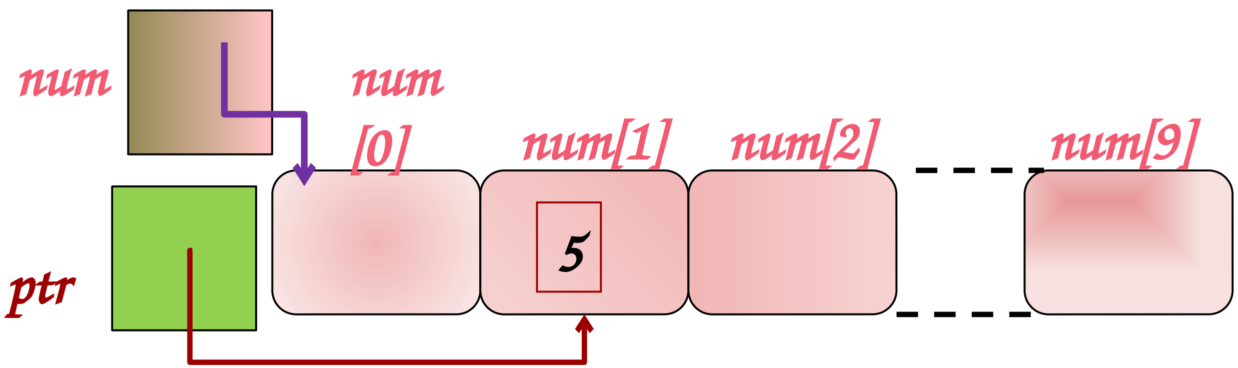
Suppose I now add the following statement after above fragment

```
scanf("%d",ptr);
```

Input

and input is : 5

Does num[1] become 5?

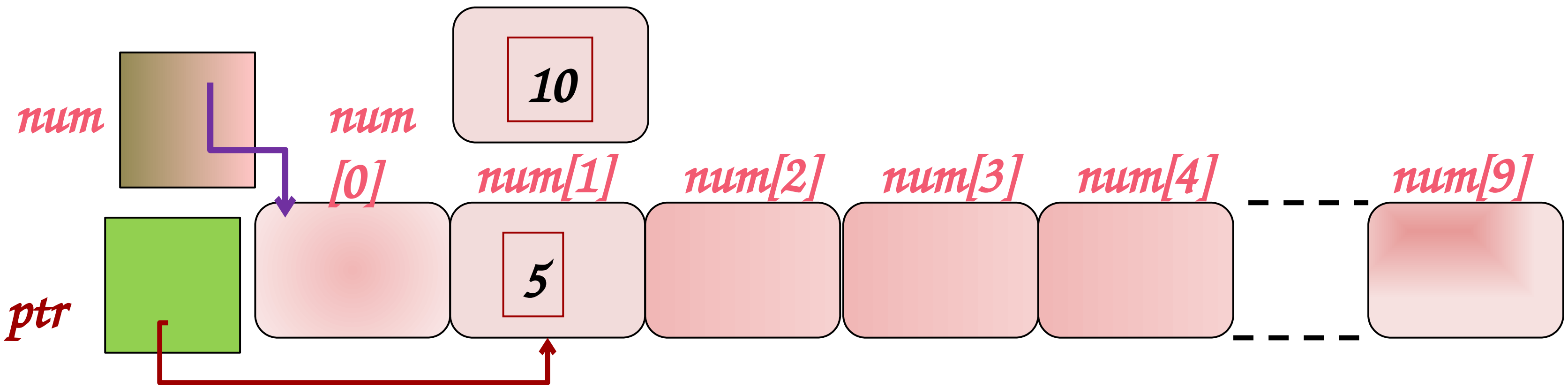


Well, what else can we do with ptr?

num is of type int [] (i.e., array of int). In C the box num stores the pointer to num[0]. Internally, C represents num and ptr in the same way. So the type int * can be used wherever int[] was used.

Here are the interesting parts! We can

1. de-reference the pointer.
2. do simple arithmetic + - with pointers.
3. compare pointers and test for ==, <, > etc., similar to ordinary integers.



De-referencing pointer ptr gives the box pointed to by ptr. The de-referencing operator in C is also *.

printf("%d", *ptr);

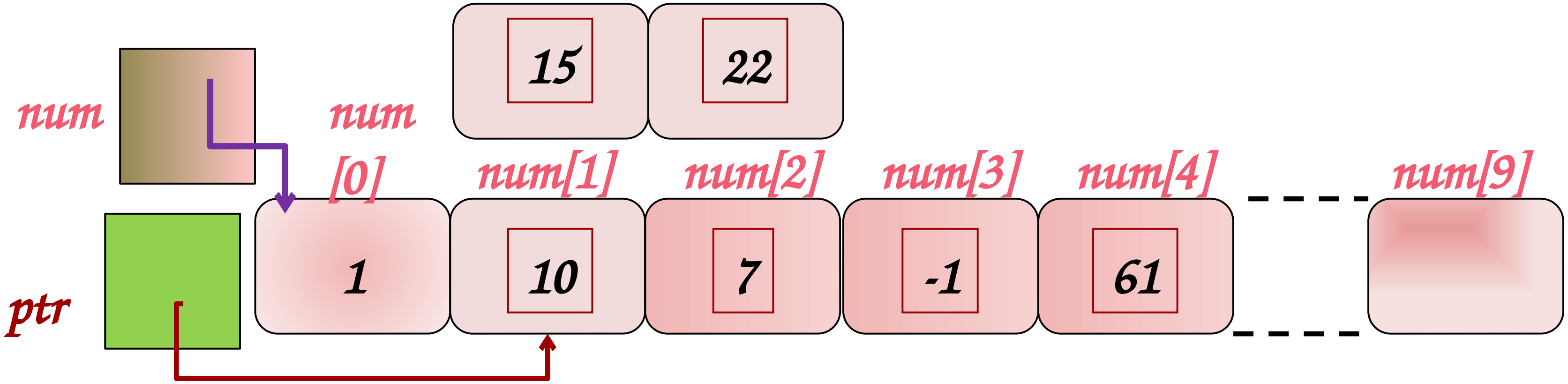
Output 5

Since ptr points to num[1], *ptr is the box num[1]. Printing it gives the output 5.

Consider statement

*ptr = *ptr + 5;

This will add 5 to the value in box pointed by ptr. So num[1] will become 5+5 = 10



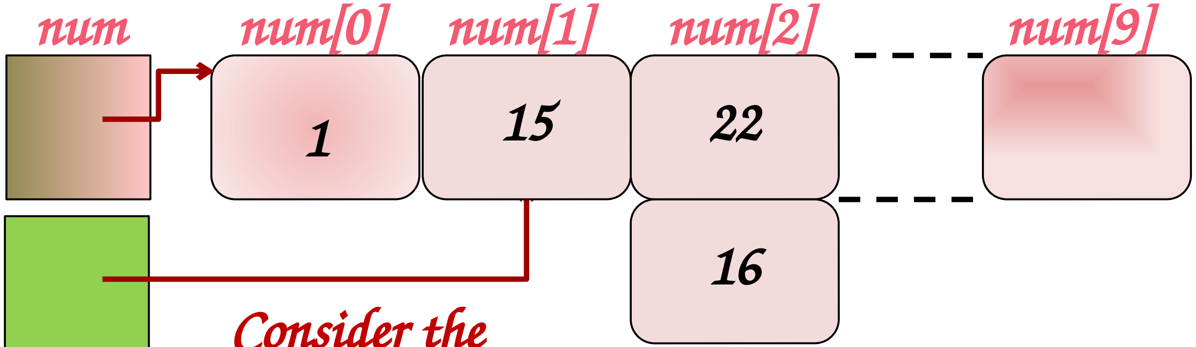
Recall rule about pointers:

*De-referencing a pointer **ptr** gives the box pointed to by **ptr**. The de-referencing operator in C is ***.***

Consider the statements. Execute them on above memory state.

```
*ptr = *ptr + 5;
num[2] = num[1]+num[2];
```

1. 1^{st} statement will add 5 to the value in box pointed by ptr. So *ptr becomes 10 + 5 = 15.
2. But *ptr and num[1] are the same box. So 2^{nd} statement assigns 15 + 7 equals 22 to num[2].



ptr

Consider the statement

num[2]= *num + *ptr;

Is it a legal statement?
What would be the result?

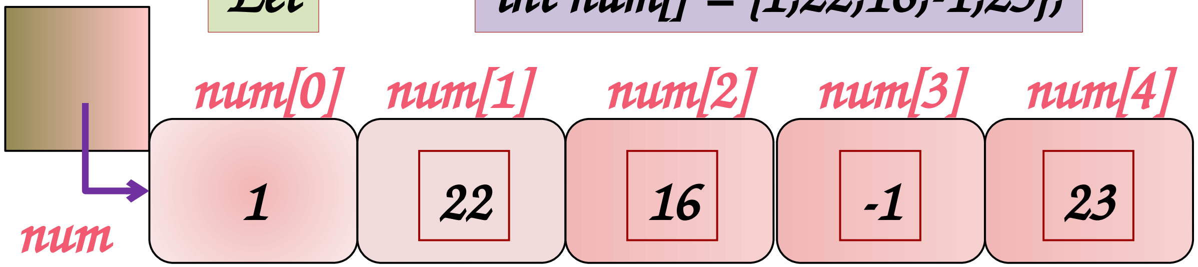
Its **legal** because

1. num can be thought to be of type int *, and, ptr is of type int *.
2. So *num is of type int, which is 1 and *ptr is of type int with value 15
3. So num[2] is set to 16.

Let's now do some pointer arithmetic.

Let

int num[] = {1,22,16,-1,23};



num+1 points to integer box just next to the integer box pointed to by num. Since arrays were consecutively allocated, it points to num[1].

So num+1 points to num[1]. Similarly, num+2 points to num[2], num + 3 points to num[3], and so on.

Can you tell me the output of this printf statement?

```
printf("%d %d %d", *(num+1),
        *(num+2),*(num+3));
```

Output would be

22 16 -1

Predict the output

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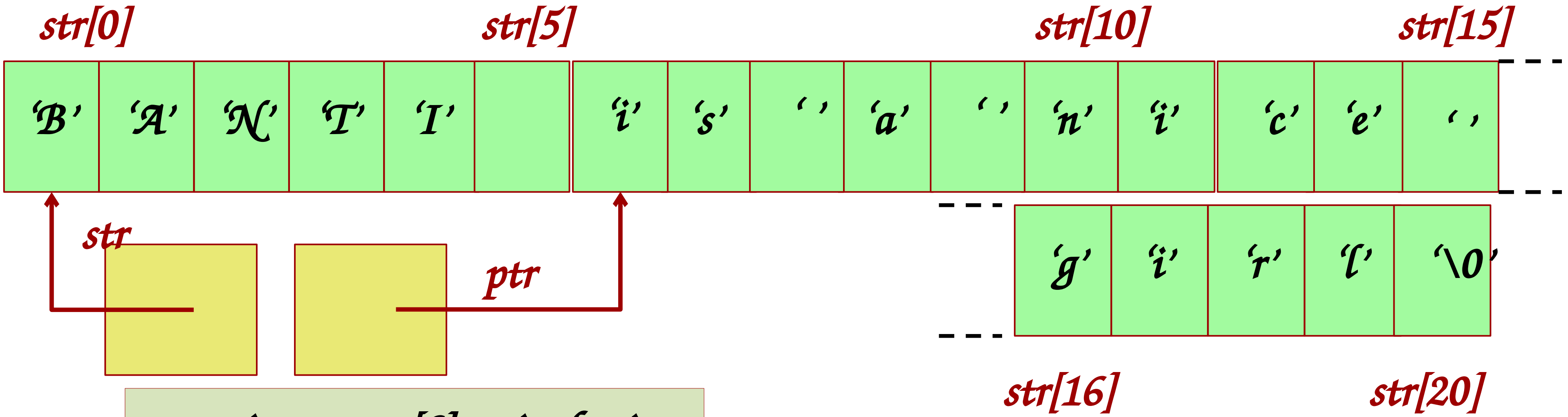
```
char str[] = "BANTI is a nice girl";
char *ptr = str + 6; /*initialize*/
printf("%s",ptr);
```

First let us draw the state of memory.



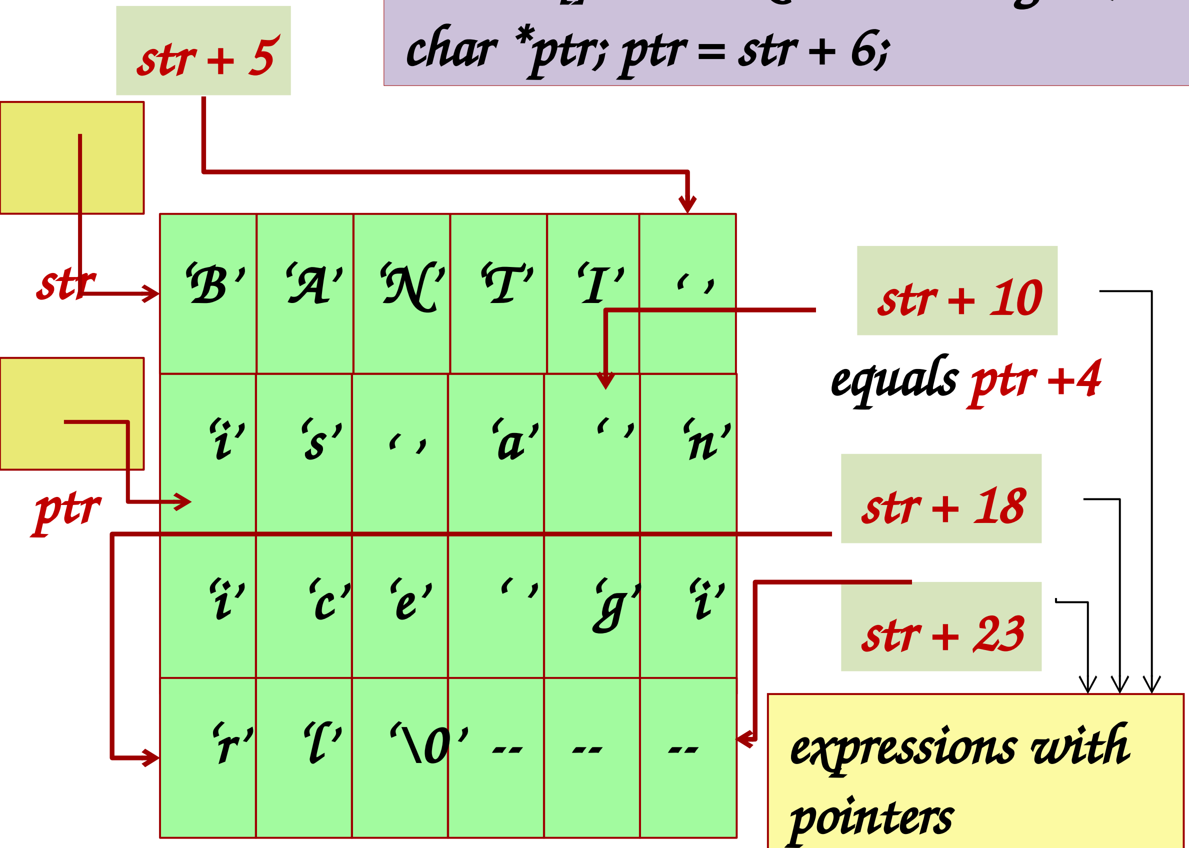
ptr points to str[6]. printf prints the string starting from str[6].

Output

is a nice girl

char array str[] was initialized as below.

```
char str[] = "BANTI is a nice girl";
char *ptr; ptr = str + 6;
```



*str is of type char *. So str + 6 points to the 6th character from the character pointed to by str. That is ptr.*

Here are some other pointer expressions.

Can you tell me the output of:

```
printf("%s",ptr-5);
```

```
char str[] = “BANTI is a nice girl”;
char *ptr; ptr = str + 6;
printf(“%s”,ptr-5);
```

str

ptr

‘B’	‘A’	‘N’	‘T’	‘I’	‘ ’
‘i’	‘s’	‘ ’	‘a’	‘ ’	‘n’
‘i’	‘c’	‘e’	‘ ’	‘g’	‘i’
‘r’	‘l’	‘\0’	--	--	--

ptr -5 should point to the 5th char backwards from the char pointed to by ptr. So ptr-5 points here

The string starting from this point is “ANTI is a nice girl”. That would be the output. Correct?

Output	ANTI is a nice girl

Yes, that’s correct

Pointers play an important role when used as parameters in function calls.

Let's start with the old example.

```
int main() {
   int a = 1, b = 2;
   swap(a,b);
   printf("From main");
   printf("a = %d",a);
   printf("b=%d\n",b);
}
```

```
void swap(int a, int b) {
      int t;
      t = a; a=b; b =t;
      printf("From swap");
      printf("a = %d",a);
      printf("b= %d\n",b);
}
```

The swap(int a, int b) function is intended to swap (exchange) the values of a and b.

But, the value of a and b do not change in main(), they are only swapped in swap().

OK, let's first trace the call to swap

```c
int main() {
   int a = 1, b = 2;
   swap(a,b);
   printf("From main");
   printf(" a = %d",a);
   printf("b = %d",b);
}
```

```c
void swap(int a, int b) {
      int t;
      t = a; a=b; b =t;
      printf("From swap ");
      printf("a= %d",a);
      printf("b= %d\n",b);
}
```

S T A C K

main(): a = 1, b = 2

swap(): return address = main.3, a = 2, b = 1, t = 1

Output:

From swap a= 2 b= 1

Now swap() returns:

1. Return address is line 3 of main(). Program counter is set to this location.
2. Stack for swap() is deleted.

```
int main() {
   int a = 1, b = 2;
   swap(a,b);
   printf("From main");
   printf(" a = %d",a);
   printf("b = %d",b);
}
```

```
void swap(int a, int b) {
      int t;
      t = a; a=b; b =t;
      printf("From swap ");
      printf("a = %d",a);
      printf("b = %d\n",b);
}
```

S
T
A
C

a: 1

b: 2

main()

Output:

From swap a = 2 b = 1

Returning back to main(),we resume execution from line 3.

But the variables a and b of main() are unchanged from what they were before the call to swap(). They are printed as is.

Changes made by swap() remained local to the variables of swap(). They did not propagate back to main().

```
int main() {
   int a = 1, b = 2;
   swap(a,b);
   printf("From main");
   printf(" a = %d",a);
   printf("b = %d",b);
}
```

```
void swap(int a, int b) {
      int t;
      t = a; a=b; b =t;
      printf("From swap ");
      printf("a = %d",a);
      printf("b = %d\n",b);
}
```

a 1

b 2

Output:

From swap a = 2 b = 1

From main a = 1 b = 2

1. Passing int/float/char as parameters does not allow passing "back" to calling function.
2. Any changes made to these variables are lost once the function returns.

Pointers will help us solve this problem!

Here is the changed program.

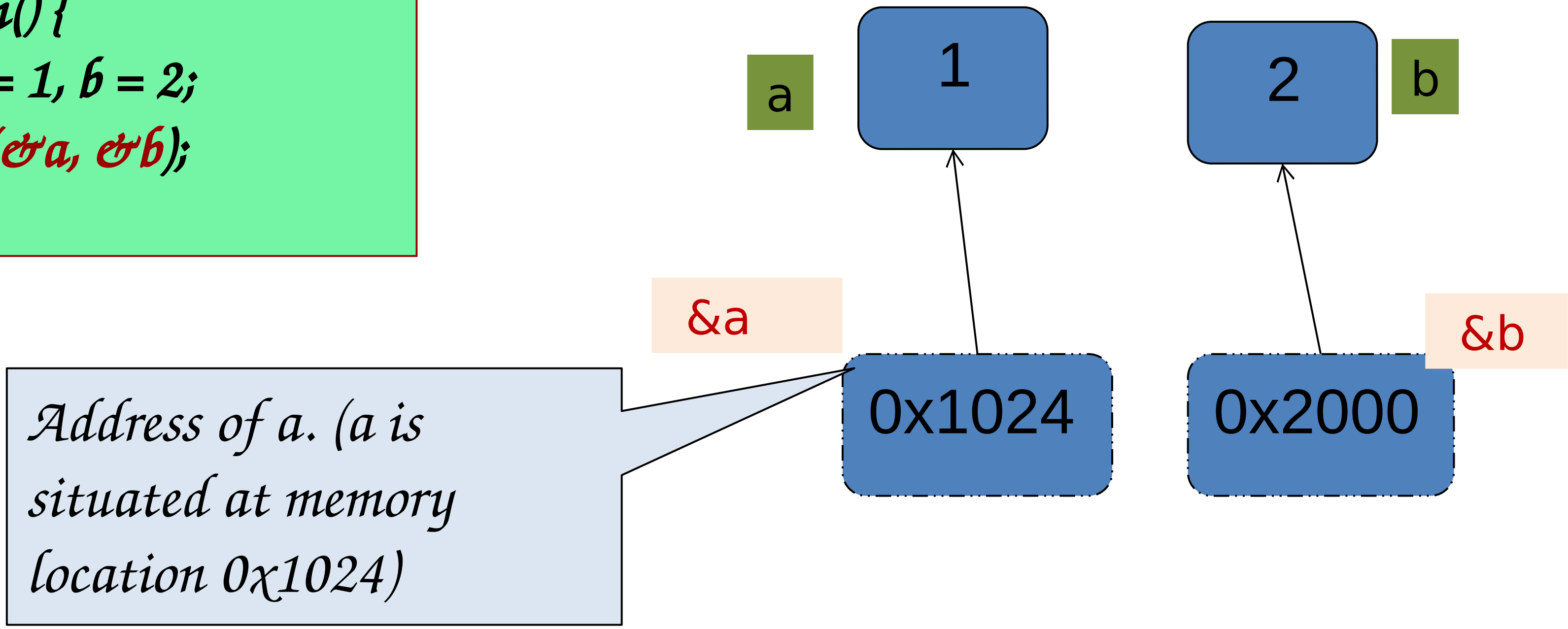
```
void
swap(int *ptra, int *ptrb)
{
    int t;
    t = *ptra;
    *ptra= *ptrb;
    *ptrb =t;
}
```

```
int main() {
   int a = 1, b = 2;
   swap(&a, &b);
   printf("a=%d, b=%d",
          a, b);
   return 0;
}
```

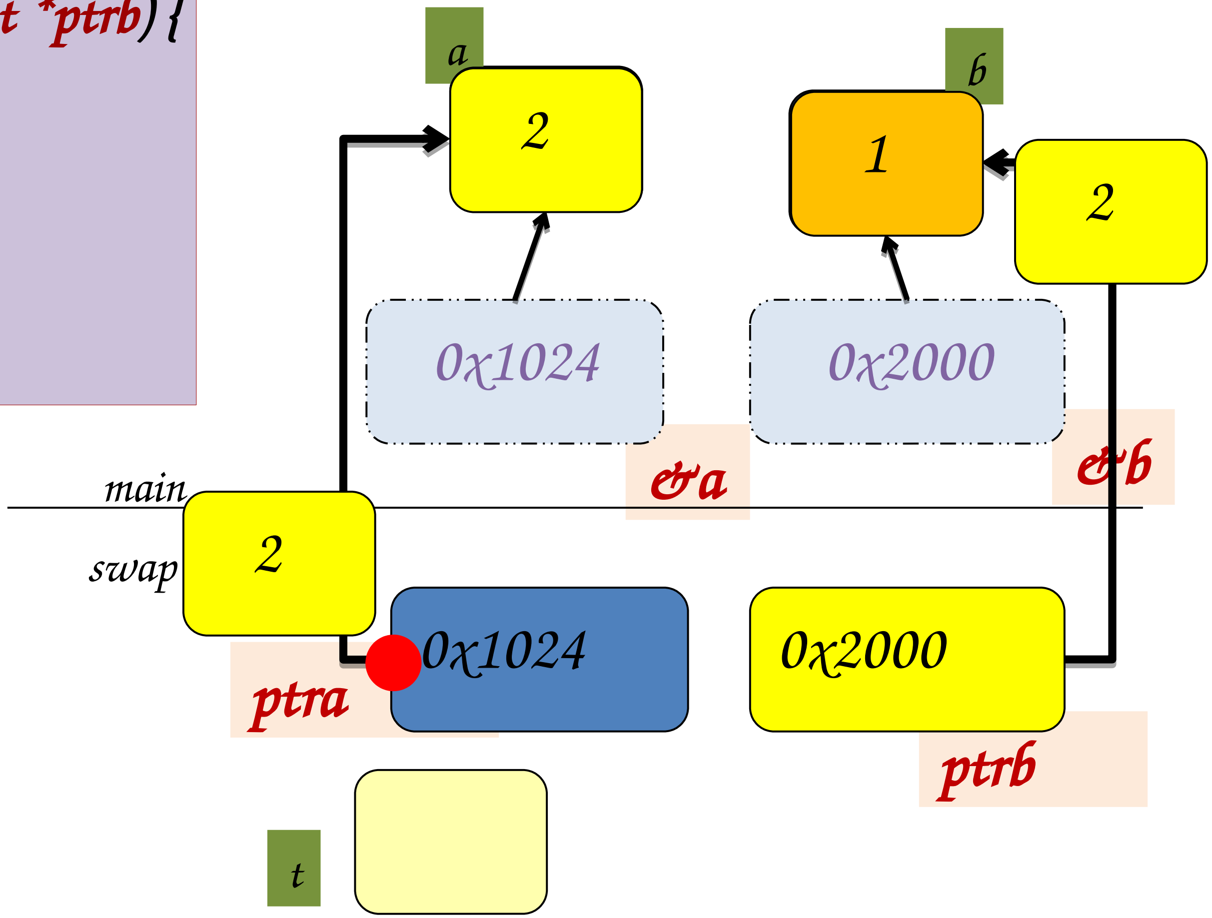
1. The function swap() uses pointer to integer arguments, int *ptra and int *ptrb.
2. The main() function calls swap(&a,&b), i.e., passes the addresses of the ints it wishes to swap.

Tracing the swap function

```
int main() {
  int a = 1, b = 2;
  swap(&a, &b);
}
```



```
void swap(int *ptra, int *ptrb) {
    int t;
    t = *ptra;
    *ptra= *ptrb;
    *ptrb =t;
}
```



Next Class

- Dynamic Memory Allocation