Piscine — Tutorial D3

version #v3.2.0

Assistant C/UNIX 2021 <assistants@tickets.assistants.epita.fr>

Contents

*https://intra.assistants.epita.fr

1 Arrays

An array is a group of elements *of the same type*. Each element is identified by an index specifying its position within the array.

1.1 Size type

You already know all the basic types in C. But other types are defined in headers that you can include in your code. For example, you can use the type `size_t` by adding the following line before your code:

```c
#include <stddef.h>
```

As you should know, the `int` type is limited. It has a maximal value[1]. The `size_t` type is always the same size as the type that controls memory addresses. Therefore, on our architecture (*x86_64*), it is twice as big as an `int`, which means the maximum value is much higher. Besides, it is unsigned (i.e. cannot be negative).

As its name suggests, `size_t` is designed to manipulate size values. It is a better choice than `int` when you want to manipulate array indices and sizes because you are sure that, even if your array spans across all your memory, the `size_t` type is big enough to contain the `index` of the last element.

The return value of the `sizeof` keyword is always a `size_t`.

1.2 One-dimensional arrays

1.2.1 Declaration

```c
type var_name[N];
```

With `N` being a positive integer setting the size of the array, which is the total number of items that can be stored in the array.

1.2.2 Initialization

```c
int arr[5] =
{
    3, 42, 51, 90, 34
};
```

Or, by specifying only the first few elements of the array:

```c
int arr[5] =
{
    1, 2, 3
};
```

[1] https://en.wikipedia.org/wiki/C_data_types#Basic_types

The two non-specified elements are then initialized to 0. Thus, it is possible to initialize an array entirely to 0 this way:

```
int arr[24] =
{
    0
};
```

It is also possible not to specify the size of an array, **only** if you initialize it during its declaration. The size will then be determined based on the number of values:

```
int arr[] =
{
    3, 42, 51, 90, 34
};
```

Here, `arr` is an array of size 5.

1.2.3 Accessing values

To access an element of an array, we use the bracket operator `[.]`:

```
arr[index]
```

- `index` can go from `0` to *N - 1* (`N` being the size of the array).
- `index` can, for example, be an arithmetic expression.

```
int arr[5] =
{
    1, 2, 3, 4, 5
};
int a = 0;

a = arr[2];          // OK
a = arr[3 + 1];      // OK
a = arr[4 + 1];      // Undefined behaviour
```

Going further...

The expression *undefined behaviour* means that this action (in this case, accessing a value out of range of an array) is not specified by the language, and therefore the compiler implements it arbitrarily. The execution may continue, potentially leaving your program in an erroneous state.

The bracket operator `[.]` is also used to assign a value in an array:

```
int arr[5] =
{
    1, 2, 3, 4, 5
};

arr[2] = 42;         // {1, 2, 42, 4, 5};
```

1.2.4 Predefined array sizes

You will often encounter a situation where you use an array's size at multiple places in your code. Here is an example:

```
size_t arr[5] = { 0 }; /* { 0, 0, 0, 0, 0 } */

for (size_t i = 0; i < 5; i++)
    arr[i] = i
```

Now imagine you want your array to be of a different size. You would have to change the size in the declaration, but also in the `for` loop. This is tedious, and it is relatively easy to forget to change the size everywhere it is used, especially when you are dealing with source files composed of a few hundreds or thousands lines of code.

The number `5` here is what we call a *magic value*: it has no name associated with it, and it is unclear what its purpose is. Such values make the code more difficult to understand and maintain, and you **want** your code to be understandable and maintainable (and it also helps assistants to be in a better mood when they try to help you). In order to avoid using magic numbers[2] like this that don't require a variable (because the array size is a constant here), you can use macros like this:

```
#define ARR_SIZE 5

size_t arr[ARR_SIZE] = { 0 };

for (size_t i = 0; i < ARR_SIZE; i++)
    arr[i] = i;
```

Finally, you should try to avoid defining macros like `ARR_SIZE` inside functions. A nice place to put macros like this is at the top of the file, below includes.

1.3 Matrix with a one-dimensional array

You will learn about multidimensional arrays in another section of this tutorial, however you have to know that it is possible to *emulate* them with a one-dimensional array.

Going further...

A matrix is simply a two-dimensional array.

The following matrix M:

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$$

can be represented by the following one-dimensional array:

```
int arr[6] =
{
    1, 2, 3, 4, 5, 6
};
```

[2] In case the value is a number, the term *magic number* can also be used.

A simple *formula* exists to convert two-dimensional coordinates in one-dimension coordinates (i.e. the index):

```
Index = Row * Width + Column
```

For example, if we wanted to get the index of '6', which is located on the second row and the third column:

Be careful!

Arrays are zero-indexed, so all matrix coordinates have to be decremented by one. As such, if we want the value at M_{23}, we have:

```
Row = (2 - 1)
Column = (3 - 1)
```

```
Index = 1 * 3 + 2
Index = 5
```

And `arr[5] == 6`.

We have just shown you how to emulate a two-dimensional array with a one-dimensional array, but it is also possible to emulate dimensions higher than two although the formula to access elements inside it will be different.

1.4 Determining size

You can use the C keyword `sizeof` with an array to get the size of the array. However, be careful. It works in the same scope as the array declaration, but, if the array was, for example, given as parameter of a function, `sizeof` inside the scope of the function would not work because the array was cast to a *pointer* and `sizeof` returns the size of the pointer type. You will see pointers in depth later, so just keep in mind that `sizeof` works with arrays but only in the scope of the array declaration.

Here are some examples. Note that it only works with statically declared arrays.

Going further...

The *const* keyword in C is a reserved keyword, part of the type declaration and used to declare constants, e.g. non-alterable-after-declaration data.

```c
const int vec[] = {1, 2, 3, 4, 5};
sizeof(vec);                /* 20 */
sizeof(int);                /* 4  */
sizeof(vec) / sizeof(int);  /* 5  */
sizeof(vec) / sizeof(vec[0]) /* 5  */
```

The last example shows you how to get a static array's size in a way that is type agnostic[3].

[3] Meaning you, the programmer, do not need to know the type of the elements contained in the array to know the number of elements. You could change the type of the elements in the array without changing this line to get the correct size!

1.5 Exercises

1.5.1 Max array

Write a function that returns the maximum value of an array of integers given as argument. If the array is empty you should return INT_MIN. The size of the array will always be correct.

```
int max_array(const int array[], size_t size)
```

2 Array vice max

Write a function that returns the vice-maximum (the *second* largest value) of an array of integers given as argument. Assume that the vector always contains at least two elements, that its size will always be correct and that all elements will have a different value.

Prototype:

```
int array_vice_max(const int vec[], size_t size);
```

3 Strings

A string is an ordered sequence of characters.

In C, there is no built-in type to represent strings. So, in order to represent this kind of data, we use a **character array** (`char[]`) that ends with '*\0*', a special character symbolizing the end of the string. There are many special characters including:

`\n`	line break
`\t`	tabulation
`\0`	end of string character, equals 0
`\\`	to write \
`\"`	double quote
`'`	single quote '

Let's see with a basic example:

```
#include <stdio.h>

int main(void)
{
    char s[] =
    {
        't', 'e', 's', 't', '\0'
    };
    puts(s);
    return 0;
}
```

We can easily see that writing strings in this form is not practical at all. Fortunately for us, the C language provides a simple way to write strings: **string literals** (or *constant strings*).

The following example is semantically identical to the one above, and the terminating character (*'\0'*) is automatically added at the end of string:

```
#include <stdio.h>

int main(void)
{
    char s[] = "test";

    puts(s);
    return 0;
}
```

Another advantage of string literals: they can be passed directly to functions taking `char[]` as arguments!

```
#include <stdio.h>

int main(void)
{
    puts("test");
    return 0;
}
```

Going further...

You may have noticed by reading the man of `puts(3)` that the prototype of this function indicates that the argument is *const char *s*. Do not worry about this at the moment, it is exactly the same as *const char s[]* when passing arguments.

Another example with `const`:

```
char str1[19] = "The cake is a lie.";
char str2[]   = "The cake is a lie.";
const char str3[] = "The cake is a lie.";

str1[14] = 'p'; // OK
str2[14] = 'p'; // OK
str3[14] = 'p'; // Compilation error
```

Finally, the length of a string is the number of characters before `\0`. Please notice that it is different from `sizeof(string)`, which returns the number of bytes used by the array, including the `\0`.

```
char str1[] = "Portable";
char str2[] = "Por\0table";
```

Try to print these two strings with `puts`. You will see that the first string has 8 characters while the second one has only 3 characters.

Be careful, string literals are null-terminated (`\0` added automaticaly at the end), but arrays declared with braces are not.

Also, you cannot always provide a string literal to a function like:

```
foo("bar");
```

The string `bar` cannot be modified, if the `foo` function tries to change it, the program will crash. If you need to modify the string, declare it:

```
char str[] = "bar";
foo(str);
```

Tips

Again, this part refers to the notion of `pointers` that will be introduced in the very next section. Don't hesitate to read this part again *after* reading the section on pointers. For now, just keep in mind that the following function declarations are equivalent:

```
void foo(char arr[]);
void foo(char *arr);
```

Thus:

```
#include <stdio.h>

void foo(char *str)
{
    str[0] = 'p';
}

int main(void)
{
    char str[] = "toto";
    printf("%s\n", str);    // "toto"
    foo(str);
    printf("%s\n", str);    // "poto"
}
```

However note that when declaring the string literal like this:

```
char *str = "toto";
```

The string is **read-only**, thus you cannot modify its content.

3.1 Exercises

3.1.1 My strlen

Prototype:

```
size_t my_strlen(const char *s);
```

Behavior:

This function must have the same behavior as the `strlen` function described in the third section of the man. Your code will not be tested with NULL pointers.

4 My strlowcase

4.1 Prototype:

```
void my_strlowcase(char *str);
```

4.2 Behavior:

This function changes all upper case ASCII letters into lower case. *NULL* pointer will not be tested.

```
#include <stdio.h>
#include "my_strlowcase.h"

int main(void)
{
  char str[] = "azerty1234XYZ &(";
  my_strlowcase(str);
  printf("%s\n", str);
  return 0;
}
```

```
42sh$ ./my_strlowcase | cat -e
azerty1234xyz &($
```

5 Pointers

5.1 Introduction

Be careful!

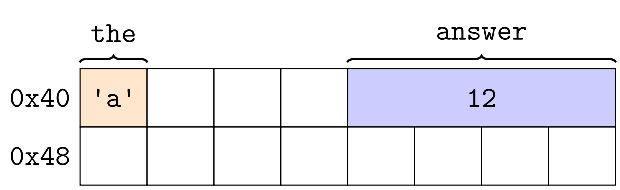
Pointers are a fundamental concept, pay extra attention!

Every variable used in your program needs to be present in your computer's memory somewhere in order to be accessed. By knowing a variable's type and its address you can access your memory to look-up the current value of your variable.

Tips

All the addresses written in the examples are arbitrarily chosen.

```
char the = 'a'; /* address: 0x40 */
int answer = 12; /* address: 0x44 */
```



Tips

`the` and `answer` do not take the same amount of space in memory, because they are different types of different size. On the PIE an `int` takes four bytes, and `char` takes one byte of memory to be stored.

This memory-address and type combo is called a pointer. The type associated to an address is needed to make sense of the value located at that address.

A pointer is an address associated with a type. Here, `0x40` and `char` allows us to create the pointer to `the`.

You can write out a pointer type like so: `<pointed type>*`. For example `int*` is a pointer to int type.

Tips

The * indicates that we are adding a level of indirection to access an `int`.

You can hold a pointer inside a variable, which introduces the following syntax for such a variable declaration: `<pointed type> *<var name>;`.

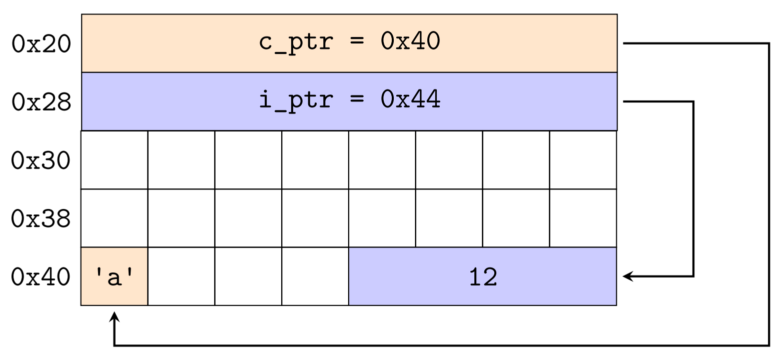
```
char *c_ptr;
int *i_ptr;
```

Here we declared a variable named `c_ptr` whose type is `pointer to char`, and `i_ptr` whose type is `pointer to int`.

Like any other variable, you can assign a value to your pointer. To do so, you just need an address to assign to your variable with the correct associated type. We can use those variables to point to `the` and `answer` respectively.

`<type> *<variable> = <address>`.

```
char *c_ptr = 0x40; /* Address: 0x20, value 0x40 */
int *i_ptr = 0x44; /* Address: 0x28, value 0x44 */
```



Tips

As you can see on the above diagram, pointer variables take space in memory too, which makes sense because they are variables. Because pointers are also a type, they have a size. On the PIE it turns out that pointer variables take eight bytes of memory space.

Be careful!

Because memory addresses are not guaranteed to stay the same, you should never hard-code them directly into your code. We're only showing you this for the example.

5.2 Variable address

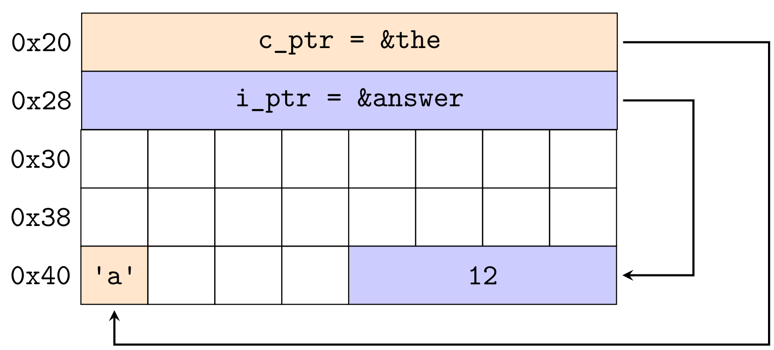
Where can we find an address to assign to a pointer? As you just saw, any variable in your program lives somewhere in the computer's memory. You can, therefore, use its address for your pointer.

To get the address of a variable, we need to use the operator &. For example, getting the address of our variable answer would return 0x44.

```
&the; /* 0x40 pointing to char */
&answer; /* 0x44 pointing to int */
```

Now that we know the basics of pointers and how to get a variable's address, we can initialize a pointer variable with another variable's address:

```
c_ptr = &the;
i_ptr = &answer;
```



Tips

You will see other ways to get valid memory addresses to point to later.

5.3 Dereferencing

Pointers allow us to manipulate memory. At some point we need access to the value at this address: this is called **dereferencing**.

The dereferencing syntax is *<pointer>.

Be careful!

Be careful, do not mistake *ptr; (dereferencing) for a pointer declaration like int *ptr;

```
int foo = *i_ptr; /* Address 0x48 , value 12 */
foo += 1; /* foo: value to 13, answer: value to 12 (unchanged) */
*i_ptr += 2; /* foo and i_ptr values do not change, answer: value changes to 14 */
```

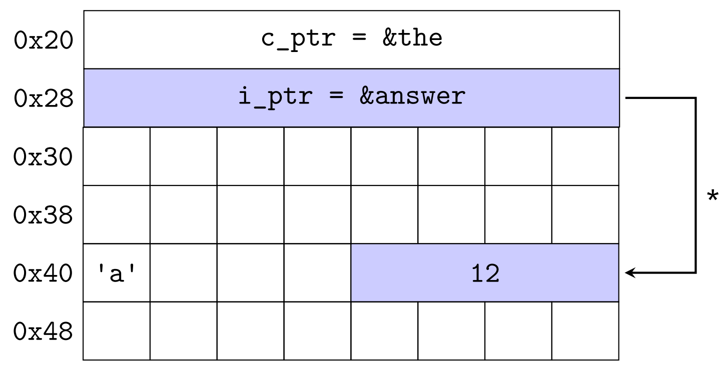


Fig. 1: `i_ptr` is dereferenced, accessing the value at address `0x44`

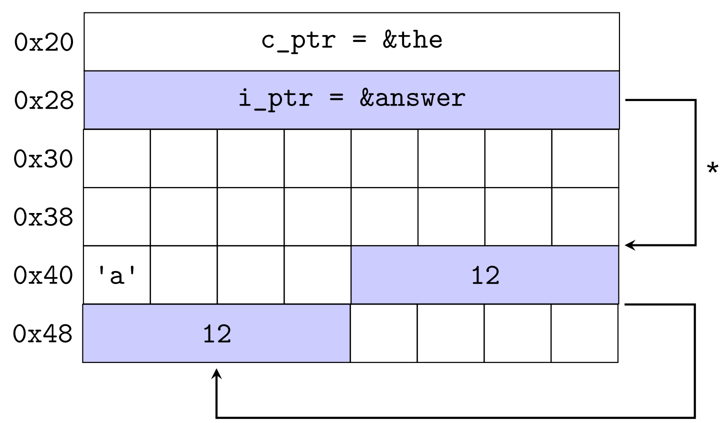


Fig. 2: The value at `0x44` is copied in `foo`, at `0x48`

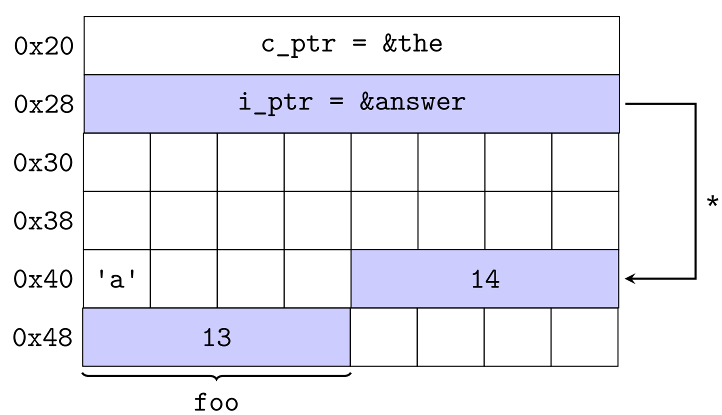


Fig. 3: `foo` and `*i_ptr` are different values

5.3.1 Get int value

Write a function that takes a pointer to an `int` as parameter and returns its value. You don't have to handle the case where the pointer is `NULL`.

```
int get_int_value(int *n)
```

5.4 Variable address & dereferencing: Practical example

Please compile the following pieces of code without the `-pedantic` flag. Otherwise, you would get a warning when printing `&x`. Be careful, this is for illustrative purposes only, you won't ever need to print `&x` again. Don't forget to compile with the `-pedantic` flag in other situations. What does the following code print?

```
#include <stdio.h>

int main(void)
{
    int x = 42;
    printf("%d\n", x);  /* show the value of x */
    printf("%p\n", &x); /* show the address of x */
    return 0;
}
```

Here, `&x` corresponds to the address of the `x` variable, instead of its value it returns a pointer to the variable (notice the `%p` in `printf(3)`).

```
#include <stdio.h>

int main(void)
{
    int x = 42;
    int *ptr_x = &x;
    printf("%d\n", x);      /* shows the value of x */
    printf("%p\n", &x);     /* shows the address of x */
    printf("%p\n", ptr_x);  /* shows the value of ptr_x (which is the address of x) */
    printf("%d\n", *ptr_x); /* shows the value of what ptr_x points to: x */
    return 0;
}
```

`int*` is a pointer to an integer and here we call it `ptr_x`. The `ptr_x` pointer is then set to point to the address of `x` which is `&x`. Calling a pointer with the `*` **dereferences** the pointer and accesses the pointed value. Indeed, `*ptr_x` returns the value that the address `&x` points to, instead of the numerical value of the address.

5.5 Passed by copy

In C, variables are passed **by copy**. This means that the parameters will be **copied** for the function, and therefore will have a different address. Here is an example:

```
void do_the_magic(int i, int j)
{
    /* i ->            Value:   42      Address: Somewhere else in the memory */
    /* j ->            Value:   51      Address: Somewhere else in the memory */
    i = 12;
    j = 27;

    printf("i: %d, j: %d\n", i, j); // Prints "i: 12, j: 27"
}

int main(void)
{
    int foo = 42;  /* Value:   42      Address: 0x52 */
    int bar = 51;  /* Value:   51      Address: 0x35 */

    printf("foo: %d, bar: %d\n", foo, bar); // Prints "foo: 42, bar 51"
    do_the_magic(foo, bar);
    printf("foo: %d, bar: %d\n", foo, bar); // Prints "foo: 42, bar 51"

    return 0;
}
```

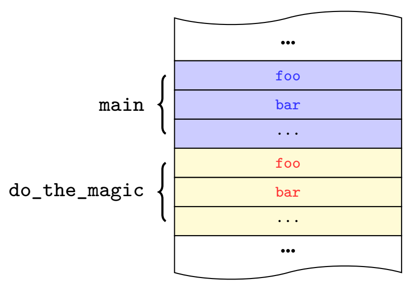


Fig. 4: Local copies are modified.

Because we are passing them by copy, `i` and `j` inside `do_the_magic` do not have the same address as `foo` and `bar`. But we *want* to reference the *same address*, therefore we need to provide their address to the function: by using pointers instead.

```
void do_the_magic(int *i, int *j)
{
    /* *i ->            Value:   42      Address: 0x52                        */
    /* *j ->            Value:   51      Address: 0x35                        */
    /* i  ->            Value:   0x52    Address: Somewhere else in the memory */
    /* j  ->            Value:   0x35    Address: Somewhere else in the memory */
    *i = 12;
    *j = 27;
    printf("*i: %d, *j: %d\n", *i, *j); // Prints "*i: 12, *j: 27"
}
```

(continues on next page)

(continued from previous page)

```
int main(void)
{
    int foo = 42;  /* Value:   42      Address: 0x52 */
    int bar = 51;  /* Value:   51      Address: 0x35 */

    printf("foo: %d, bar: %d\n", foo, bar); // Prints "foo: 42, bar 51"
    do_the_magic(&foo, &bar);
    printf("foo: %d, bar: %d\n", foo, bar); // Prints "foo: 12, bar 27"

    return 0;
}
```

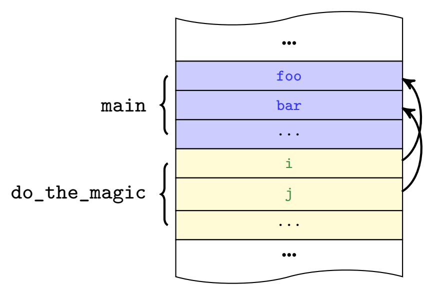


Fig. 5: Have pointers to `foo` and `bar` variables to modify their values in the `main` context.

Be careful!

When writing `int *i`, we are declaring a variable named `i` of type `int *`; when writing `*i`, we are dereferencing the variable `i`.

Here `foo` and `bar` are passed by address.

5.5.1 Practical example

```
void ineffective_swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}

int main(void)
{
    int a = 42;
    int b = 51;

    ineffective_swap(a, b);                 /* No effect. */
    printf("%d %d\n", a, b);   /* 42 51 */
    return 0;
}
```

This `ineffective_swap` function has no effect because the arguments are passed **by copy**.

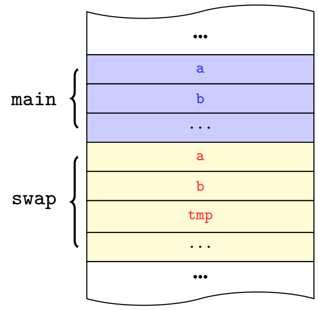


Fig. 6: Local copies are swapped.

Here, pointers offer us a solution:

```
void swap(int *pa, int *pb)
{
    int tmp = *pa;
    *pa = *pb;
    *pb = tmp;
}

int main(void)
{
    int a = 42;
    int b = 51;

    swap(&a, &b);             /* a's value and b's value are switched! */
    printf("%d %d\n", a, b); /* 51 42 */
    return 0;
}
```

The two arguments of `swap` are again passed by copy, but this time, the copied values are two pointers to integers (`int*`), not integers (`int`). Then in the `swap` function, we *dereference* those pointers to modify the value at the memory location they point to. In the above example, those two pointers contains the memory addresses of the `a` and `b` variable declared in the `main` function, so the `swap` function will effectively swap the values of `a` and `b`.

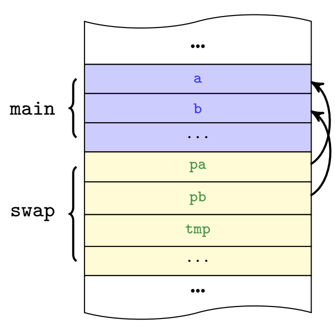


Fig. 7: Have pointers to `a` and `b` variables to swap their values in the `main` context.

5.6 NULL

The following code:

```
int *foo; /* not initialized */
int bar = *foo;
```

Is **undefined behavior**, meaning the C Language Specification has not specified any particular behavior when dereferencing a pointer variable that was initialized without a value (just like any variable). Thus, you should always initialize it either with a valid address:

```
int bar = 42;
int *foo = &bar;
```

Or the `NULL` macro:

```
int *foo = NULL;
```

You cannot dereference a `NULL` pointer, or you will have a **segmentation fault**:

```
int *foo = NULL;
int bar = *foo; /* segfault */
```

> **Tips**
>
> A segmentation fault is a specific type of error where you try to access some memory which you do not have access to.

The `NULL` macro usually corresponds to `0x0` the first address in your memory space, and thus it evaluates to `false`:

```
int *foo = NULL;

if (!foo)
    printf("Foo is NULL.\n");
else
    printf("Foo is not NULL.\n");

/* Will print "Foo is NULL.\n". */
```

> **Tips**
>
> When we say you should always initialize your pointers, it means you **must** always initialize your pointers. If you dereference a pointer that was not initialized, the outcome is *undefined*. It may work, it may not work, or it may segfault. That random behaviour will definitely not help during debugging (it is way easier to debug a guaranteed segfault, rather than a random segfault).

5.7 Array notation & pointer arithmetic

We have seen before that we cannot predict the memory location of a variable in advance. However, we can make an assumption with arrays: all elements are contiguous in memory.

```
int arr[] = { 12, 27, 42, 51 };
// the array is stored between 0x50 and 0x60
```

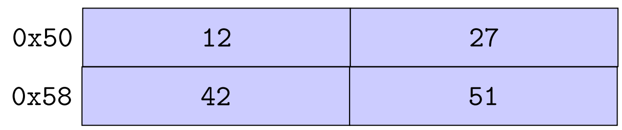


Fig. 8: The array is contiguous in memory, starting at 0x50

To access an element of an array, you use the `[<index>]` operator, the first element being at index 0, the second at index 1, etc...

If `arr[0]` is located at `0x50` then, `arr[1]` would be at `0x54`, and `arr[2]` at `0x58` (remember that an int is four bytes long). This is the reason why an array can only contain elements of a single type. By knowing the array elements' type we know their size and how to access them at any index in the array.

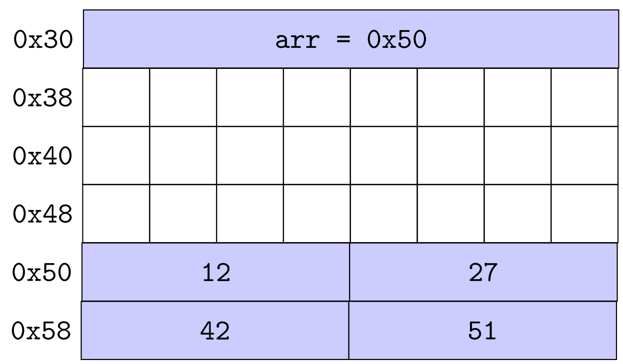


Fig. 9: `arr` contains the address of the first value of the array, `0x50`

```
i_ptr = arr;       /* i_ptr = arr = 0x50 */
arr[0] == i_ptr[0]; /* true */
&arr[0] == &i_ptr[0]; /* true */
```

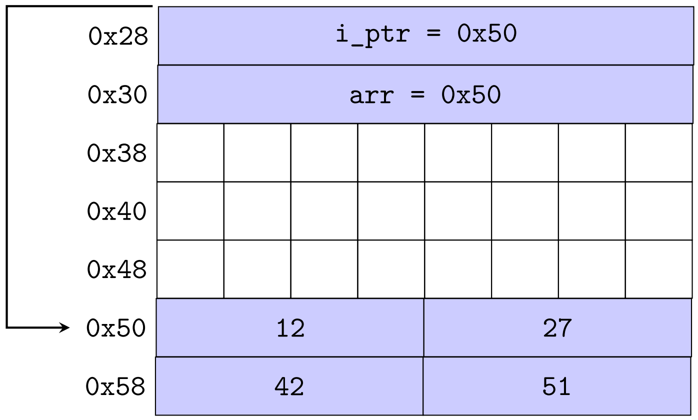


Fig. 10: `i_ptr` is now pointing to `0x50`

Note from the above code that pointers can be manipulated like an array whose first element is at the address being pointed to. Indeed they contain the same information, namely an address associated with a type (giving us the starting element, and the size of each element).

The reason we need the type of an array's elements is that when trying to access the n-th element of that array, we need to know at which offset in memory it is from the first element of the array to retrieve the queried value.

Arrays being contiguous in memory, they allow an easier manipulation of the memory by grouping its elements in one group, making them easy to index in relation to one-another.

```
i_ptr = arr + 1;
arr[1] == *i_ptr; /* true */
&arr[1] == i_ptr; /* true */
```

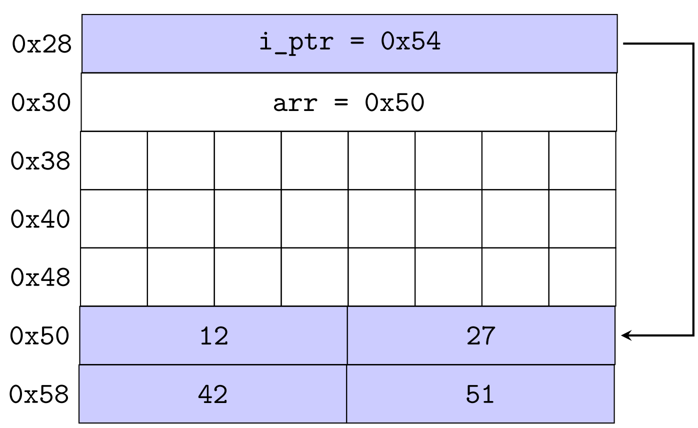


Fig. 11: `i_ptr` is now pointing to `0x54`

The operation `arr + 1` tries to compute the memory address corresponding to the element that comes right after `arr`'s beginning (i.e: its second element). The `+i` means you want to access the i-th element of the array. To do so, we first calculate the address of that element by using its size and the array's starting point, we can offset the address of the first element by `i * <size of an element>`, getting the address of the i-th element. At that point we can access the memory containing that element and manipulate its value.

So basically, just like you can use pointers to access elements of a type in memory, you can use array notation to do the same operation. The pointer notation (using `*`) and array notation with brackets (`[0]`) are mutually interchangeable.

Going further...

So, when using `a[i]` you are doing the same operation as when you write `*(a + i)` (which is also perfectly valid). However, using the array notation usually makes your code easier to read and reason about.

This also means that an array, when passed as arguments to a function, is not copied, only the pointer to its first element is copied. Thus every modifications done to the array in the function will persist.

Here are some examples:

```c
void array_modifier(int *arr)
{
    arr[0] = 14;
    arr[1] = 15;
}

// After a call to `array_modifier` the elements will still be modified
```

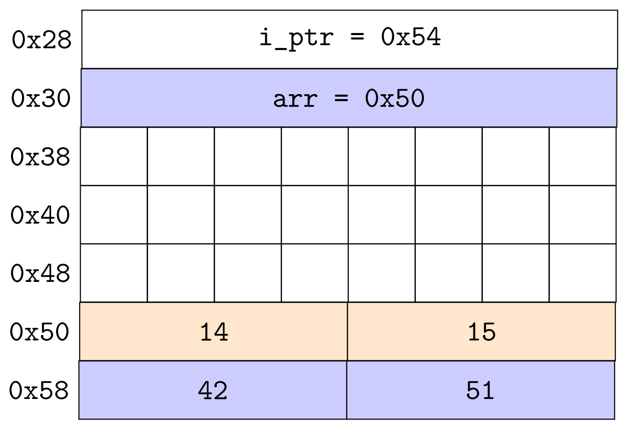


Fig. 12: Values at `0x50` and `0x54` are changed to `14` and `15` respectively

Going further...

You can also substract two pointers of the same type, resulting in the number of elements of the type being pointed to between those two addresses.

```c
&(arr[3]) - &(arr[0]); // The result is 3
```

5.8 Application

Now that we know more about pointers, strings, and the `NULL` macro, we can reimplement some known functions. Earlier today, you learned about the `strlen(3)` function which allows you to get the length of a given string.

```c
#include <stddef.h>

size_t my_strlen(const char *str)
{
    if (!str)
        return 0;

    size_t i = 0;

    while (str[i] != '\0')
        ++i;

    return i;
}
```

The `while`'s condition is made of two parts:

1. We test that `str` is `true`, i.e. it is not a `NULL` pointer. Otherwise we return 0.
2. We check that we have not yet reached the null-terminating character `\0` at the index `i`.

6 Array extremas

6.1 Goal

Write a function that takes an array of integer and its length, along with two pointers and set the value of the two pointers to the maximum and minimum of the array.

If `tab` is `NULL` or `len` is equal to 0, the function does nothing.

Prototype:

```c
void array_max_min(int tab[], size_t len, int *max, int *min)
```

6.2 Example

```c
int main(void)
{
    int max = 0;
    int min = 0;
    int tab[] = { 5, 3, 1, 42, 53, 3, 47 };
    size_t len = 7;
    array_max_min(tab, len, &max, &min);
    printf("max : %d\n", max);
```

(continues on next page)

(continued from previous page)

```
    printf("min : %d\n", min);

    return 0;
}
```

Output:

```
42sh$ ./array_max_min
max : 53
min : 1
```

7 The `main` function

The `main` function is the first function to be executed when a C program is launched: this function is called the entry point of the program. Every C program must contain a single `main` function.

You already learnt the `main` function prototype when no arguments are to be passed to the program:

```
int main(void)
```

However, if arguments are to be passed to the program, the prototype of the `main` function will be as follows:

```
int main(int argc, char *argv[])
```

`argc` contains the number of arguments given to the program, plus one (because **the first argument is the program's name**), and `argv` is an array of strings. Here is an example of passing arguments to a program:

Tips

Since you have seen pointers, you should not be surprised if you ever encounter `argv` being declared as `char **argv`.

```
42sh$ ./path/to/my_prog toto titi tata
```

In the above example, `argc` will have the value 4 and `argv` will contain:

- argv[0] = `"./path/to/my_prog"`
- argv[1] = `"toto"`
- argv[2] = `"titi"`
- argv[3] = `"tata"`
- argv[4] = `NULL`

Tips

`argv` is always `NULL` terminated, meaning `argv[argc]` is **always** `NULL`.

7.1 Exercises

7.1.1 Print arguments

Files to submit:

- print_arguments/print_arguments.c

Authorized functions: You are only allowed to use the following functions:

- puts(3)

Write a program using `puts`(3) that displays all the arguments in `argv`, except `argv[0]`.

```
42sh$ ./print_arguments | cat -e
42sh$ ./print_arguments Epita my new home | cat -e
Epita$
my$
new$
home$
42sh$
```

8 Multi dimensional array

We will take two-dimensional arrays as an example, which are arrays of arrays, but you might as well have *N*-dimensional arrays.

8.1 Declaration

You can declare two-dimensional arrays this way:

```
type var[A][B];
```

`var` is an array of size `A` containing arrays of size `B`. The first dimension is of size `A` and the second of size `B`. Arrays of the last dimension contain `B` elements of type `type`.

Tips

If it helps, you can see a two-dimensional array as a matrix.

8.2 Initialization during declaration

```
int arr[2][3] =
{
    {1, 2, 3},
    {4, 5, 6}
};
```

The dimension of the **external array** can be omitted:

```
int arr[][3] =
{
    {1, 2, 3},
    {4, 5, 6}
};
```

The size is deduced by the compiler.

8.3 Accessing values

```
arr[i][j]
```

For instance, in the previous example *arr[0][2]* is *3* and *arr[1][2]* is *6*.

Tips

For a matrix, previous examples would refer to the first row, third column and second row, third column. Do not forget that, in `C`, the index starts from `0`!

The only way out is through