# C Pointers

## An Advanced Introduction to Unix/C Programming


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# Pointer Advantages

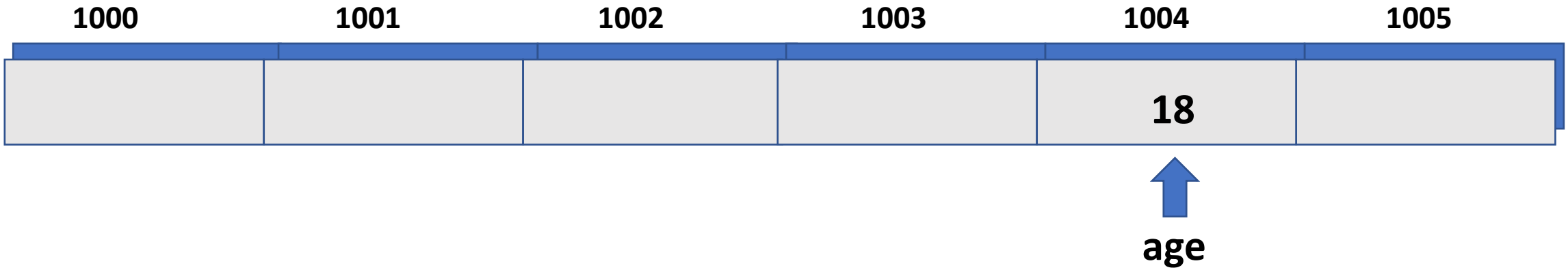
- Pointers are important!
- Pointers can reduce the size of and increase the execution speed of a program.
- Pointers allow you to allocate/deallocate memory while the program is running.
- Pointers allow you to save memory by passing only the address of an object instead of copying all of the data contained in the object.
- There is a closer association between pointers and the underlying hardware. In many engineering applications, low-level hardware interactions should be as close as possible.

# Pointer Disadvantages

- Pointers add complexity to the code.
- Segmentation violations will occur if pointers are not initialized.
- Using pointers set to the wrong location can cause crazy, hard to debug problems and corrupt memory.
- Memory leaks may occur if memory is constantly being allocated, but never freed.  If left unchecked, you'll run out of memory and program will crash.
- It's your responsibility to set pointers carefully and manage allocated memory.

# Pointers

**int age = 18;**

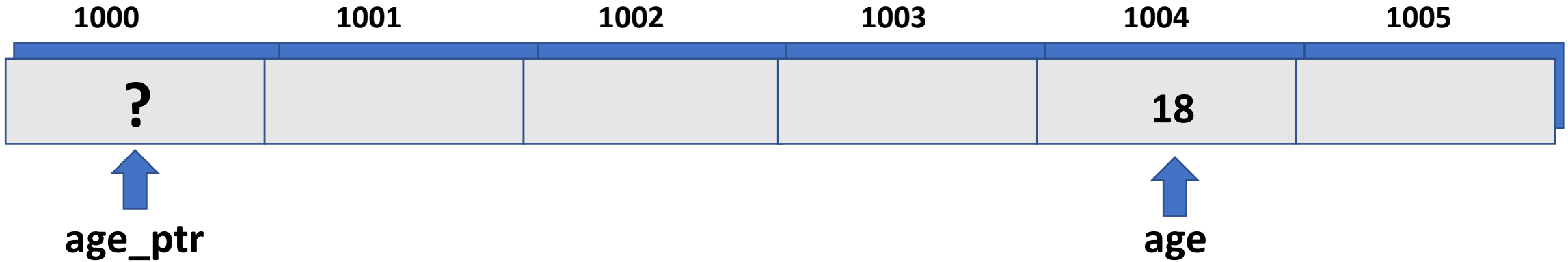



- When you declare a variable, like “int age;”, the compiler allocates memory for the variable with a unique address to store the variable. You don’t know, nor need to know, the variable’s actual address.
- The compiler associates the memory address with the variable’s name.
- When the variable is used, the program accesses the memory location in order to read or write the variable’s value.

# Pointers

**int age = 18;**

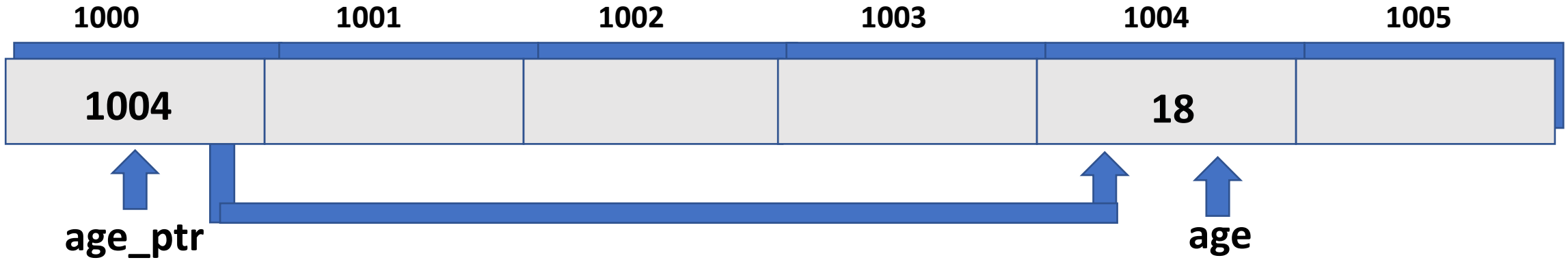
**int *age_ptr;** ← **The * indicates age_ptr will hold a pointer to an integer variable.**




- An address is just a number and can be treated like any other number.
- To create a pointer, you need to declare a second variable to hold the address of the first variable.
- Declaring age_ptr above allocates space to hold an address to any variable defined as an integer. age_ptr has not yet been initialized, is NOT defined to hold an integer value, but is defined to point to an integer type.

# Pointers

```
int      age = 18;
int     *age_ptr;
```




- To initialize age_ptr, we set age_ptr to the memory address of where age is stored, which in this case is the address of 1004, by using:

  **age_ptr = &age;**

- age_ptr now points to age or is a pointer to age, because age_ptr holds the address of where age is stored in memory.

# Pointers

- Pointers can point to different data types, like int, float, and typedef struct, using the following format:

```
data_type    *name_of_ptr;
```

e.g.

```
int          *age_ptr;
```

- The * is the indirection operator.
- The * indicates the variable name_of_ptr is a pointer to a data_type variable, e.g., age_ptr can be a pointer to any variable defined as an int.
- name_of_ptr can hold an address pointing to a data_type.

# Pointer Declaration Examples

```
int         trip, *trip_ptr;                    ← Pointer to an integer value.

double   percent, *percent_ptr;                 ← Pointer to a double value.

typedef struct person_struct {
            char     first_name[15];
            char     last_name[25];
            float    age;
} PERSON;
PERSON          person, *person_ptr;            ← Pointer to a PERSON struct.
```

# Pointers – You Must Initialize Pointers!

- Pointers are not initialized. To initialize a pointer to point to a variable, you can use:

```
pointer = &variable;
```

e.g.,

```
trip_ptr    = &trip;
percent_ptr = &percent;
person_ptr  = &person;
```

- The & copies the memory address where variable is stored into the pointer variable.

- Note how the & looks like the letter A and ampersand starts with the letter A, which I like to think represents the Address Of.

# Pointers – How To Use

- Once a pointer has been defined and initialized, you can use them.

To print out the value of age, you can use:

**printf("age = %d\n", age);** **← Direct Access**

or

**printf("age = %d\n", *age_ptr);** **← Indirect Access (or Indirection)**

The address of age can be printed using:

**printf("age_ptr = %p or &age = %p\n", age_ptr, &age);**

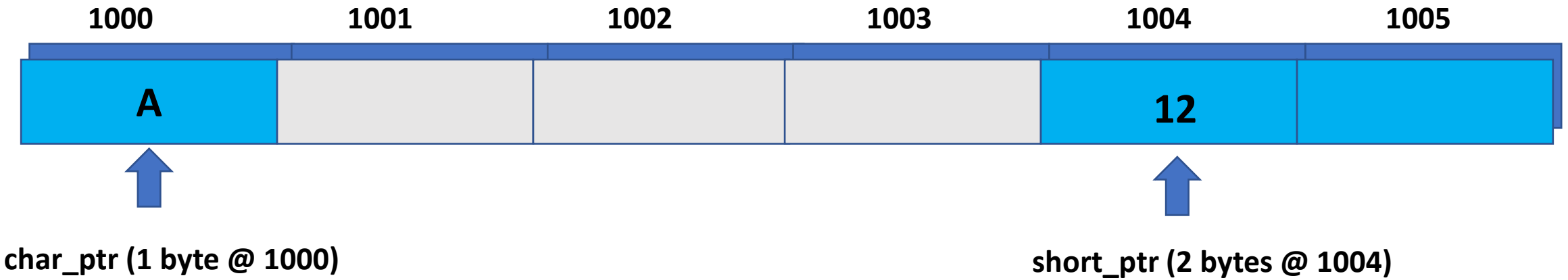
# Pointers – Program to Print Value & Address

```
john@oho:~$ cat pointer.c
#include <stdio.h>
int main()
{
        int     age = 18;
        int     *age_ptr;

        age_ptr = &age;
        printf("age = %d or *age = %d\n", age, *age_ptr);                       // Direct Access
        printf("The address of age_ptr = %p or &age = %p\n", age_ptr, &age);    // Indirect Access
}

john@oho:~$ gcc pointer.c; a.out
age = 18 or *age = 18
The address of age_ptr = 0x7fffd5dc914c or &age = 0x7fffd5dc914c
john@oho:~$ a.out
age = 18 or *age = 18
The address of age_ptr = 0x7ffffcdae50c or &age = 0x7ffffcdae50c       ← Note: The address of age can change
john@oho:~$ a.out
age = 18 or *age = 18
The address of age_ptr = 0x7fffdcf7ef4c or &age = 0x7fffdcf7ef4c       ← Change each time the program is run.
```

# Pointers

Different data types define data of different sizes, e.g., a char is 1 byte, a short int is 2 bytes, an int is 4 bytes, and a struct is a fixed size.

But pointers are smart!  A pointer will (1) point to the first byte of the data and (2) the compiler remembers the type of data being pointed to, and as such, knows its size.



# Pointers

When using arrays, you're actually using pointers.

To initialize numbers_ptr to the first element of the numbers array, you can:

```
int     numbers[10], *numbers_ptr;

numbers_ptr = numbers;
```

or

```
number_ptr = &numbers[0];
```

# Pointers – Memory Addresses For Different Types

```
john@oho:~$ cat pointer2.c
#include <stdio.h>
int main()
{
      typedef struct  person_struct {
            char    first_name[10];
            char    last_name[20];
            int     age;
      } PERSON;

      int     i;
      int     integer_array[10];
      PERSON  person_array[10];

     printf("size of i = %ld\n", sizeof(int));
     printf("size of PERSON = %ld\n", sizeof(PERSON));

      for (i=0; i<10; i++) {
        printf("Address of integer_array[%d]=%p,
              person_array[%d]=%p\n",
              i, &integer_array[i], i, &person_array[i]);
      }
}
```

```
john@oho:~$ gcc pointer2.c; a.out
size of i = 4
size of PERSON = 36
Address of integer_array[0]=0x7fffccf41c40, person_array[0]=0x7fffccf41c70
Address of integer_array[1]=0x7fffccf41c44, person_array[1]=0x7fffccf41c94
Address of integer_array[2]=0x7fffccf41c48, person_array[2]=0x7fffccf41cb8
Address of integer_array[3]=0x7fffccf41c4c, person_array[3]=0x7fffccf41cdc
Address of integer_array[4]=0x7fffccf41c50, person_array[4]=0x7fffccf41d00
Address of integer_array[5]=0x7fffccf41c54, person_array[5]=0x7fffccf41d24
Address of integer_array[6]=0x7fffccf41c58, person_array[6]=0x7fffccf41d48
Address of integer_array[7]=0x7fffccf41c5c, person_array[7]=0x7fffccf41d6c
Address of integer_array[8]=0x7fffccf41c60, person_array[8]=0x7fffccf41d90
Address of integer_array[9]=0x7fffccf41c64, person_array[9]=0x7fffccf41db4
```

The integer_array increments by 4 bytes because an int is 4 bytes.

The PERSON struct is 36 bytes, but increments by 24 bytes.  Why?

# Pointers – Addresses By Incrementing Pointers

```
#include <stdio.h>
int main()
{
      typedef struct  person_struct {
            char    first_name[10];
            char    last_name[20];
            int     age;
      } PERSON;

      int     i;
      int     integer_array[10];
      int     *integer_array_ptr;
      PERSON  person_array[10];
      PERSON *person_array_ptr;

      integer_array_ptr = &integer_array[0];
      person_array_ptr = person_array;

      for (i=0; i<10; i++) {
        printf("Address of integer_array[%d]=%p,
person_array[%d]=%p\n",
            i, integer_array_ptr, i, person_array_ptr);
        integer_array_ptr++;
        person_array_ptr++;
      }
}
```

```
john@oho:~$ gcc pointer3.c; a.out
Address of integer_array[0]=0x7fffef2b7c10, person_array[0]=0x7fffef2b7c40
Address of integer_array[1]=0x7fffef2b7c14, person_array[1]=0x7fffef2b7c64
Address of integer_array[2]=0x7fffef2b7c18, person_array[2]=0x7fffef2b7c88
Address of integer_array[3]=0x7fffef2b7c1c, person_array[3]=0x7fffef2b7cac
Address of integer_array[4]=0x7fffef2b7c20, person_array[4]=0x7fffef2b7cd0
Address of integer_array[5]=0x7fffef2b7c24, person_array[5]=0x7fffef2b7cf4
Address of integer_array[6]=0x7fffef2b7c28, person_array[6]=0x7fffef2b7d18
Address of integer_array[7]=0x7fffef2b7c2c, person_array[7]=0x7fffef2b7d3c
Address of integer_array[8]=0x7fffef2b7c30, person_array[8]=0x7fffef2b7d60
Address of integer_array[9]=0x7fffef2b7c34, person_array[9]=0x7fffef2b7d84
```

**integer_array_ptr increments by 4 bytes in hex.**

**person_array_ptr increments by 24 bytes in hex.**

# Pointers

- An array name without brackets points to the array's first value.
- As such …

*(array) == array[0] ← Both point to the value held in array[0]
*(array+1) == array[1] ← Both point to the value held in array[1]
*(array+2) == array[2] ← Both point to the value held in array[2]
…
*(array+n) == array[n] ← Both point to the value held in array[n]

# Pointers – Function Calls

- There are two ways to pass arguments to a function:
  1. By Value
  2. By Reference

- To pass an array, you can simply provide the name of the array to the function, which is call by reference.

- Strings are passed from one function to another using the address of the first character, not as the whole array.

# Pointers – Passing An Array To Function

```
#include <stdio.h>
#include <string.h>

typedef struct  person_struct {
      char    first_name[10];
      char    last_name[20];
      int     age;
} PERSON;

void print_integer_array(int my_int_array[], int count)
{
      int     i;
      for (i=0; i<count; i++)
        printf("print_integer_array: my_int_array[%d] = %d\n",
              i, my_int_array[i]);
}

void print_person_array(PERSON my_person_array[], int count)
{
      int     i;
      for (i=0; i<count; i++)
        printf("print_person_array: %d. first_name=%s, last_name=%s, age=%d\n",
              i,
              my_person_array[i].first_name,
              my_person_array[i].last_name,
              my_person_array[i].age);
}
```

```
int main()
{
      int     i;
      int     integer_array[10];
      PERSON  person_array[10];
      PERSON *person_array_ptr;

      person_array_ptr = person_array;

      for (i=0; i<10; i++) {          // Initialize integer and person arrays.
        integer_array[i] = i;
        sprintf(person_array_ptr->first_name, "John%d", i);
        sprintf(person_array_ptr->last_name, "Smith%d", i);
        person_array_ptr->age = i+10;
        *person_array_ptr++;
      }

      print_integer_array(integer_array, i);

      print_person_array(person_array, i);
}
```

# Pointers

```
john@oho:~$ gcc pointer_function.c; a.out
print_integer_array: my_int_array[0] = 0
print_integer_array: my_int_array[1] = 1
print_integer_array: my_int_array[2] = 2
print_integer_array: my_int_array[3] = 3
print_integer_array: my_int_array[4] = 4
print_integer_array: my_int_array[5] = 5
print_integer_array: my_int_array[6] = 6
print_integer_array: my_int_array[7] = 7
print_integer_array: my_int_array[8] = 8
print_integer_array: my_int_array[9] = 9
print_person_array: 0. first_name=John0, last_name=Smith0, age=10
print_person_array: 1. first_name=John1, last_name=Smith1, age=11
print_person_array: 2. first_name=John2, last_name=Smith2, age=12
print_person_array: 3. first_name=John3, last_name=Smith3, age=13
print_person_array: 4. first_name=John4, last_name=Smith4, age=14
print_person_array: 5. first_name=John5, last_name=Smith5, age=15
print_person_array: 6. first_name=John6, last_name=Smith6, age=16
print_person_array: 7. first_name=John7, last_name=Smith7, age=17
print_person_array: 8. first_name=John8, last_name=Smith8, age=18
print_person_array: 9. first_name=John9, last_name=Smith9, age=19
```

# Calling Function Using Pointers

```
john@oho:~/LAB4/CALC$ more c.c
#include <stdio.h>

void myProc(int);
void myProc2(int);

void myCaller(void (*)(int), int);

int main(void) {
        myProc(1);
        myProc2(2);

        myCaller(myProc, 3);
        myCaller(myProc2, 4);

        return 0;
}
```

```
void myCaller(void (*f)(int), int param) {
        (*f)(param);            // call function *f with param
}

void myProc(int d) {
        printf("In myProc().\tParameter = %d\n", d);
}

void myProc2(int d) {
        printf("In myProc2().\tParameter = %d\n", d);
}

john@oho:~/LAB4/CALC$ gcc c.c;a.out
In myProc().    Parameter = 1
In myProc2().   Parameter = 2
In myProc().    Parameter = 3
In myProc2().   Parameter = 4
```