Ch.11 Pointers

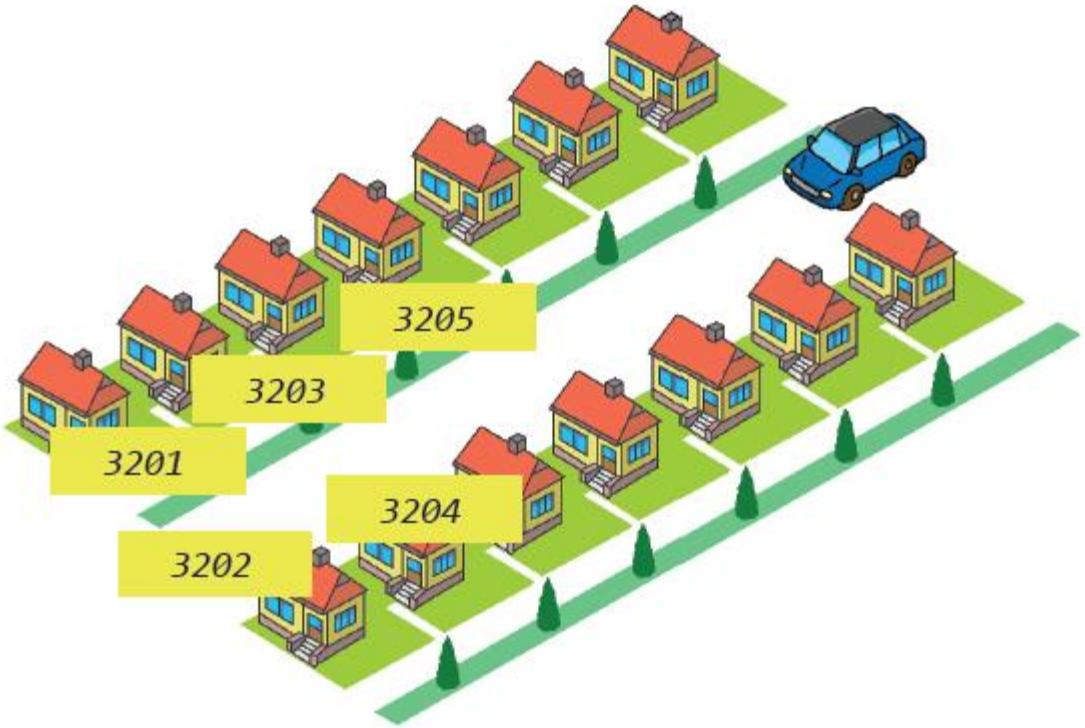
What you will learn in this chapter

- What is a pointer ?
- Address of variable
- Declaration of a pointer
- Indirect reference operator
- Pointer arithmetic
- Pointers and Arrays
- Pointers and functions

In this chapter
The basics of
pointers
Learn
knowledge .

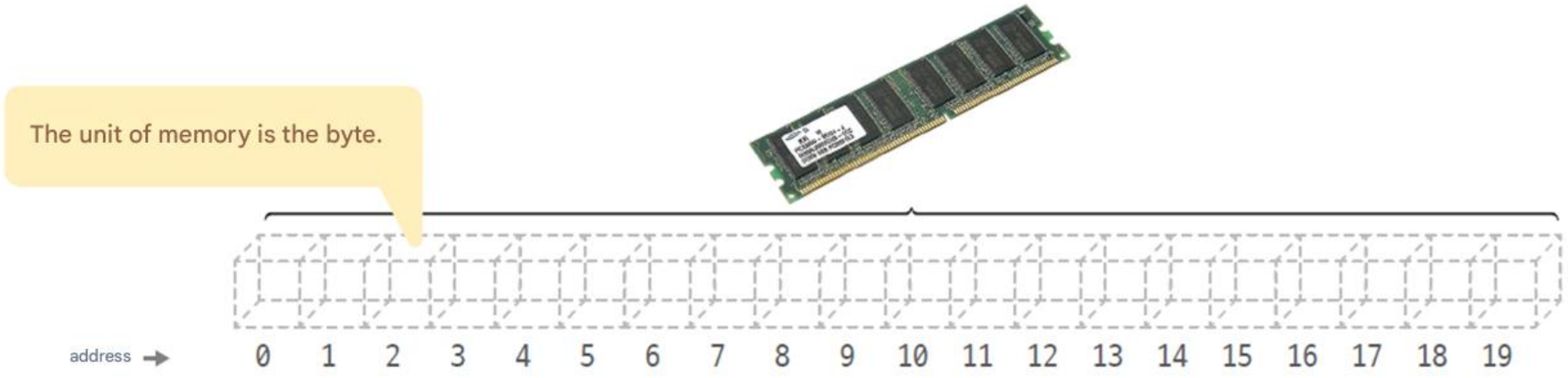
What is a pointer ?

- *Pointer :* A variable that has an address



Where is it stored in the variable ?

- Variables are stored in memory .
- Memory is accessed in bytes.
  - The address of the first byte is 0, the address of the second byte is 1, …

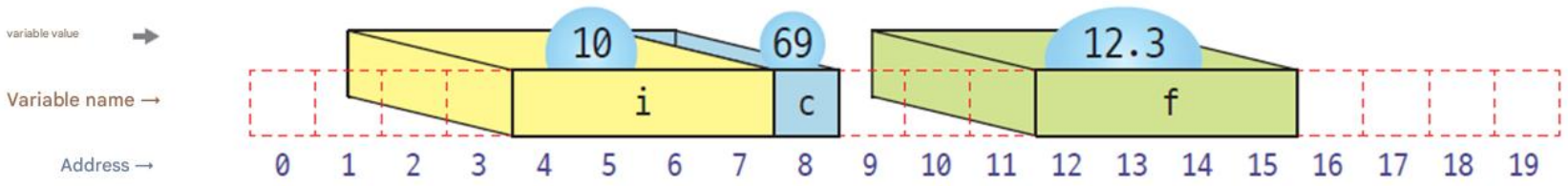


Codespaces

Variables and Memory

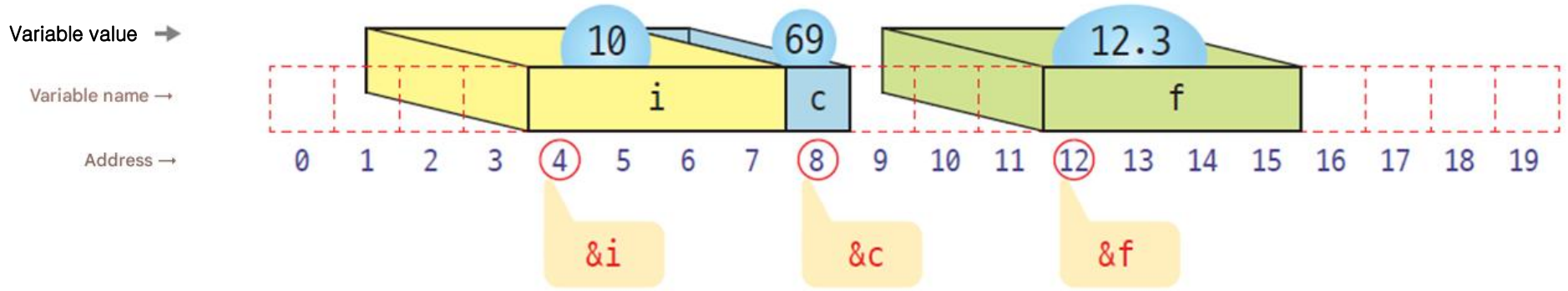
- The memory space occupied varies depending on the size of the variable.
- char type variable : 1 byte, int type variable : 4 bytes, …

```
int main( void )
{
        int i = 10;
        char c = 69;
        float f = 12.3;
        return 0;
}
```



Address of variable

- Operator to calculate the address of a variable : &
- Address of variable i : &i



Codespaces

Address of variable

```
int main( void )
{
        int i = 10;
        char c = 69;
        float f = 12.3;

        printf ( "Address of i : %p\n" , &i ); // Print address of
        printf ( "Address of c : %p\n" , &c); // Print address of
        printf ( "Address of f : %p\n" , &f); // Print address of
        return 0;
}
```

The program The address will be different each time you run it .

```
i 's address : 0000003D69DDF974
Address of c : 0000003D69DDF994
Address of f : 0000003D69DDF9B8
```

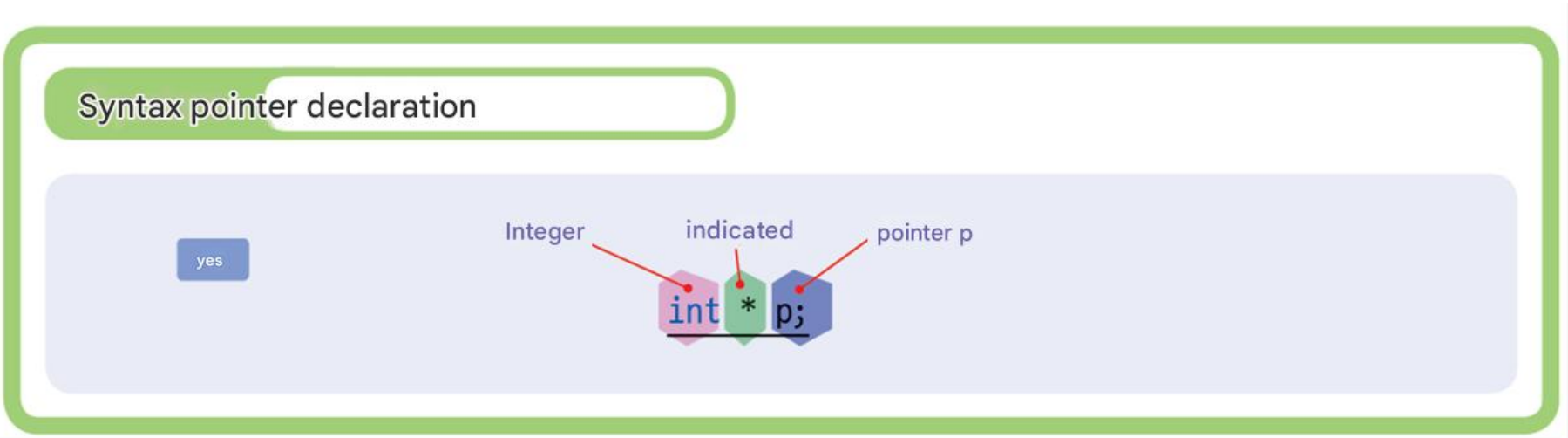
caution

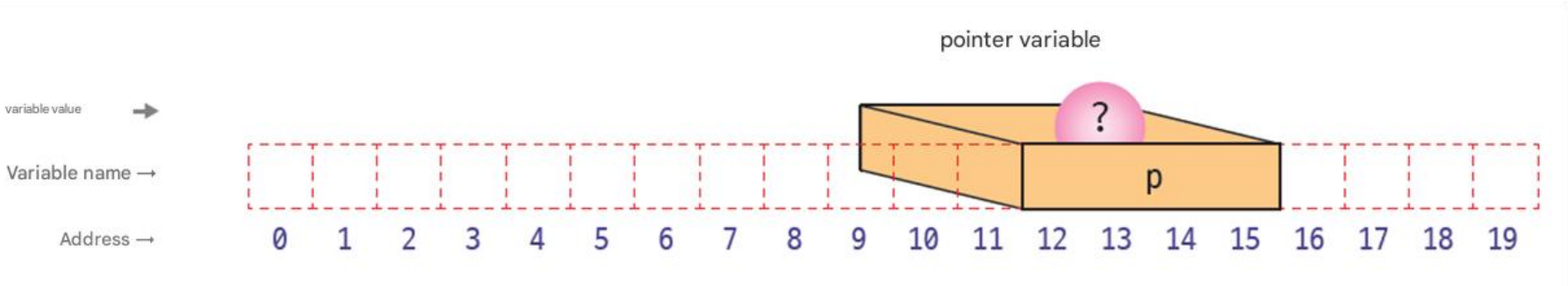
- Be careful when declaring multiple pointer variables on one line. Declaring them as follows is incorrect :
  - int *p1, p2, p3; // (×) p2 and p3 become integer variables .

- To declare correctly, you must do the following :
  - int *p1, *p2, *p3; // (○) p2 and p3 are pointer variables of integer type.

Declaration of a pointer

- Pointer : A variable that holds the address of a variable.

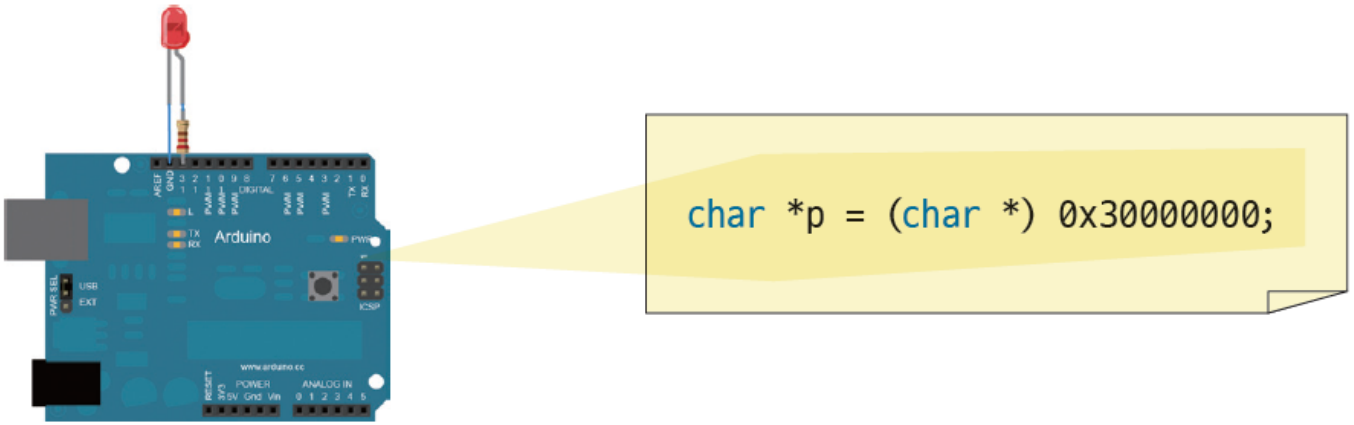




Pointer's Initialization : Initialize to absolute address

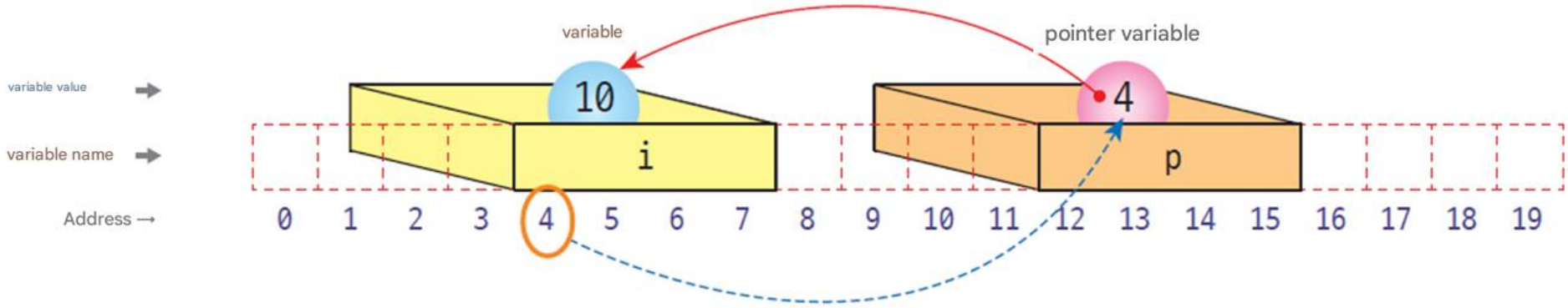
- Possible on Aduino or embedded system
- Not working on Windows
  - For security and stability, absolute address pointer initialization is not allowed.

→ Only addresses allocated by OS or memory addresses normally acquired through malloc, new, etc.



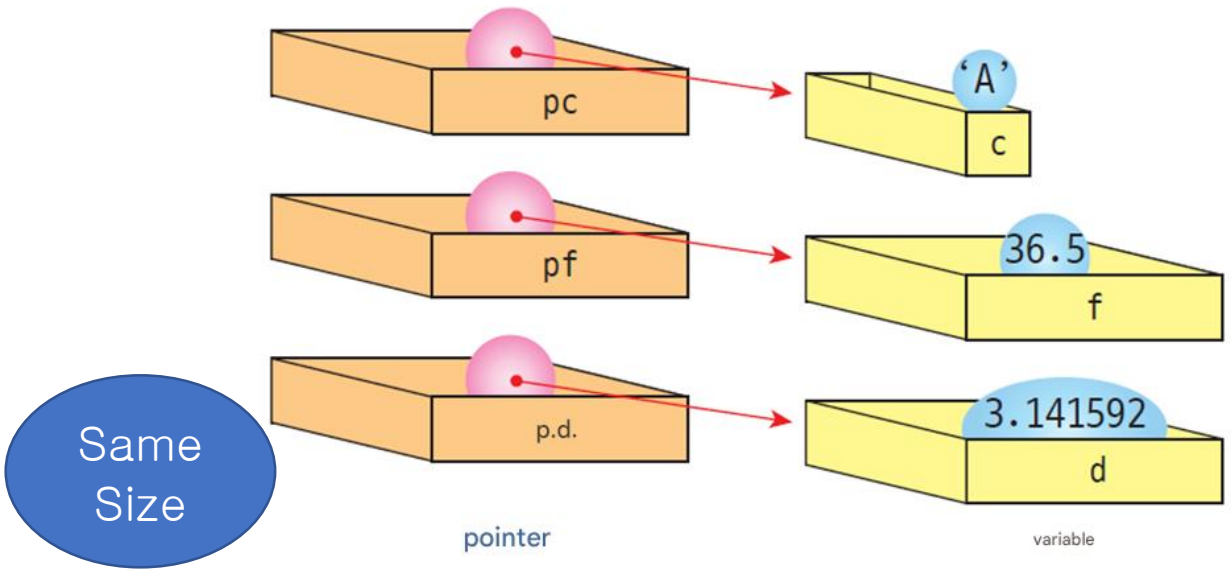
Assign the variables to pointers

```
int    i = 10; // declare of integer variable i
int    * p;     // declare of pointer variable p
p = & i ;       // assign the address of variable i to pointer p
```



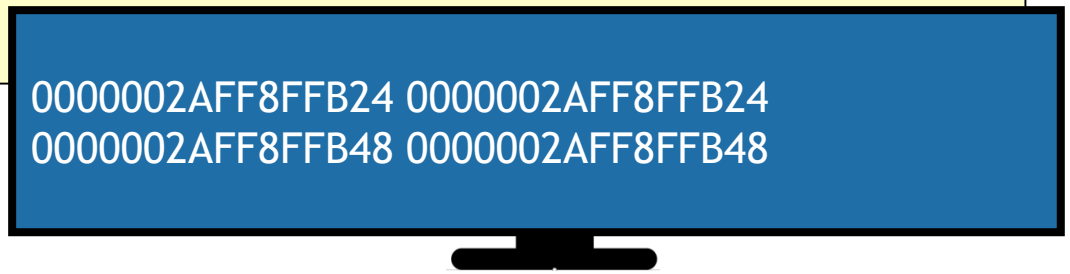
Declaration of various pointers

```
char c = 'A';              // character type Variable c
float f = 36.5;            // Real number variable f
double d = 3.141592;       // Real number Variable d

char *pc = &c;             // characters indicated pointer pc
float * pf = &f;           // Real number indicated Pointer pf
Double * pd = &d;          // Real number indicated Pointer pd
```



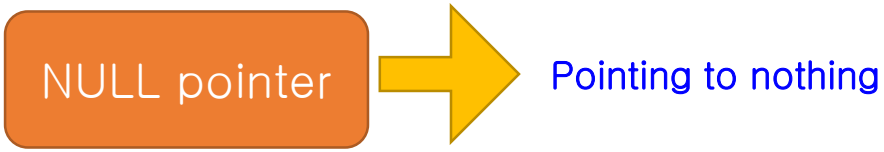
Example

```
#include < stdio.h >

int main( void )
{
        int i = 10;
        double f = 12.3;
        int * pi = NULL ;

        double * pf = NULL ;
        pi = &i ;
        pf = &f;

        printf( "%p % p\n" , pi, &i);
        printf( "%p % p\n" , pf, &f);
       return 0;
}
```



reference

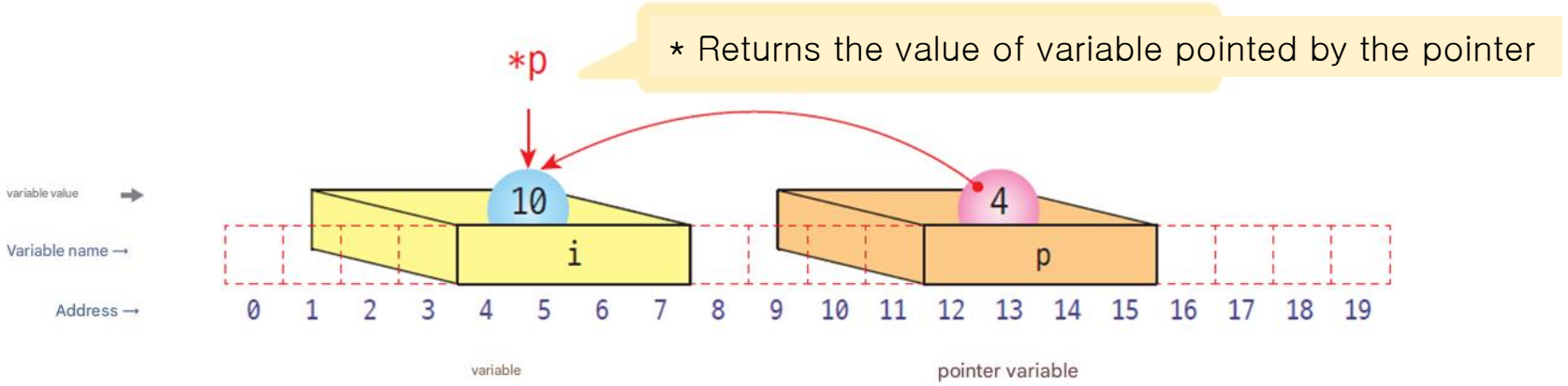
- NULL is stdio.h It means address 0, a pointer constant defined as follows in the header file .
  - #define NULL ((void *)0)
- 0 is generally unusable (the CPU uses it for interrupts). Therefore, if the value of a pointer variable is 0, we can assume that
  it is not pointing to anything .



Indirect reference operator

- Indirect reference operator * : Operator that retrieves the value pointed to by the pointer

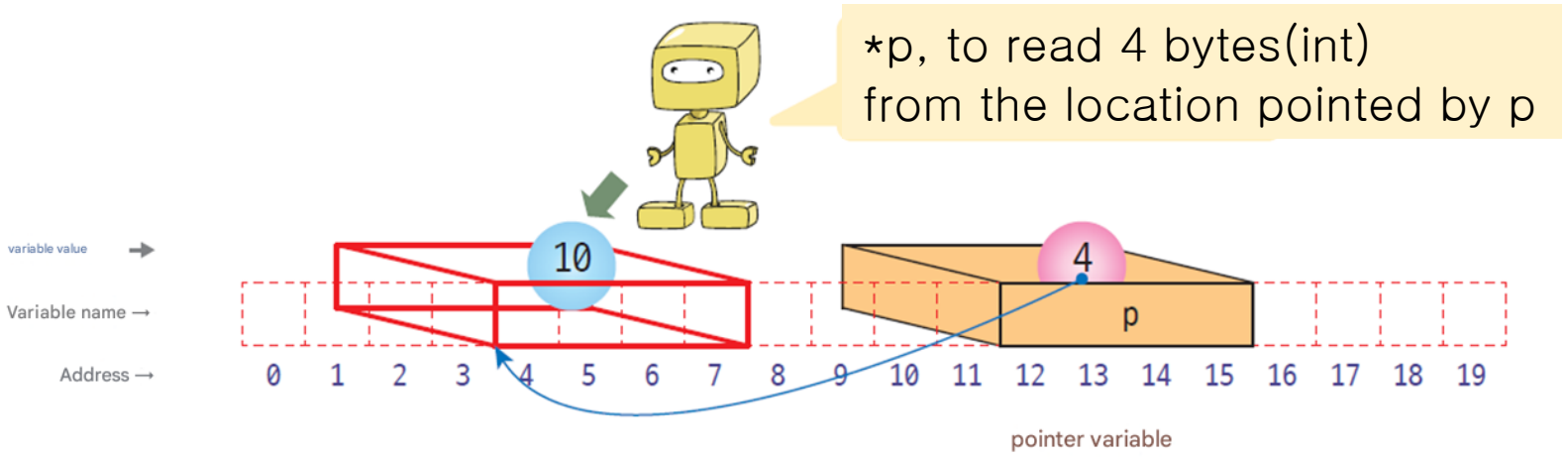
```
int i = 10;

int * p;
p = &i ;

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



Interpretation of indirect reference operators

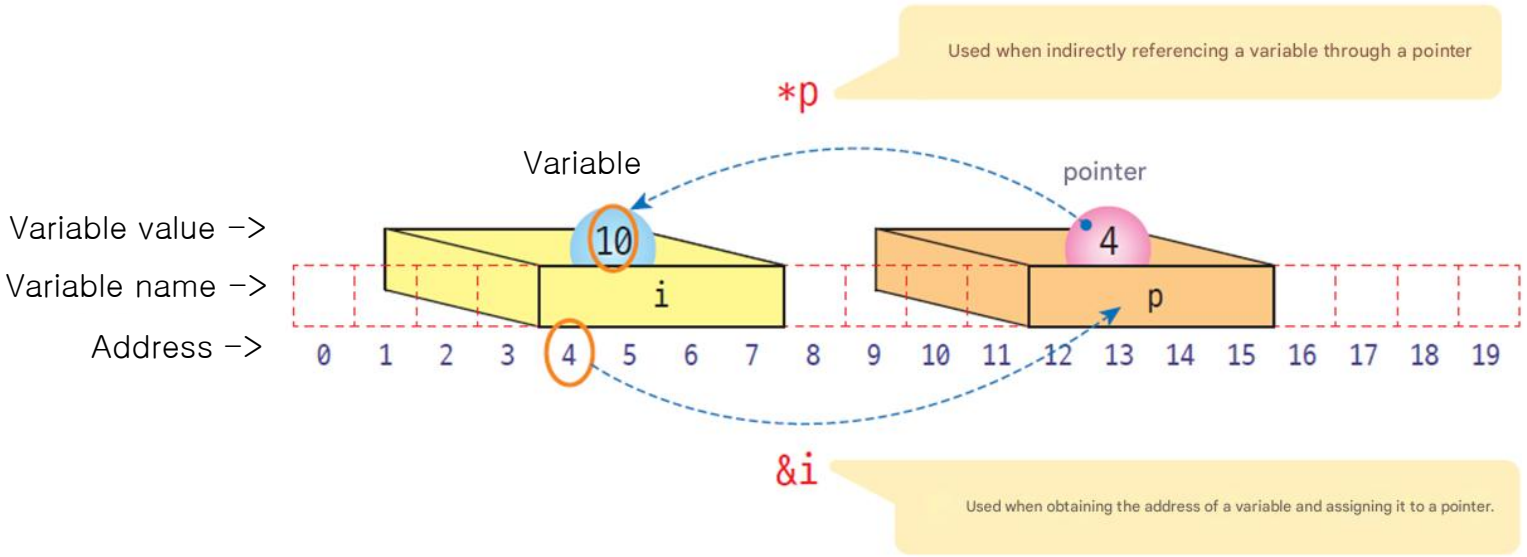
- Indirect reference operator : Reads a value based on the type of the pointer at the specified location .

```
int *pi = (int *)10000;
char *pc = (char *)10000;
double *pd = (double *)10000;
```



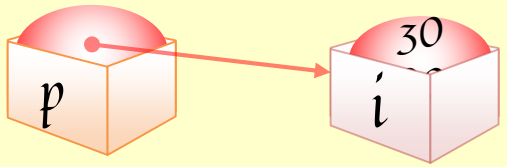
& operator and * operator

- & operator : returns the address of a variable
- * Operator : Returns the contents of the location pointed by the pointer .



Pointer Example #1

```
#include < stdio.h >
int main( void )
{
        int i = 3000;
        int *p=NULL;

        p = & i ;
        printf( "p = %p\n" , p);
        printf( "&i = %p\n\n" , &i);
        printf ( " i = %d\n" , i );
        printf( "*p = %d\n" , *p);

        return 0;
}
```



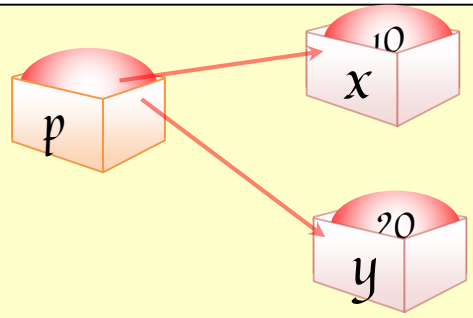

```
p = 0000006DEA0FFBD4
& i = 0000006DEA0FFBD4

i = 3000
*p = 3000
```

Codespaces

Practice

Pointer Example #2

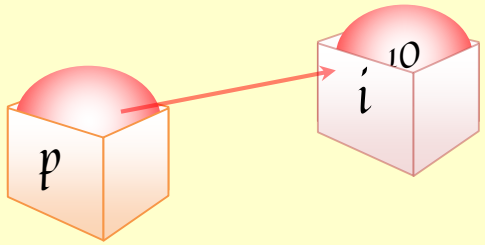
```c
#include < stdio.h >

int main( void )
{
	int x=10, y=20;
	int *p;

	p = &x;
	printf ( "p = %p\n" , p);
	printf ( "*p = %u\n\n" , *p);

	p = &y;
	printf ( "p = %p\n" , p);
	printf ( "*p = %u\n" , *p);
	return 0;
}
```



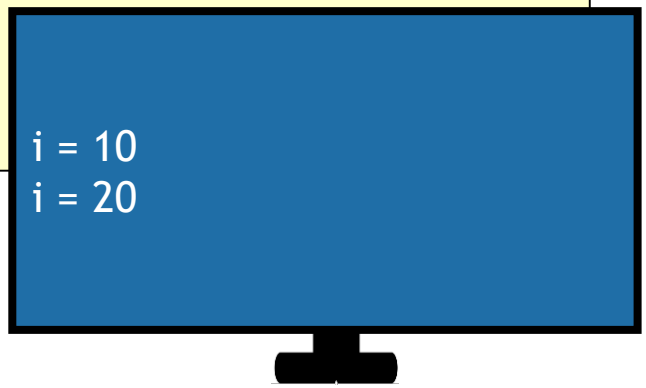

```
p = 0000007A8F3AF974
*p = 10

p = 0000007A8F3AF994
*p = 20
```

Pointer Example #3

```
#include < stdio.h >
int main( void )
{
        int i =10;
        int *p;

        p = & i ;
        printf ( " i = %d\n" , i );

        *p = 20;
        printf ( " i = %d\n" , i );
        return 0;
}
```



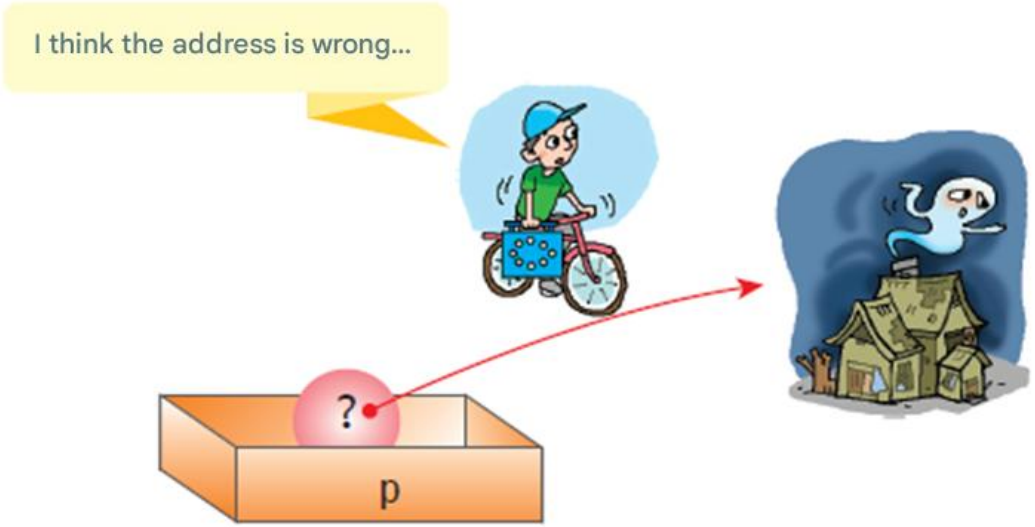
Change the value of a variable through a pointer.



Cautions when using pointers

- You should not use uninitialized pointers .

```
int main( void )
{
        int *p;      // pointer p is not initialization
        *p = 100;   // dangerous code
        return 0;
}
```



Cautions when using pointers

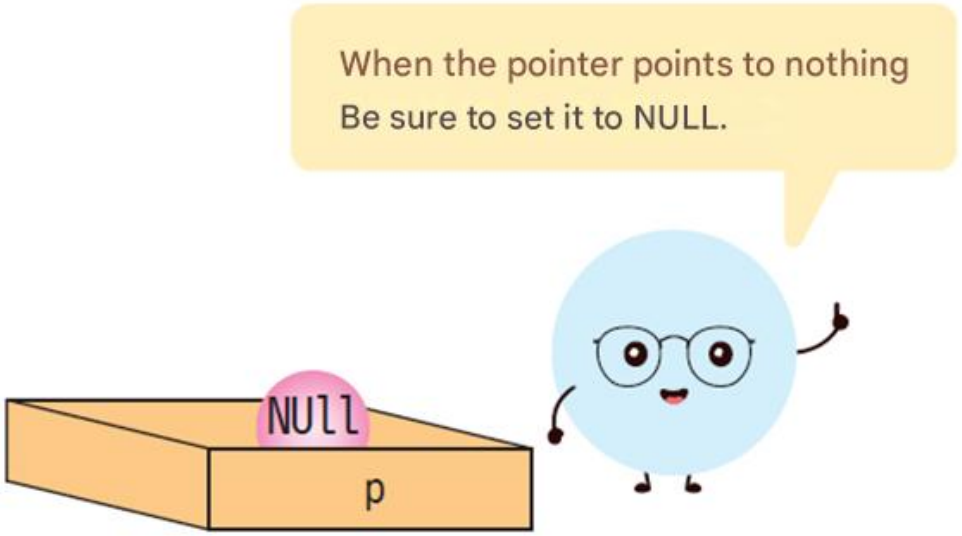
- Pointers are both a strength and a weakness of the C language.
- Developers must use it responsibly .
- When using pointers, always remember the following quote from the Spider-Man movie :

"With great power comes
great responsibility"

Cautions when using pointers

- If the pointer points to nothing, it is initialized to NULL .

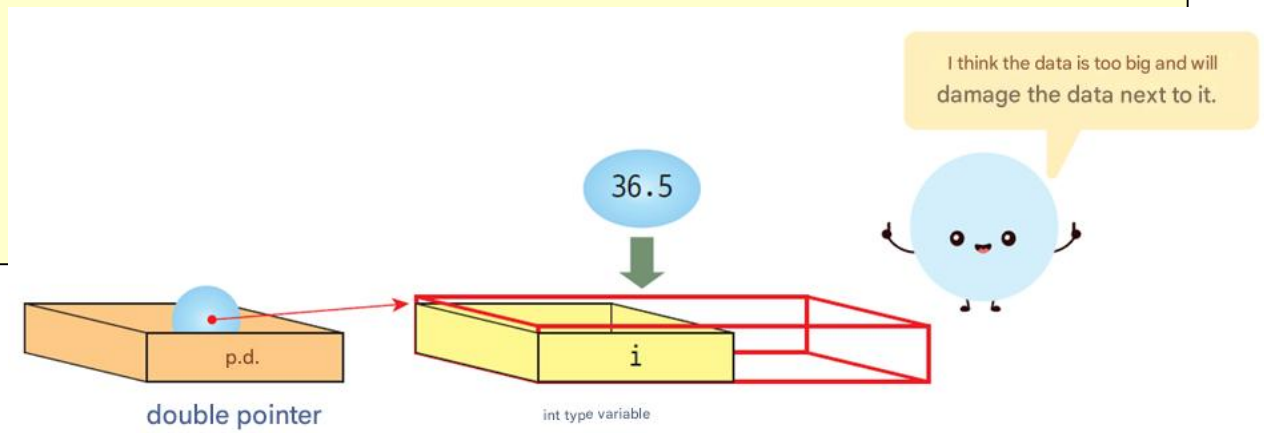
```
int *p = NULL;
```



Cautions when using pointers

- The type of the pointer and the type of the variable must match.

```
#include < stdio.h >

int main( void )
{
        int i ;
        double * pd ;

        pd = & i ;    // error !
        *pd = 36.5;

    return 0;
}
```



Pointer arithmetic

- Possible operations : increment , decrement , addition , subtraction operations
- In the case of an increment operation, the value being increased is the size of the object pointed to by the pointer.

pointer type	++value that increases after operation
char	1
short	2
int	4
float	4
double	8

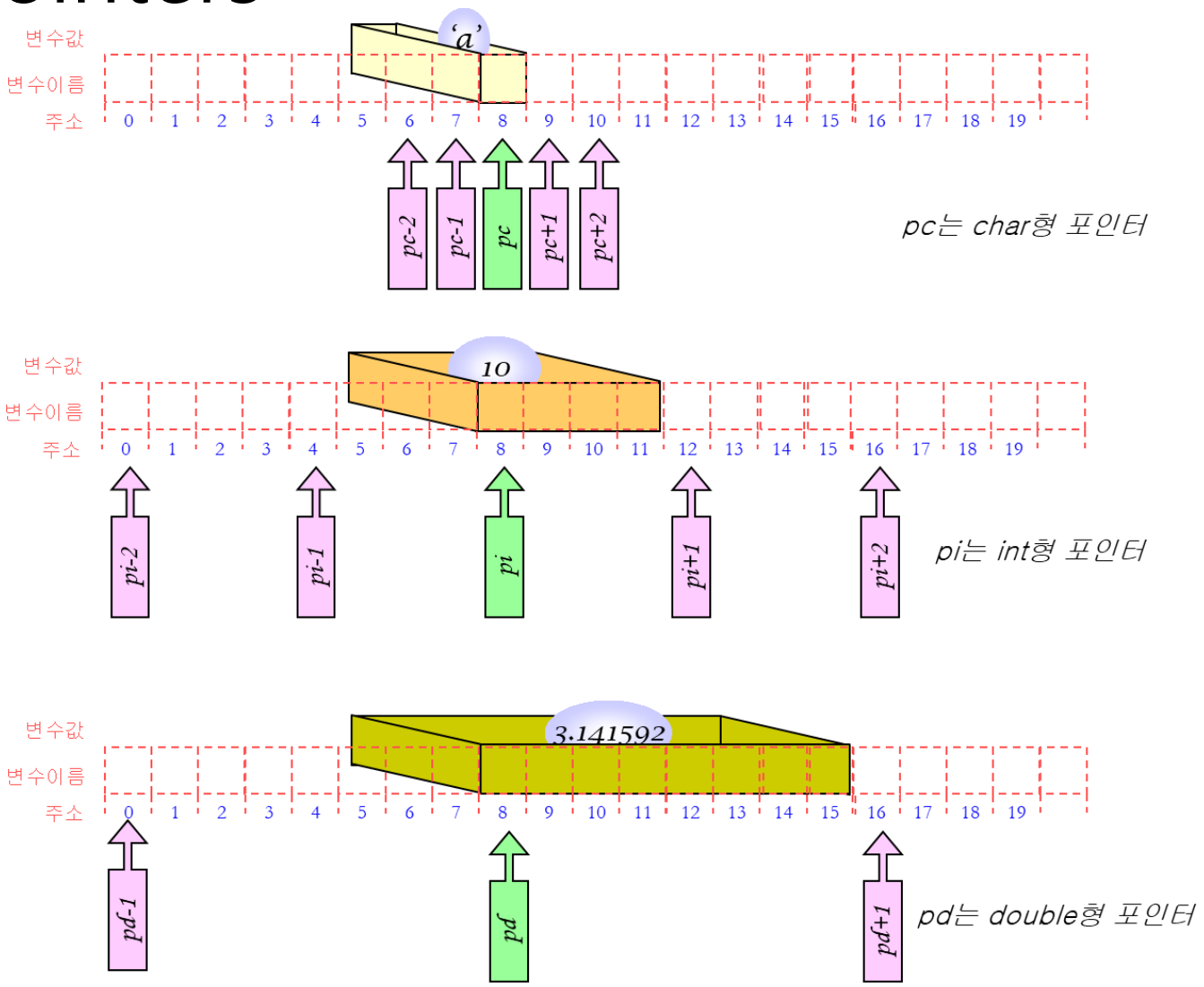
Increment operation example

그림으로 설명
Next page

```
// Increment/decrement operation of pointer
#include < stdio.h >

int main( void )
{
        char *pc;
        int *pi;
        double *pd;

        pc = ( char *)10000;
        pi = ( int *)10000;
        pd = ( double *)10000;
        printf( " pc=%u, pc+1=%u, pc+2= %u\n" , pc, pc + 1, pc + 2);
        printf( " pi=%u, pi+1=%u, pi+2= %u\n" , pi, pi + 1, pi + 2);
        printf( " pd=%u, pd+1=%u, pd+2= %u\n" , pd, pd + 1, pd + 2);

        return 0;
}
```

```
pc=10000, pc+1=10001, pc+2= 10002
pi=10000, pi+1=10004, pi+2= 10008
pd=10000, pd+1=10008, pd+2=10016
```

Increment and decrement operations of pointers



Indirect reference operator and increment/decrement operator

- *p++;
  - Increments p after getting the value from the location pointed to by p.
- (*p)++;
  - The value at the location pointed to by p It increases .

formula	meaning
v = *p++	After assigning the value pointed to by p to v , increment p.
v = (*p)++	the value pointed to by p to v, increment the value pointed to.
v = *++p	After incrementing p, assign the value pointed to by p to v.
v = ++*p	p increment that value and assign it to v.

Indirect reference operator and increment/decrement operator

Codespaces

```
// Increment/decrement operation of pointer
#include < stdio.h >

int main( void )
{
 int i = 10;
 int *pi = & i ;

 printf ( " i = %d, pi = %p\n" , i , pi);

 (*pi)++;
 printf ( " i = %d, pi = %p\n" , i , pi);

 *pi++;
 printf ( " i = %d, pi = %p\n" , i , pi);
 return 0;
}
```

Increments the value at the location pointed to pi.

After getting the value from the location pointed to by pi, increment pi.

```
i = 10, pi = 000000FFEBCFF974
i = 11, pi = 000000FFEBCFF974
i = 11, pi = 000000FFEBCFF978
```

Type conversion of pointers

- C language , you can explicitly change the type of a pointer when absolutely necessary.

```
double * pd = &f;
int * pi;

pi = ( int *)pd;
```

Supplementary?

Codespaces

Example

```
#include < stdio.h >

int main( void )
{
        int data = 0x0A0B0C0D;
        char *pc;
        int i ;

        pc = ( char *)&data;
        for (i = 0; i < 4; i++) {
            printf ( "*(pc + %d) = %02X \n" , i , *(pc + i ));
        }
        return 0;
}
```

reference

- You can feel the danger of pointers a little bit in the increment and decrement operations of pointers . We can increment and decrement pointers as we please, but the incremented
pointer may point to the wrong location.

- It may refer to other people's data, not data we created, or it may refer to a data area used by the operating system.

- In this case, writing or reading a value using a pointer can cause a serious error.

Check points

1. What operations can be applied to pointers ?
2. int pointer p points to address 80, what address does (p+1) point to ?
3. p is a pointer, what is the difference between *p++ and (*p)++ ?
4. If p is a pointer, what does * (p+3) mean ?

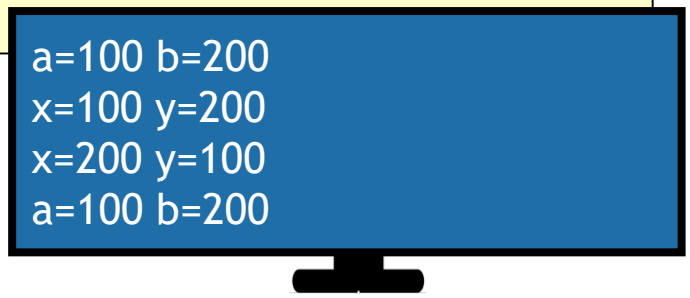
How to transfer acquisition

- Function How to pass arguments when calling
  - Call by value (call) by value)
    - Copy as a function It is delivered.
    - Basic methods in C.
  - Call by reference
    - The original is passed to the function.
    - In C, this can be emulated using pointers.

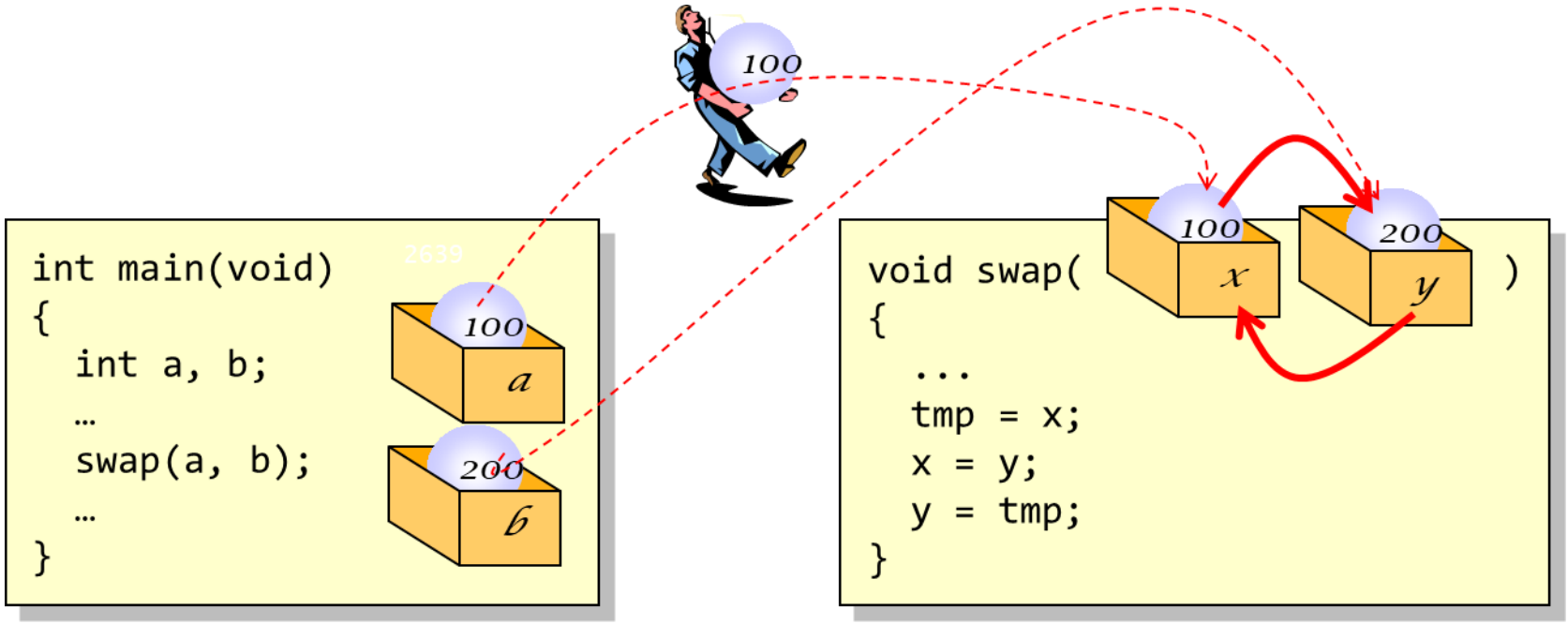
swap() function #1 (call by value)

```
#include < stdio.h >
void swap( int x, int y);
int main( void )
{
        int a = 100, b = 200;
        printf("a=%db=%d\n",a, b);

        swap(a, b);

        printf("a=%db=%d\n",a, b);
        return 0;
}
```

```
void swap( int x, int y)
{
        int tmp ;
        printf("x=%dy=%d\n",x, y);

        tmp = x;
        x = y;
        y = tmp ;

        printf("x=%dy=%d\n",x, y);
}
```



Call by value



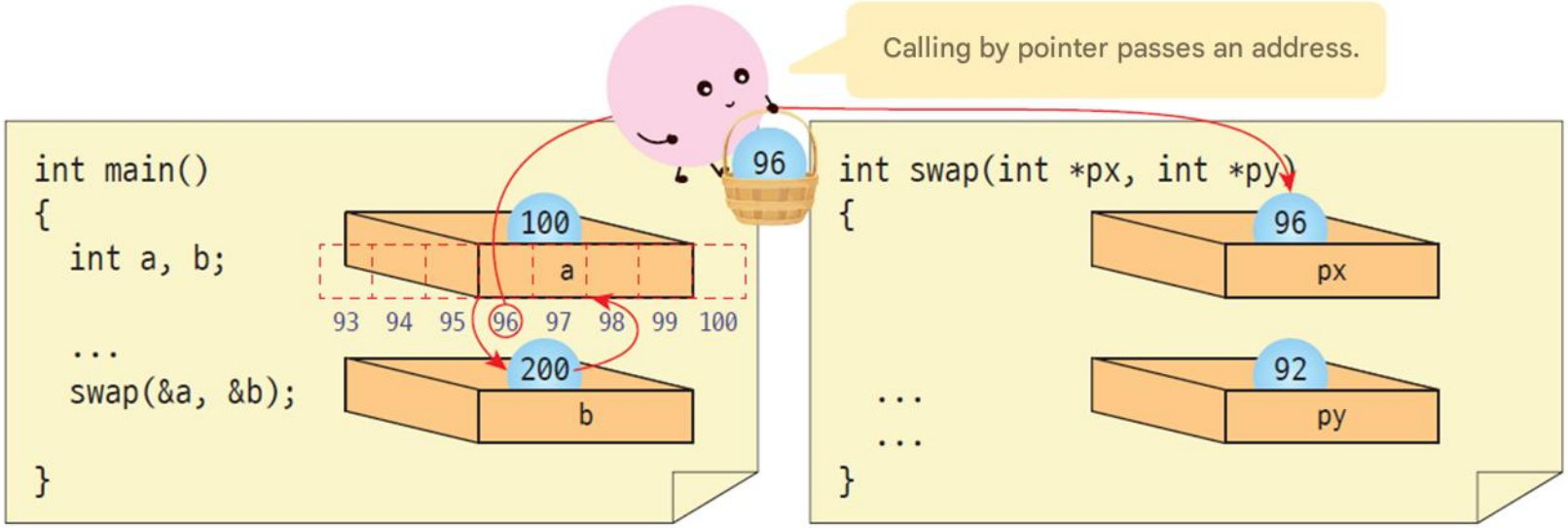
Practice

swap() function #2 (call by reference)

```c
#include < stdio.h >
void swap( int *x, int *y);
int main( void )
{
        int a = 100, b = 200;
        printf("a=%db=%d\n",a, b);

        swap(&a, &b);

        printf("a=%db=%d\n",a, b);
        return 0;
}
```

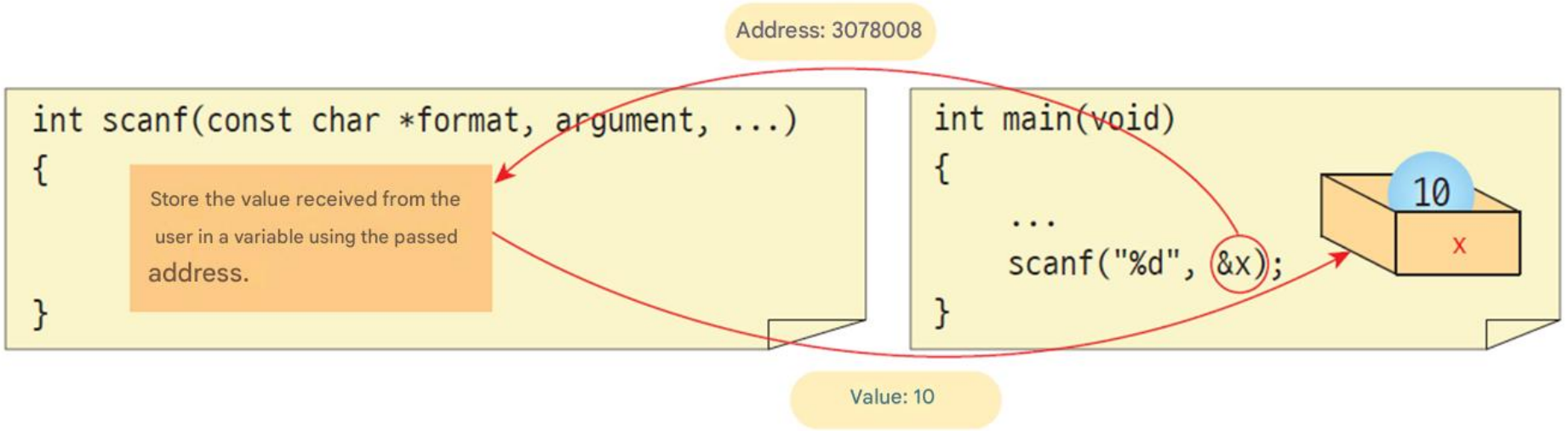
```c
void swap( int *px , int *py )
{
        int tmp ;

         tmp = *px ;
        *px = *py ;
        *py = tmp ;
}
```

Call by reference



scanf () function

- Receives the address of a variable to store a value.



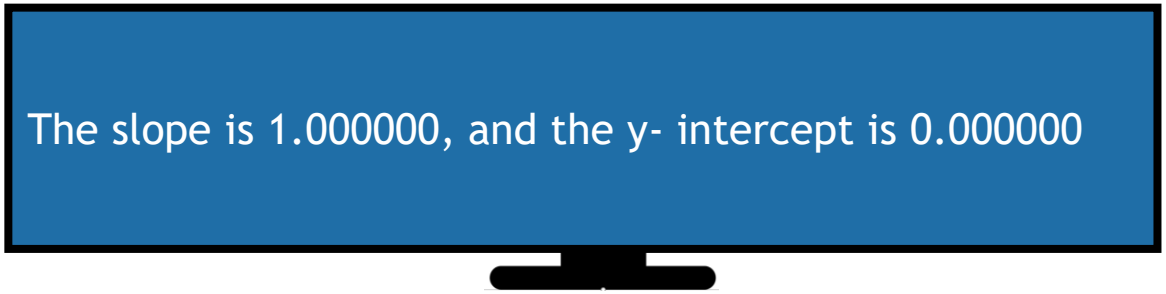
Note : How to prevent a function from changing a value through a pointer ?

- When declaring a function parameter, you can do so by adding const in front.
  Adding const in front means that the content pointed to pointer is a constant that cannot be changed.

```
void sub( const int *p)
{
        *p = 0; // error !!
}
```

Example

- If a function needs to return more than one value, one way to do this is to use pointers . Let's write a function that returns both the slope and the y- intercept of a line .



Return more than two results

```
#include < stdio.h >
// Slope and Calculate the y-intercept
int get_line_parameter ( int x1, int y1, int x2, int y2, float *slope, float * yintercept )
{
      if ( x1 == x2 )
          return -1;
      else {
          *slope = ( float )(y2 - y1)/( float )(x2 - x1);
          * yintercept = y1 - (*slope)*x1;
          return 0;
      }
}
int main( void )
{
      float s, y;
      if ( get_line_parameter (3,3,6,6,&s,&y) == -1 )
          printf ( " Error \n" );
      else
          printf ( " slope is %f, y-intercept is %f\n" , s, y);
      return 0;
}
```

slope and Y– intercept as arguments

The slope is 1.000000, and the y- intercept is 0.000000

Cautions when returning a pointer

- The address of the variable that remains even after the function ends must be returned .
- If you return the address of a local variable, it will disappear when the function ends, so it is an error.

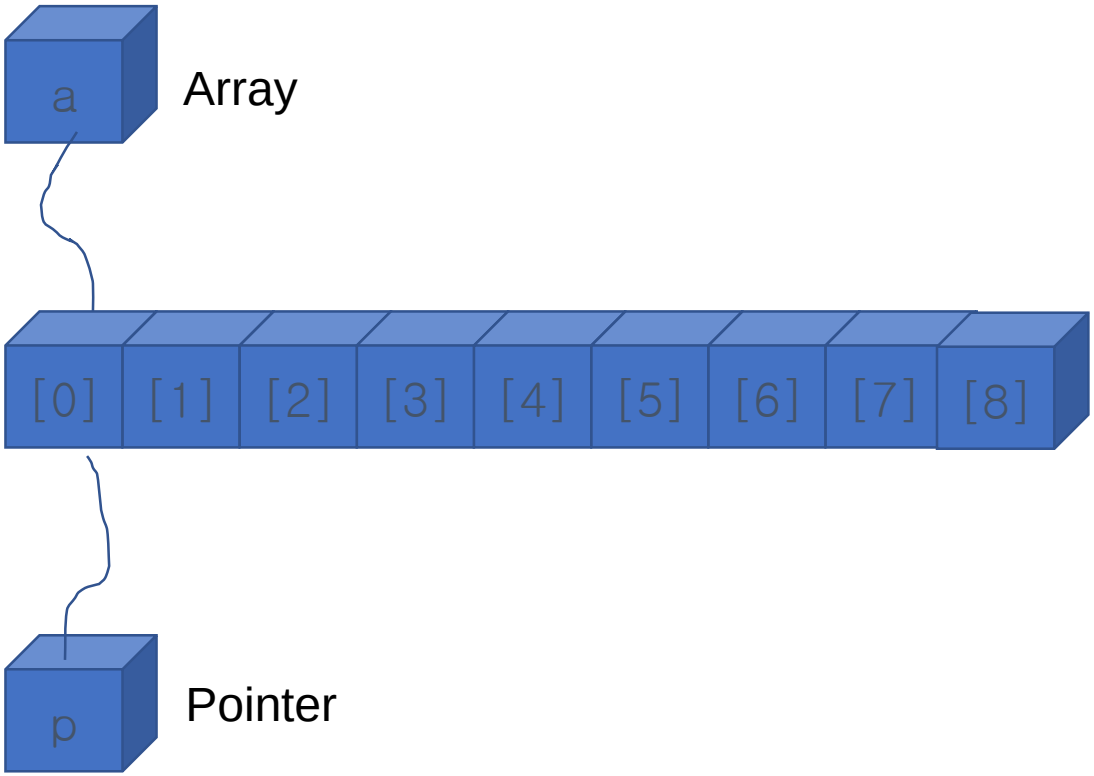
```
int *add( int x, int y)
{
        int result;

        result = x + y;
        return &result;
}
```

Local variables disappear when the function call ends, so you should not return the address of a local variable.

Pointers and Arrays

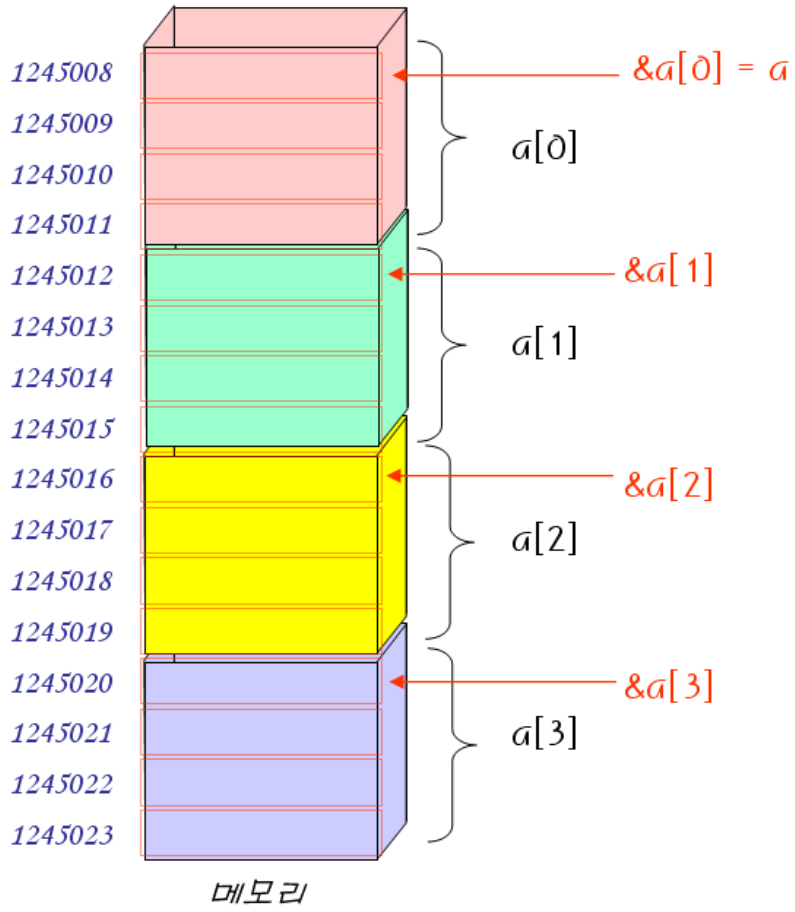
- Arrays and pointers have a very close relationship .
- The array name is actually a pointer .
- Pointers can be used like arrays .

Array Pointer



Pointers and Arrays

```
// Pointer and Array of relationship
#include < stdio.h >

int main( void )
{
        int a[] = { 10, 20, 30, 40, 50 };

        printf ( "&a[0] = %u\n" , &a[0]);
        printf ( "&a[1] = %u\n" , &a[1]);
        printf ( "&a[2] = %u\n" , &a[2]);

        printf ( "a = %u\n" , a);

        return 0;
}
```




```
&a[0] = 1245008
&a[1] = 1245012
&a[2] = 1245016
a = 1245008
```

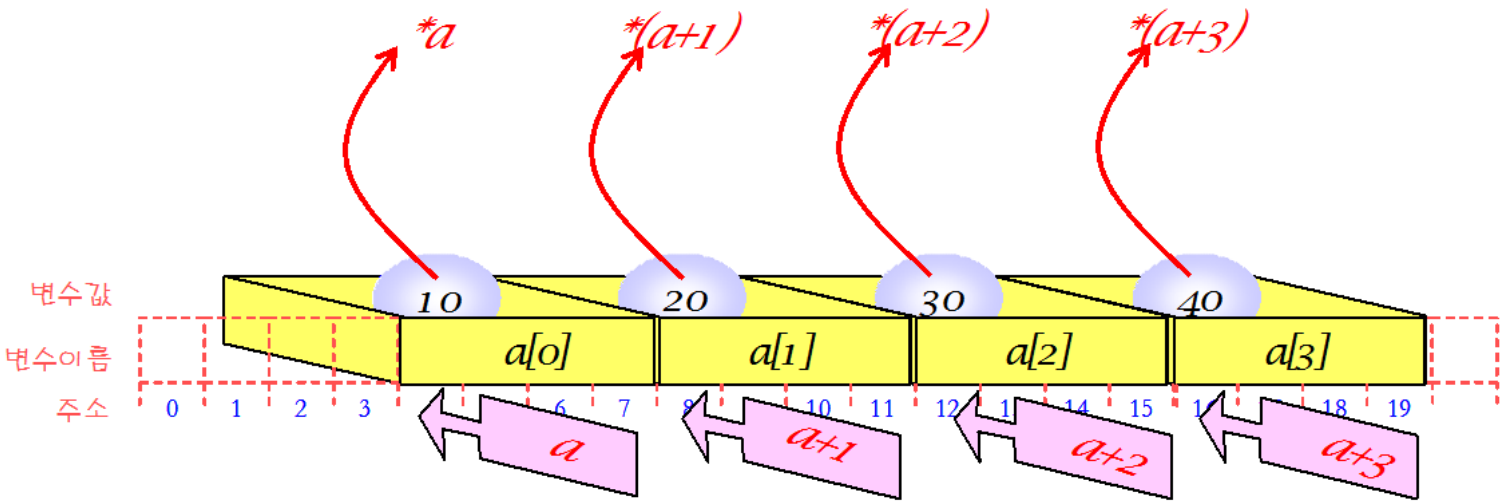
Example


```c
// Relationship between pointers and arrays
#include < stdio.h >

int main( void )
{
	int a[] = { 10, 20, 30, 40, 50 };

	printf( "a = %u\n" , a);   //pointer

	printf( "a + 1 = %u\n" , a + 1);

	printf( "*a = %d\n" , *a);

	printf( "*(a+1) = %d\n" , *(a + 1));

	return 0;
}
```

```
a = 1245008
a + 1 = 1245012
*a = 10
*(a+1) = 20
```

Pointers and Arrays

- Pointers can be used like arrays .
- Index notation can be used with pointers .

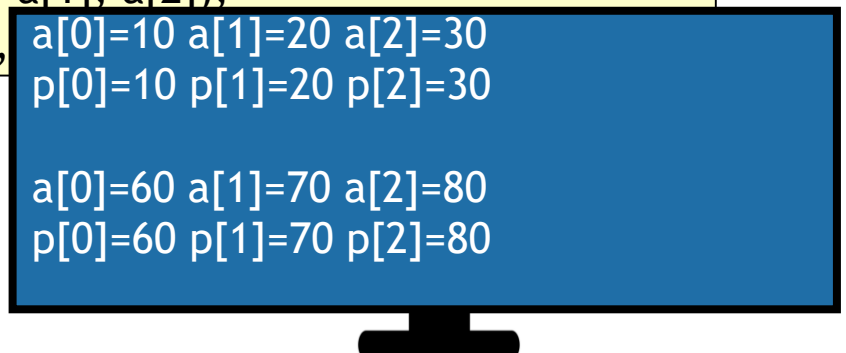


Using pointers like arrays

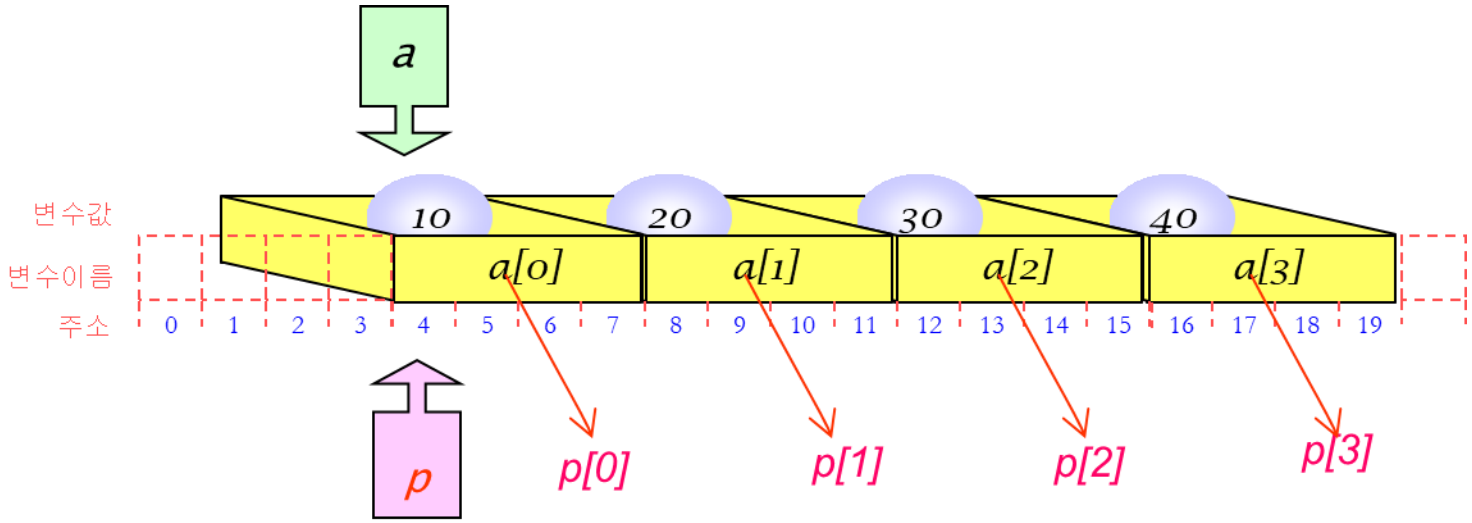
```
#include < stdio.h >
int main( void )
{
        int a[] = { 10, 20, 30, 40, 50 };
        int *p;

        p = a;
        printf ( "a[0]=%da[1]=%da[2]=%d \n" , a[0], a[1], a[2]);
        printf ( "p[0]=%dp[1]=%dp[2]=%d \n\n" , p[0], p[1], p[2]);

        p[0] = 60;
        p[1] = 70;
        p[2] = 80;

        printf ( "a[0]=%da[1]=%da[2]=%d \n" , a[0], a[1], a[2]);
        printf ( "p[0]=%dp[1]=%dp[2]=%d \n" , p[0],
        return 0;
}
```

You can see that arrays are ultimately implemented as pointers .

Array elements can be changed through pointers.



A pointer can also be used as an array name.



Array parameters

- General parameters vs Array parameters

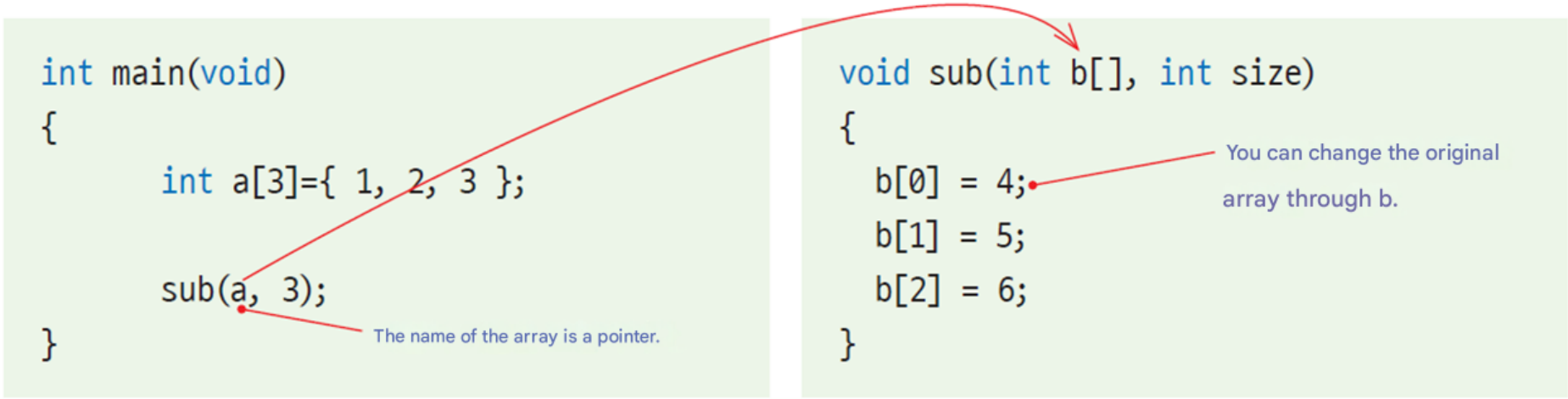
```
// Assign parameters variable x at
    memory place
void sub( int x)
{
...
}
```

```
// b does not have memory allocated to it
void sub( int b[] )
{
...
}
```

- Why? -> Copying an array to a function is time-consuming, so only pass the address of the array .

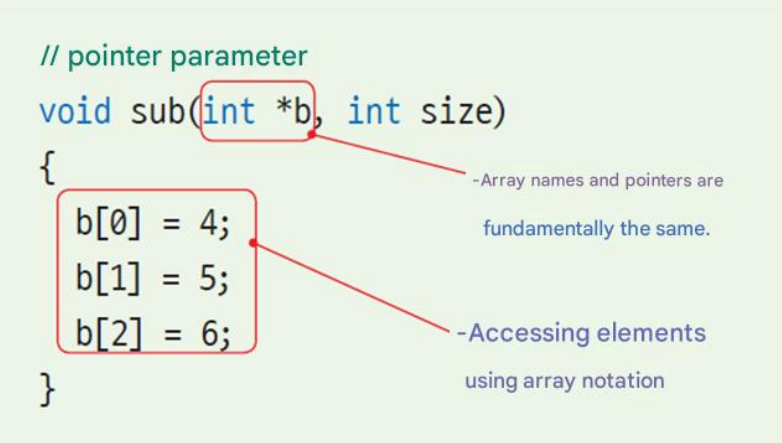
Array parameters

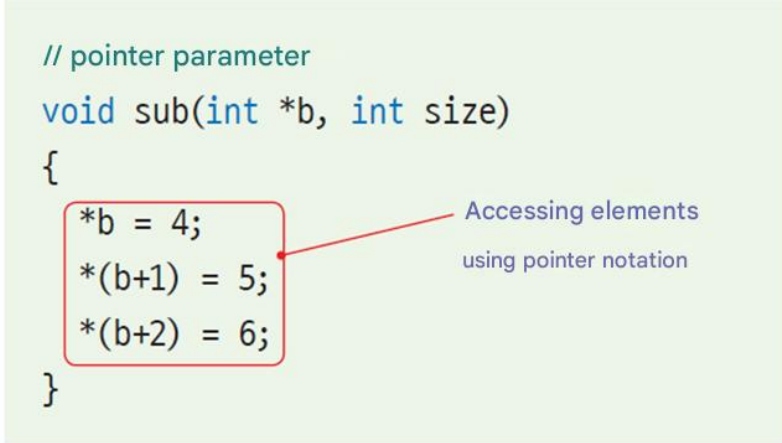
- Array parameters can be thought of as pointers .



```c
// Relationship between pointers and functions
#include < stdio.h >

void sub( int b [], int n );

int main( void )
{
	int a[3] = { 1,2,3 };

	printf( "%d %d %d\n" , a[0], a[1], a[2]);
	sub(a, 3);
	printf( "%d %d %d\n" , a[0], a[1], a[2]);

	return 0;
}

void sub( int b [], int n )
{
	b [0] = 4;
	b [1] = 5;
	b [2] = 6;
}
```

The following two methods are completely equivalent :





Advantages of using pointers

When the compiler optimizes, the performance becomes almost similar .

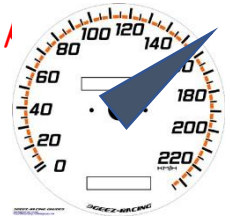
- Pointers are faster than index notation .
  - Why?: There is no need to convert index to address .

```
int get_sum1( int a[], int n)
{
        int i ;
        int sum = 0;

        for ( i = 0; i < n; i ++ )
            sum += a[ i ];
        return sum;
}
```

```
int get_sum2( int a[], int n)
{
        int i , sum =0 ;
        int *p;

        p = a;
        for ( i = 0; i < n; i ++ )
            sum += *p++;
        return sum;
}
```

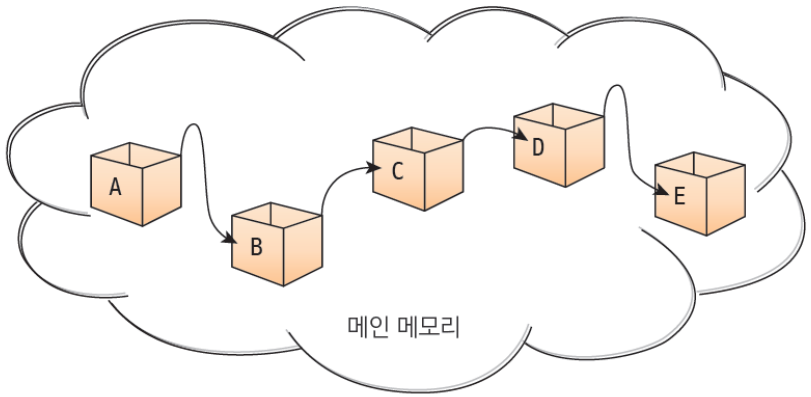
Using index not

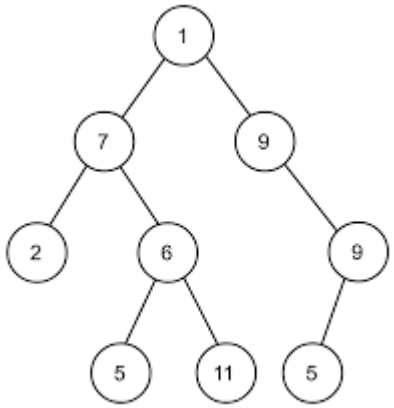
Using



Advantages of using pointers

- You can create advanced data structures such as linked lists and binary trees .





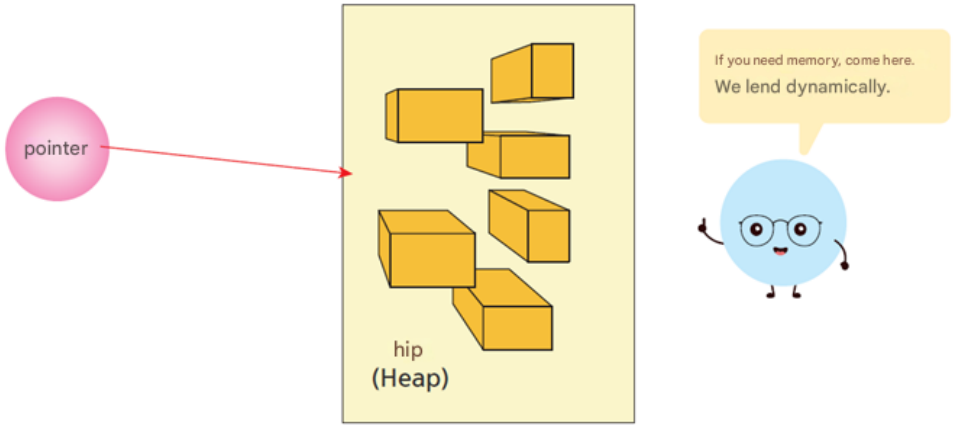
- Call by reference
  - You can change the value of a variable outside the function by using a pointer as a parameter .

Advantages of using pointers

- Memory mapping hardware
  - Memory-mapped hardware refers to hardware devices that can be accessed like memory .

```
volatile int * hw_address = (volatile int *)0x7FFF;
* hw_address = 0x0001; // Write value 0x0001 to the device at address 0x7FFF .
```

- Dynamic memory allocation
  - Covered in Chapter 17 .
  - To use dynamic memory, you must have a pointer .



Q & A