

Ch.11 Pointers

What you will learn in this chapter



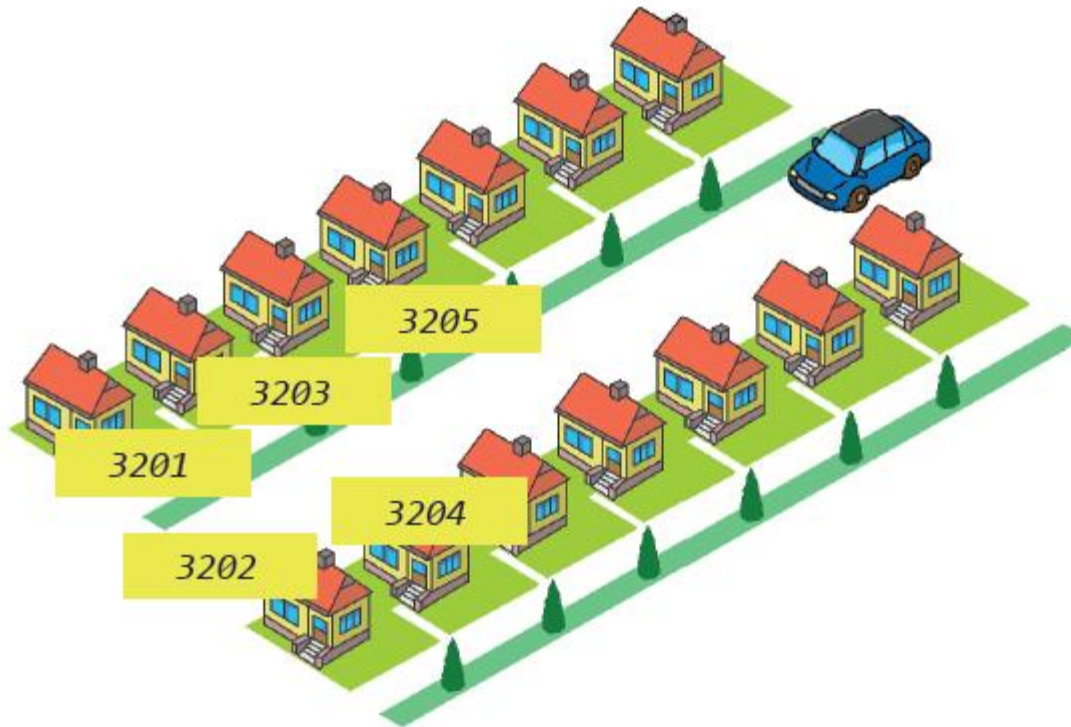
- What is a pointer ?
- Address of variable
- Declaration of a pointer
- Indirect reference operator
- Pointer arithmetic
- Pointers and Arrays
- Pointers and functions

In this chapter
The basics of
pointers
Learn
knowledge .



What is a pointer ?

- *Pointer* : A variable that has an address



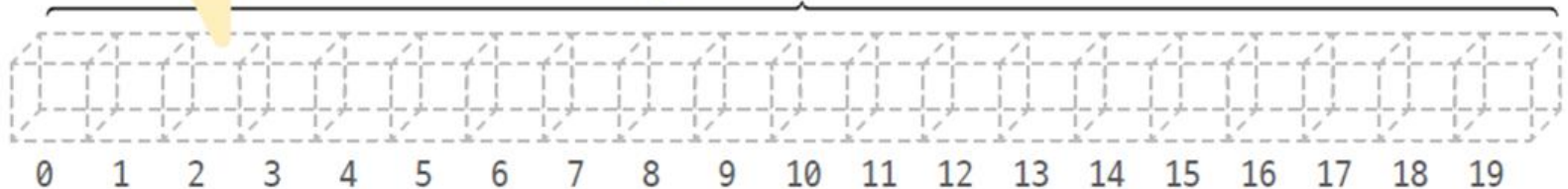
Where is it stored in the variable ?

- 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, ...

The unit of memory is the byte.



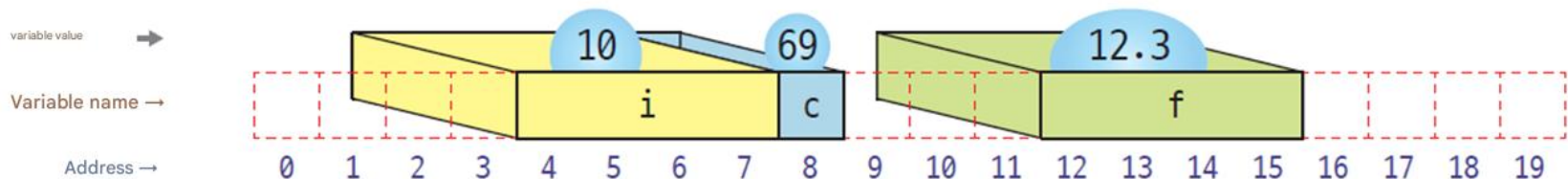
address →



Variables and Memory

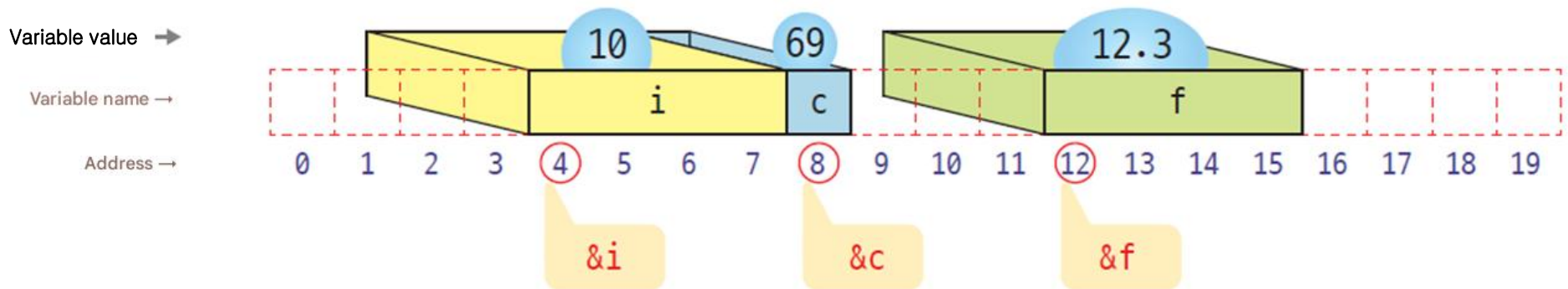
- The memory space occupied varies depending on the size of the variable.
- char type variable : 1 byte, int type variable : 4 bytes, ...

```
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`



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.

Syntax pointer declaration

yes

Integer

indicated

pointer p

```
int * p;
```

*

p3

pointer variable

variable value →

Variable name →

Address →

0

1

2

3

4

5

6

7

8

g

1

1

1

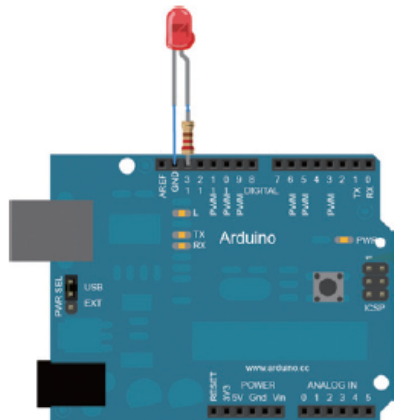
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1

3

Pointer's Initialization : Initialize to absolute address

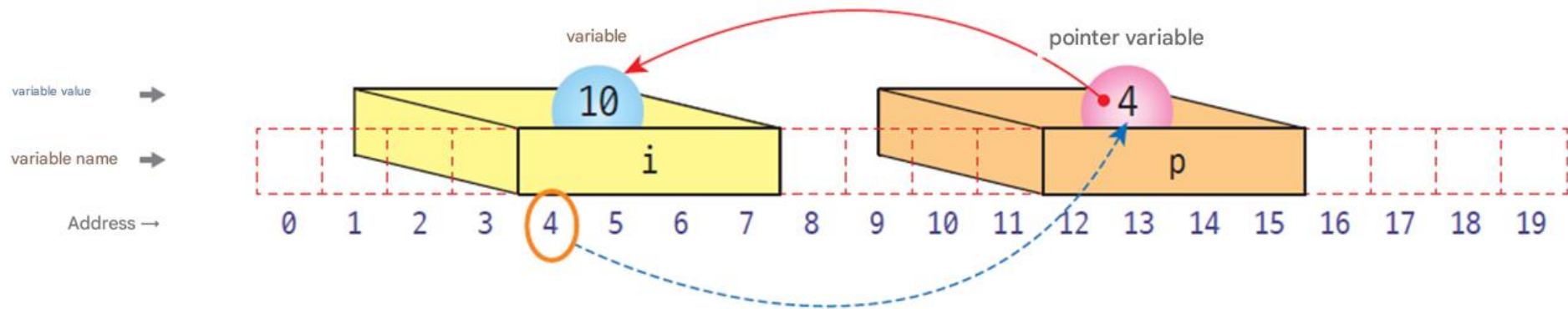
- Possible on Aduino or embedded system
 - Not working on Windows
 - For security and stability, absolute address pointer initialization is not allowed.
- Only addresses allocated by OS or memory addresses normally acquired through malloc, new, etc.



```
char *p = (char *) 0x30000000;
```

Assign the variables to pointers

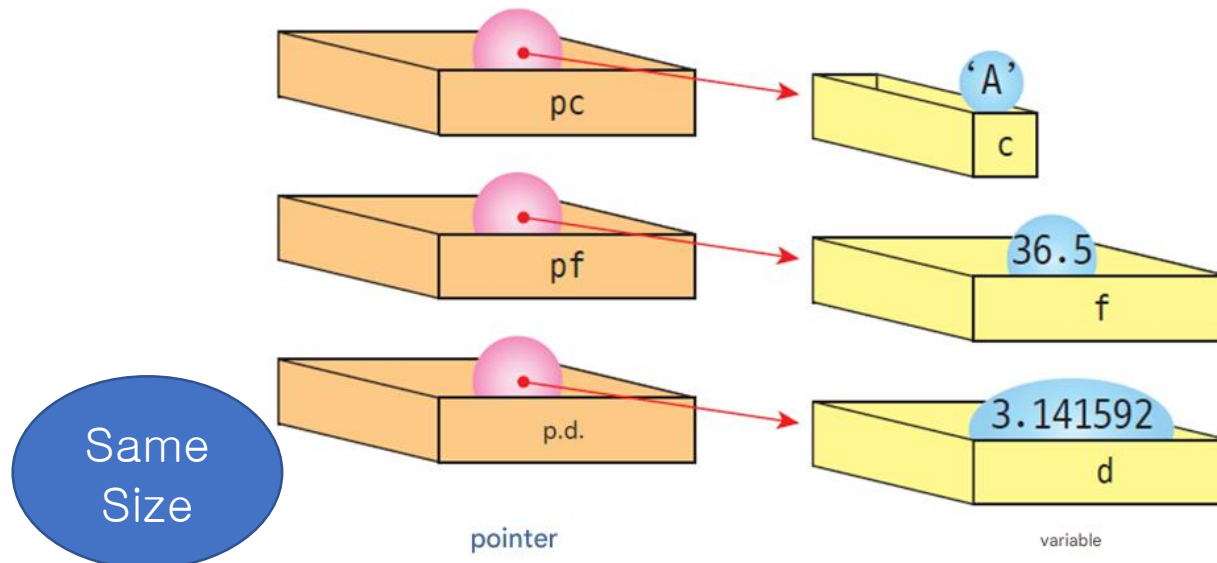
```
int i = 10; // declare of integer variable i
int * p;    // declare of pointer variable p
p = &i;     // assign the address of variable i to pointer p
```



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 ;

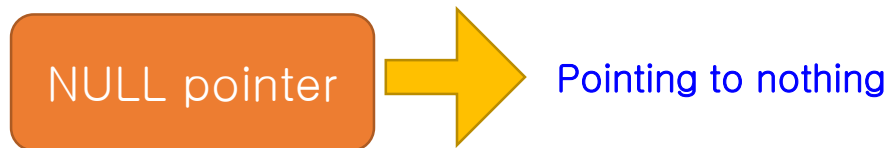
    double * pf = NULL ;
    pi = &i ;
    pf = &f;

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

```
0000002AFF8FFB24 0000002AFF8FFB24
0000002AFF8FFB48 0000002AFF8FFB48
```

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 .



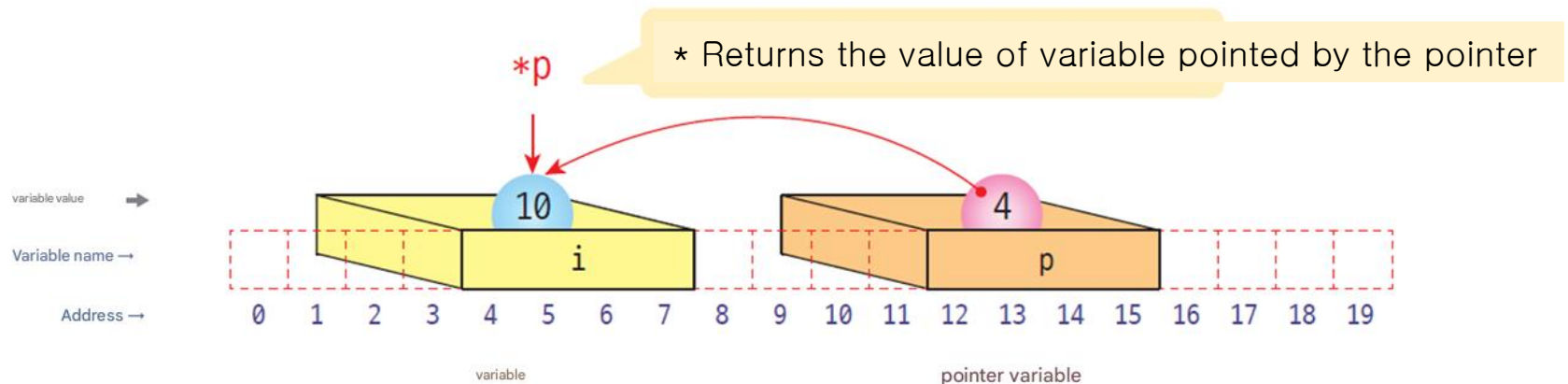
Indirect reference operator

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

```
int i = 10;
```

```
int * p;  
p = &i ;
```

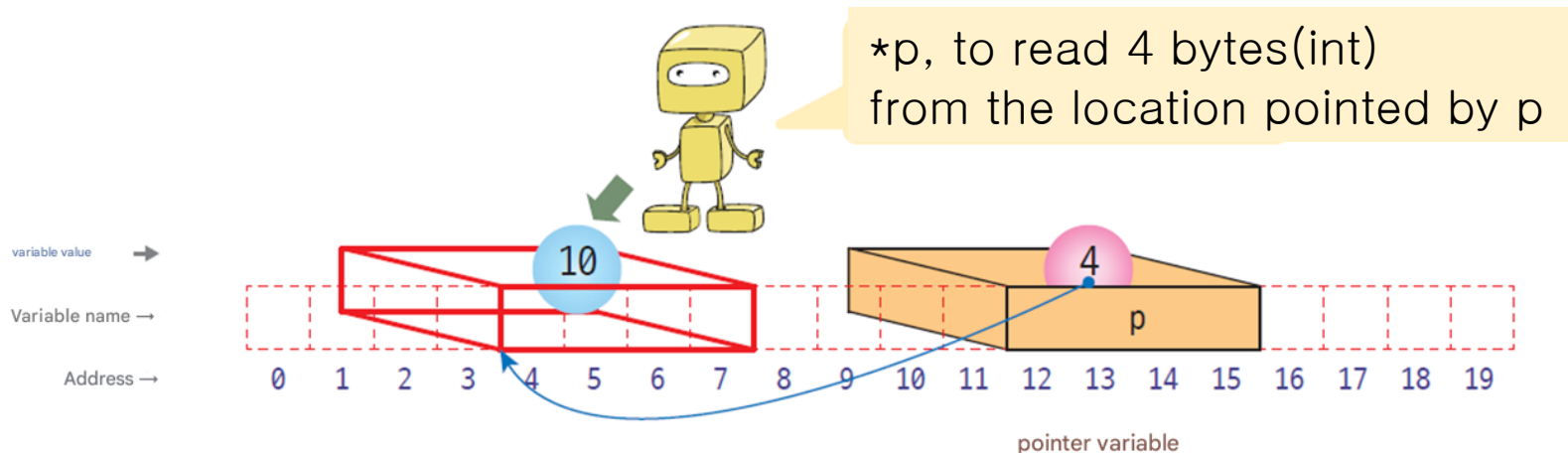
```
printf ( "%d \n" , *p);
```



Interpretation of indirect reference operators

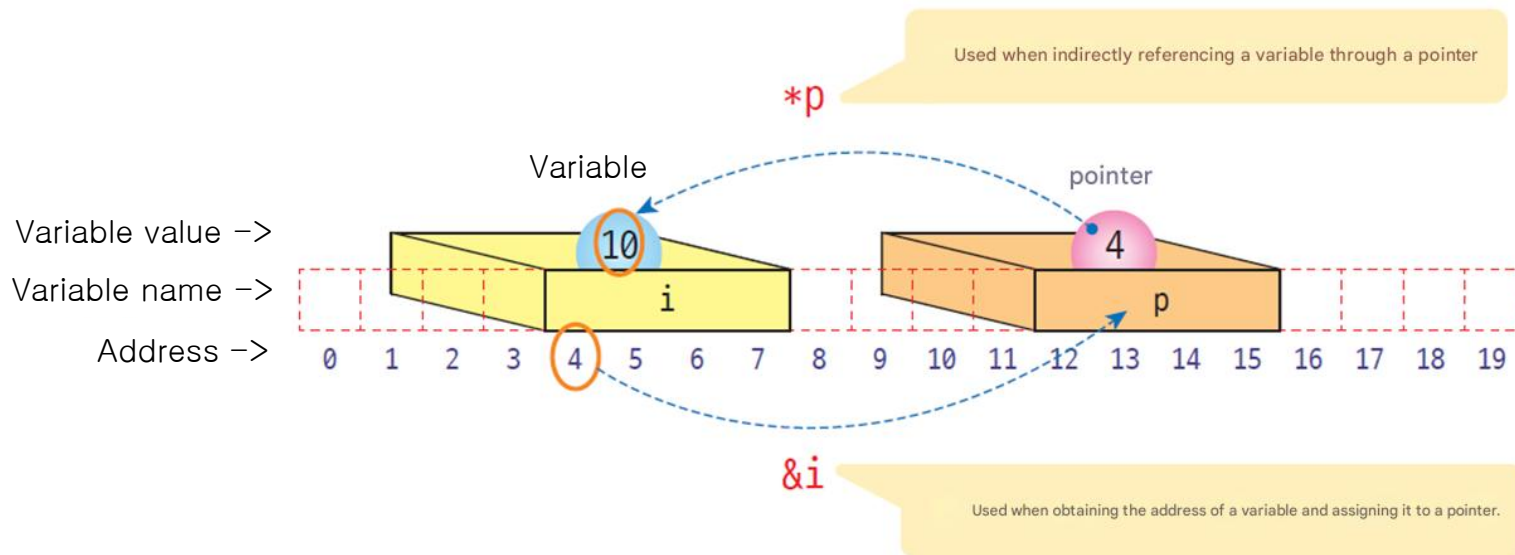
- Indirect reference operator : Reads a value **based on the type of the pointer** at the specified location .

```
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 .

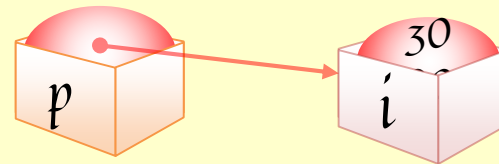


Pointer Example #1

```
#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

Pointer Example #2

```
#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);
```

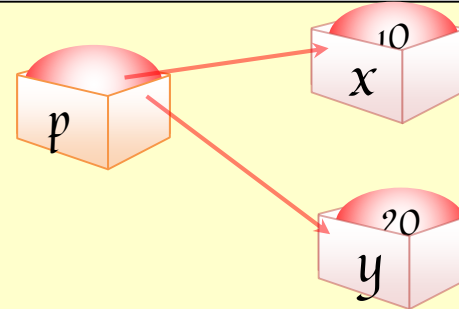
```
    p = &y;
```

```
    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;
```

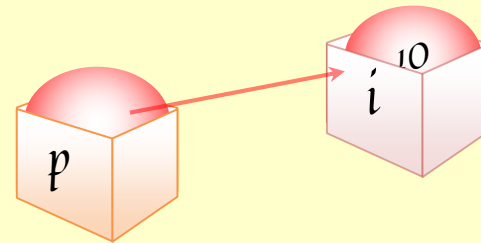
```
    printf ( " i = %d\n" , i );
```

```
    *p = 20;
```

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

```
    return 0;
```

```
}
```



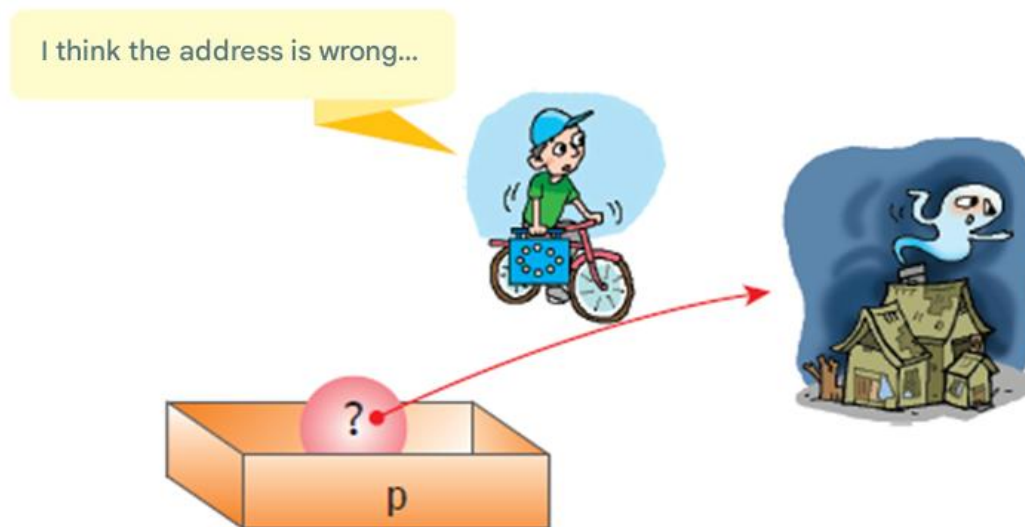
Change the value of a variable through a pointer.

```
i = 10  
i = 20
```

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”

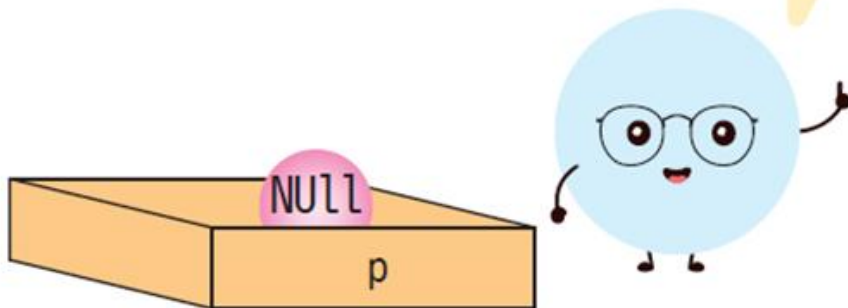


Cautions when using pointers

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

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

When the pointer points to nothing
Be sure to set it to NULL.



Cautions when using pointers

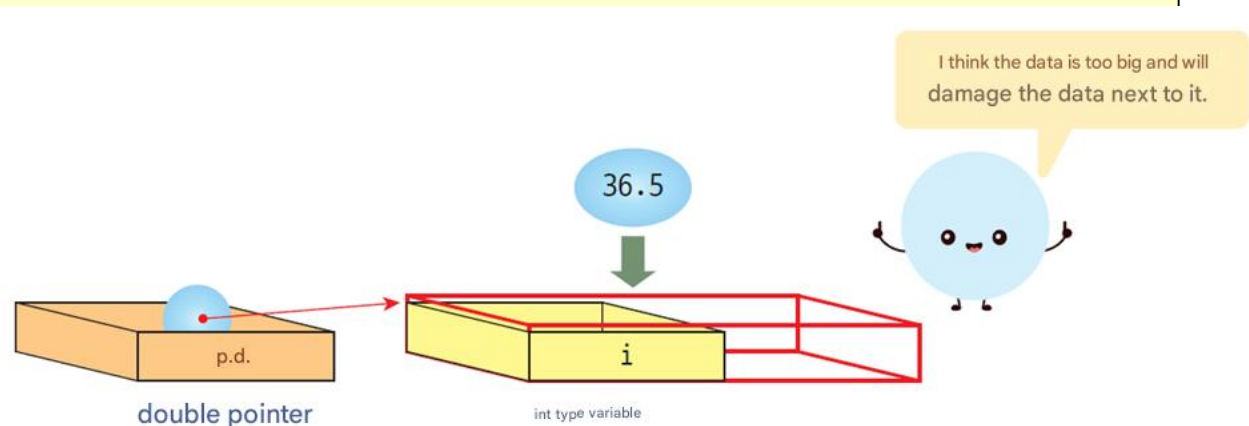
- The type of the pointer and the type of the variable must match.

```
#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

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

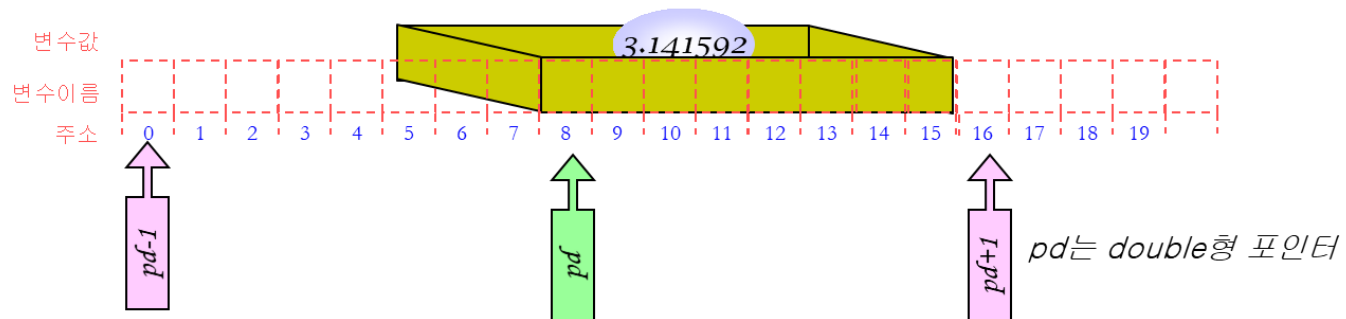
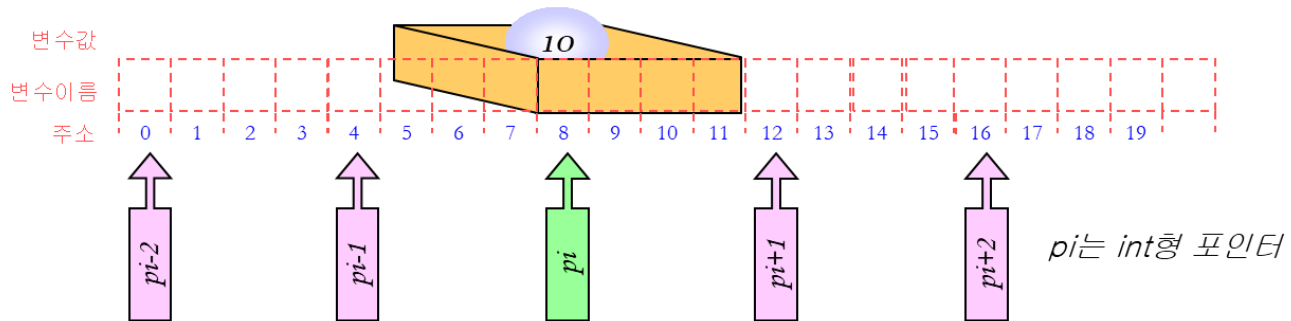
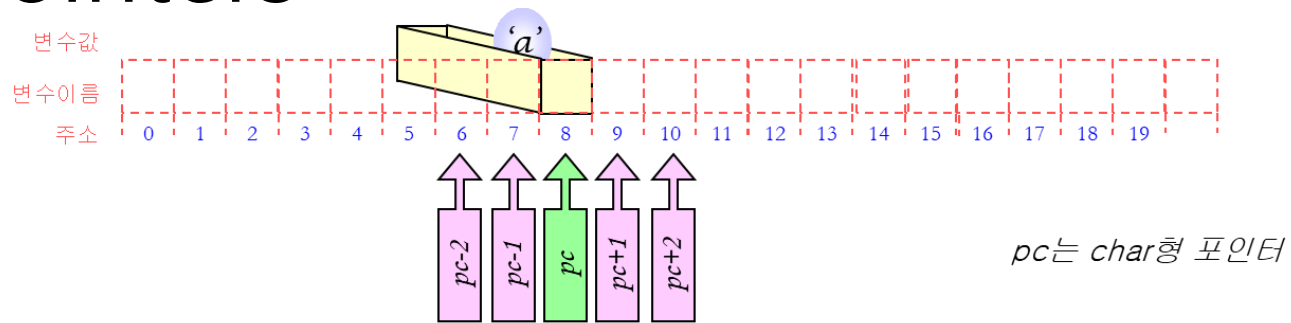
int main( void )
{
    char *pc;
    int *pi;
    double *pd;

    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
<code>v = *p++</code>	After assigning the value pointed to by <code>p</code> to <code>v</code> , increment <code>p</code> .
<code>v = (*p)++</code>	the value pointed to by <code>p</code> to <code>v</code> , increment the value pointed to.
<code>v = ++*p</code>	After incrementing <code>p</code> , assign the value pointed to by <code>p</code> to <code>v</code> .
<code>v = ++*p</code>	<code>p</code> increment that value and assign it to <code>v</code> .

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);
```

Increments the value at the location pointed to pi.

```
(*pi)++;
```

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

```
*pi++;
```

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

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

```
return 0;
```

```
}
```

i = 10, pi = 000000FFEB CFF974

i = 11, pi = 000000FFEB CFF974

i = 11, pi = 000000FFEB CFF978

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;
}
```

```
*(pc + 0) = 0D
*(pc + 1) = 0C
*(pc + 2) = 0B
*(pc + 3) = 0A
```

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);

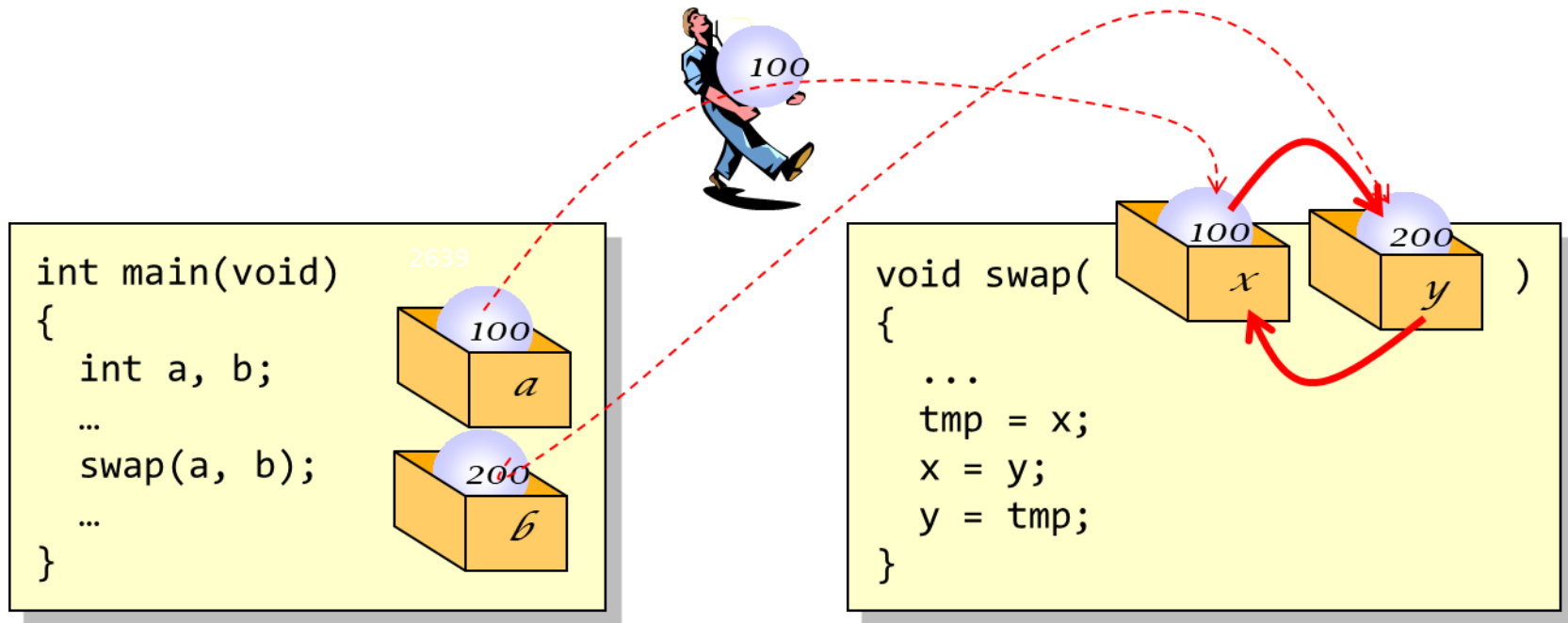
    tmp = x;
    x = y;
    y = tmp ;

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



```
a=100 b=200
x=100 y=200
x=200 y=100
a=100 b=200
```

Call by value



swap() function #2 (call by reference)

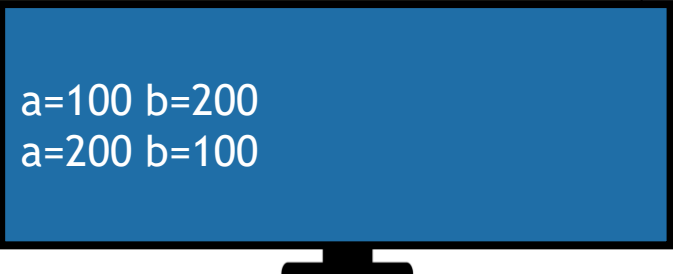
```
#include <stdio.h>
void swap( int *x, int *y);
int main( void )
{
    int a = 100, b = 200;
    printf("a=%db=%d\n",a, b);

    swap(&a, &b);

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

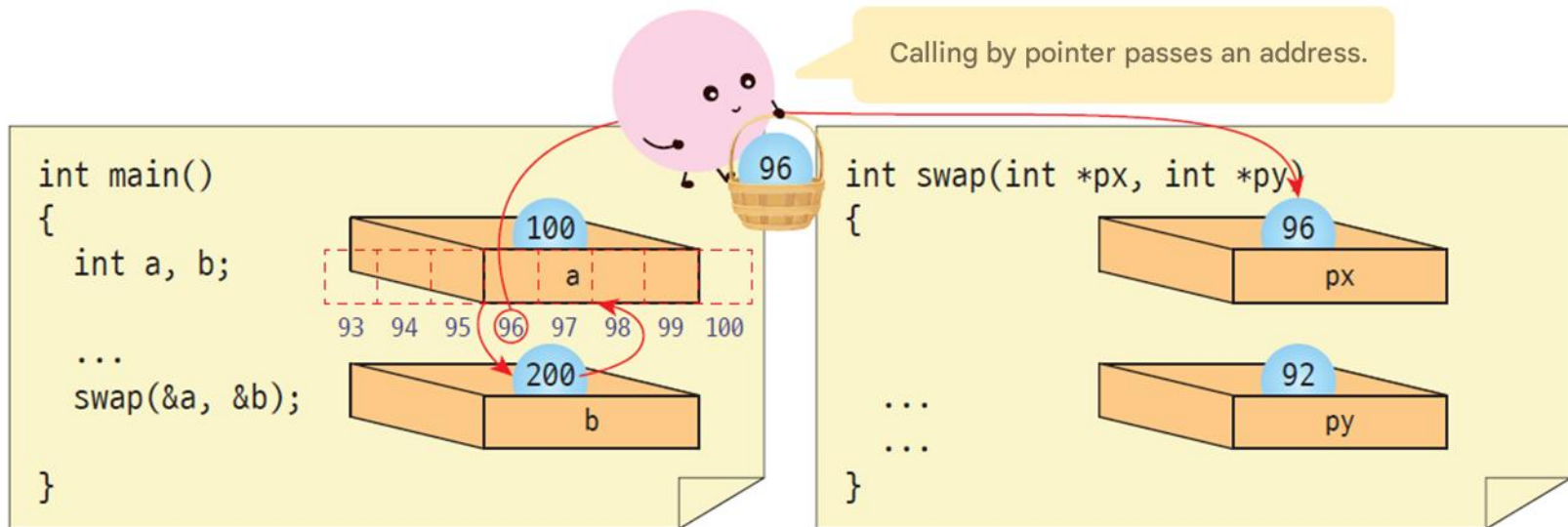
```
void swap( int *px , int *py )
{
    int tmp ;

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



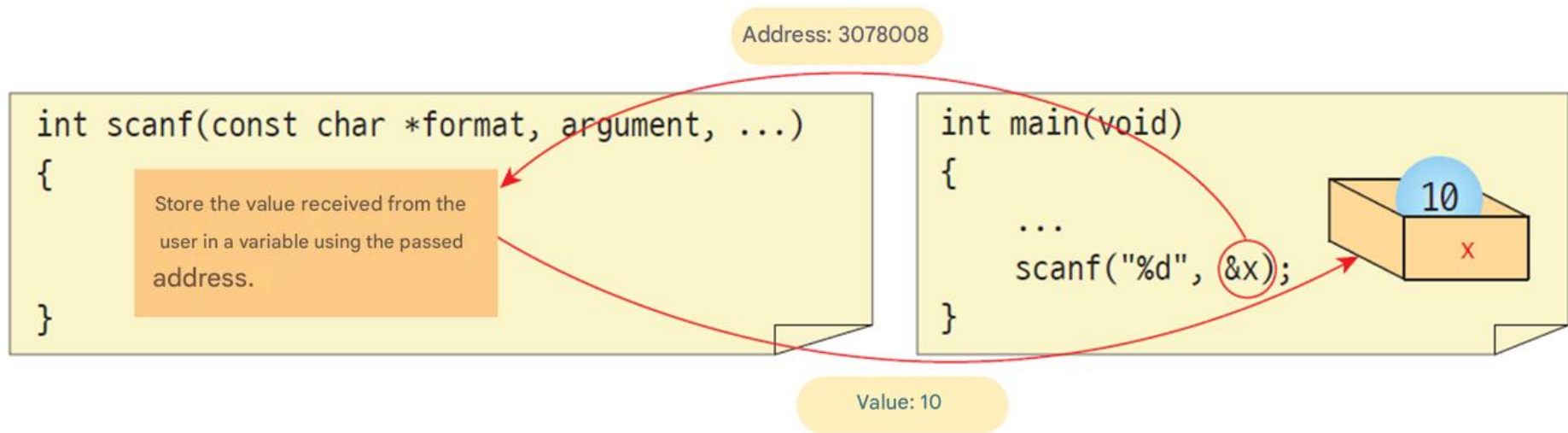
```
a=100 b=200
a=200 b=100
```

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 .



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

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;

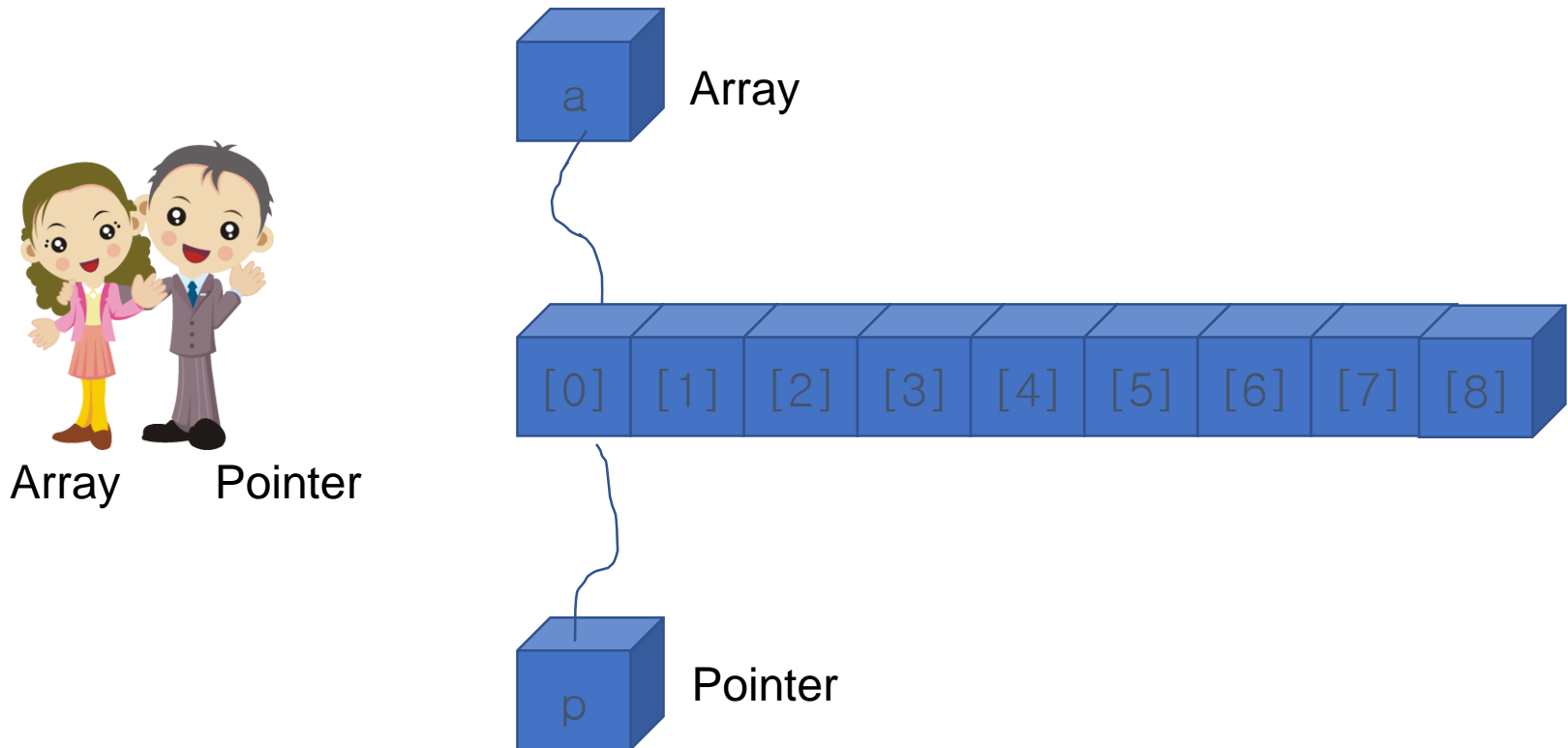
    result = x + y;
    return &result;
}
```

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 .



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]);
```

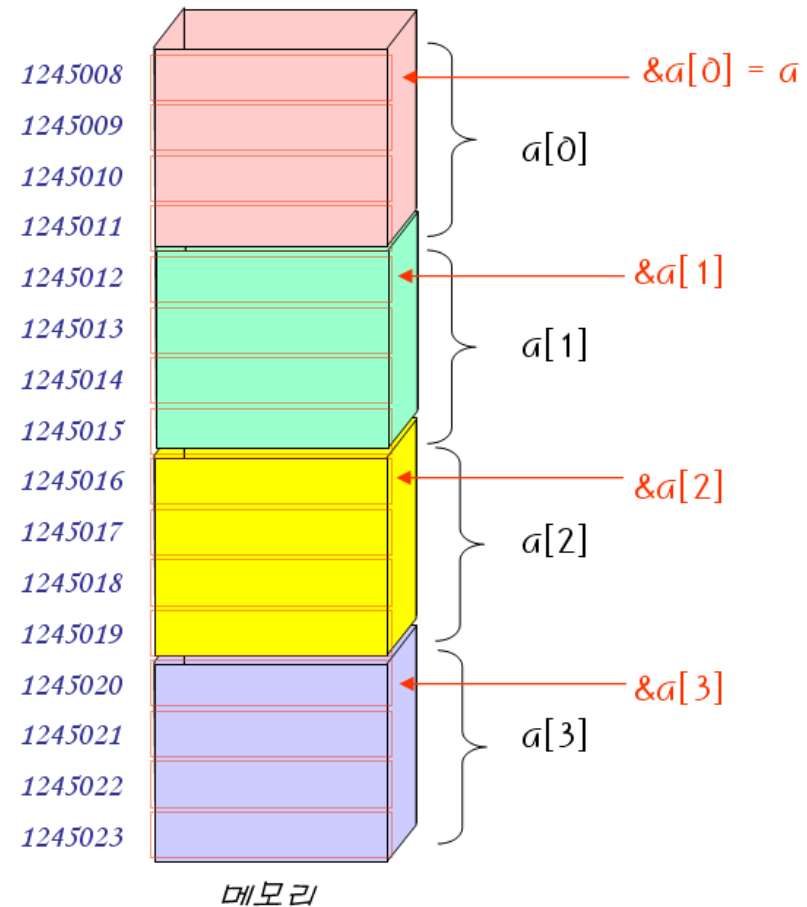
```
    printf ( "&a[1] = %u\n" , &a[1]);
```

```
    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

```
// 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
```

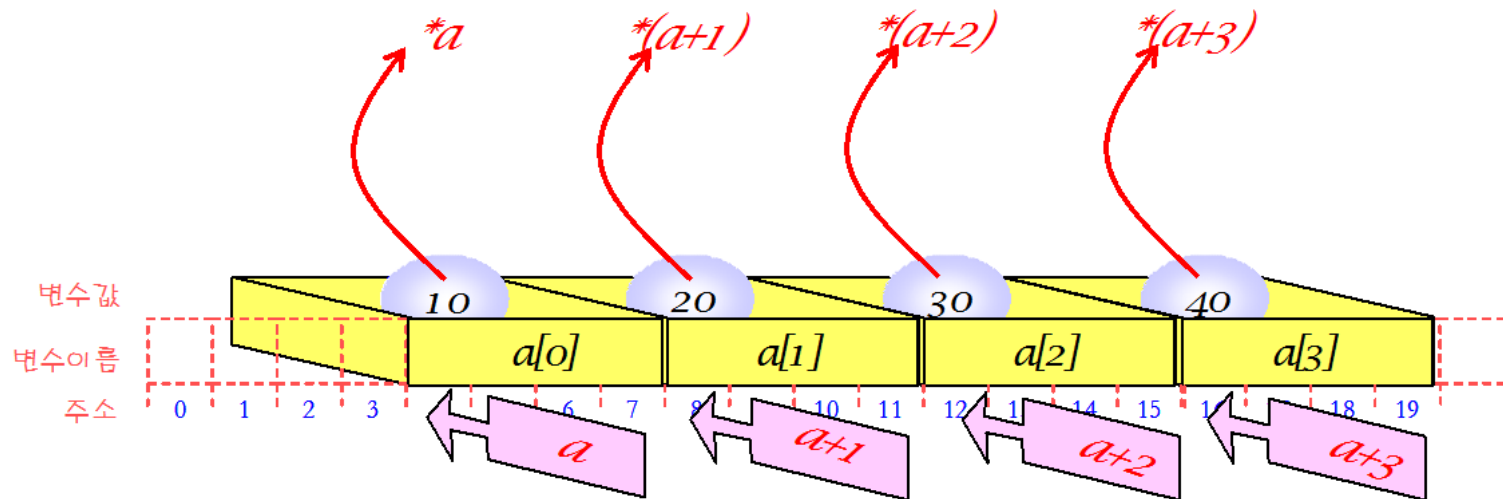
```
a + 1 = 1245012
```

```
*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], p[1], p[2]);
    return 0;
}
```

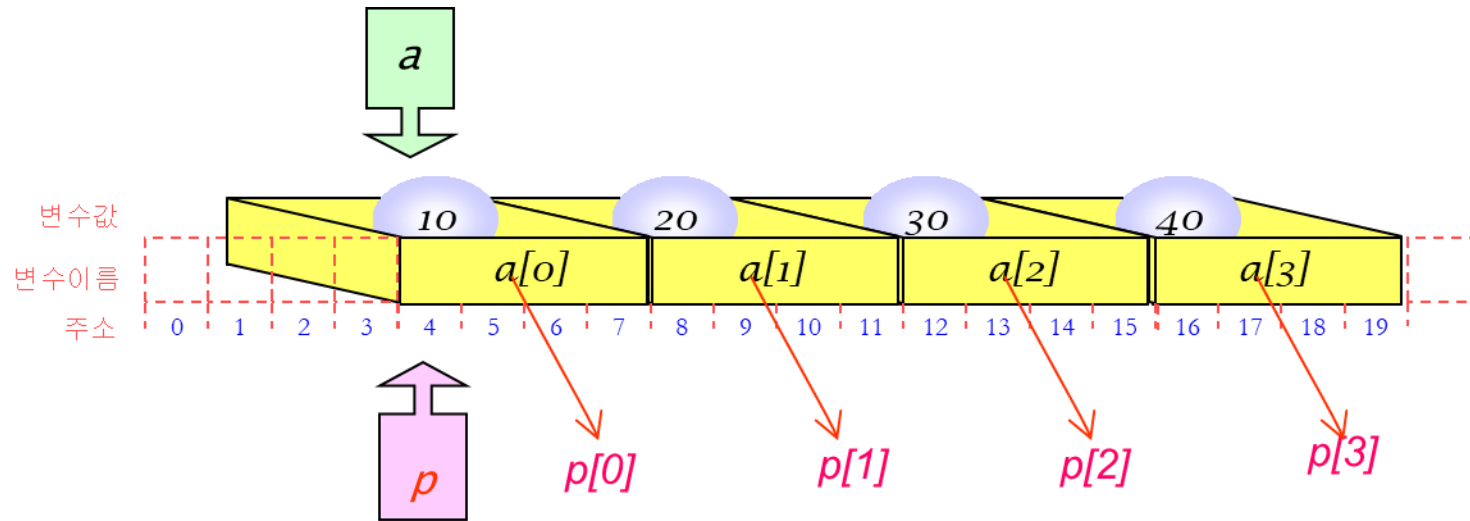
You can see that arrays are ultimately implemented as pointers .

Array elements can be changed through pointers.

a[0]=10 a[1]=20 a[2]=30
p[0]=10 p[1]=20 p[2]=30

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

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 .

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

    sub(a, 3);
}
```

The name of the array is a pointer.

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

You can change the original array through b.

// 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;
```

```
}
```



1 2 3
4 5 6

The following two methods are completely equivalent :

// pointer parameter

void sub(**int *b**, int size)

{

b[0] = 4;

b[1] = 5;

b[2] = 6;

}

-Array names and pointers are
fundamentally the same.

-Accessing elements
using array notation

// pointer parameter

void sub(int *b, int size)

{

*b = 4;

*(b+1) = 5;

*(b+2) = 6;

}

Accessing elements
using pointer notation

Advantages of using pointers

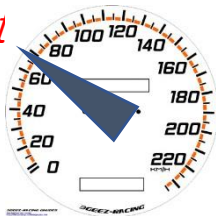
When the compiler optimizes, the performance becomes almost similar .

- 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;
}
```

*Using index
not*



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

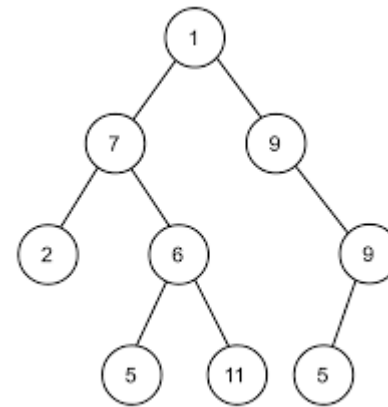
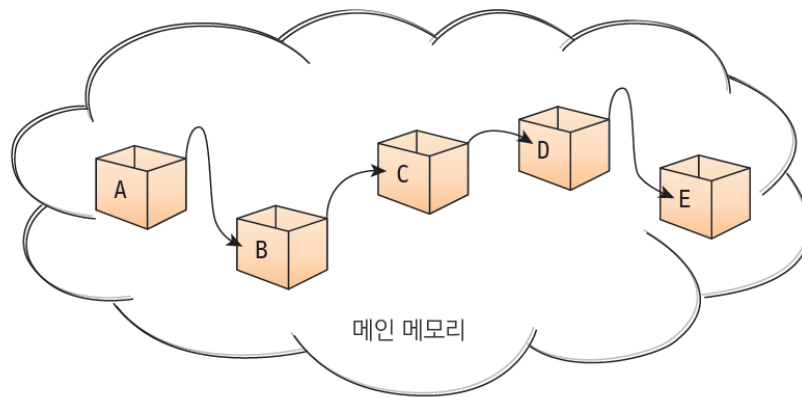
    p = a;
    for ( i = 0; i < n; i ++ )
        sum += *p++;
    return sum;
}
```

Using



Advantages of using pointers

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



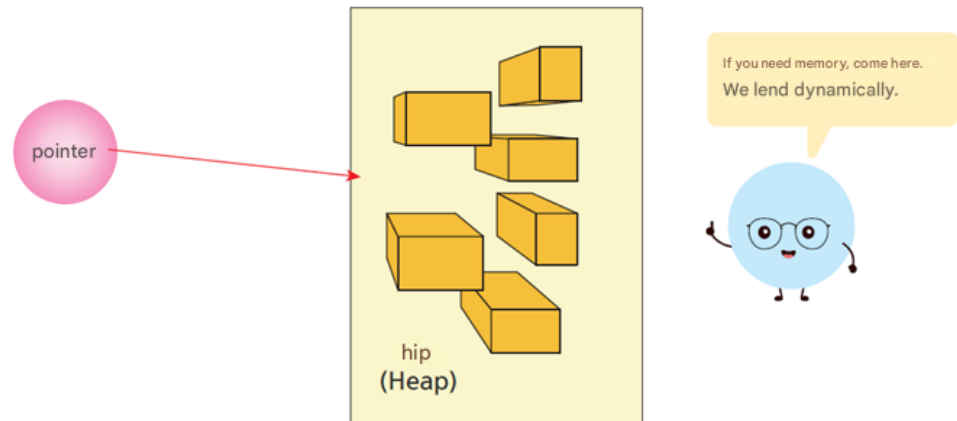
- Call by reference
 - You can change the value of a variable outside the function by using a pointer as a parameter .

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

