



EE2331 Data Structures and Algorithms

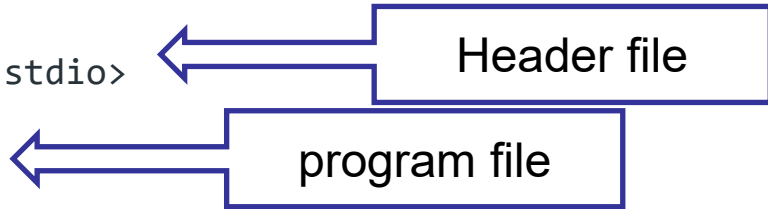
C++ Programming Review

Outline

In the lecture, we won't cover each page
but these are good reference for you.
The covered parts have gray background
in the title.

- Standard Libraries
- Basic Data Types
- Arithmetic, Bitwise, Logical Operators
- Control Structures
- Pointers
- Arrays
- Composite Structures
- Parameter Passing in Functions
- Standard I/O
- Pseudo Code
- Suggestion for Good Programming Practice

Let us start from an example (1)



```
#include <stdio>

int main()
{
    int A, B, C;                //local variable declaration

    printf("Enter the numbers A, B and C: "); //output function
    scanf("%d %d %d", &A, &B, &C);           //take inputs from standard input

    if (A >= B && A >= C)                //logic operator
        printf("%d is the largest number.", A);

    if (B >= A && B >= C)
        printf("%d is the largest number.", B);

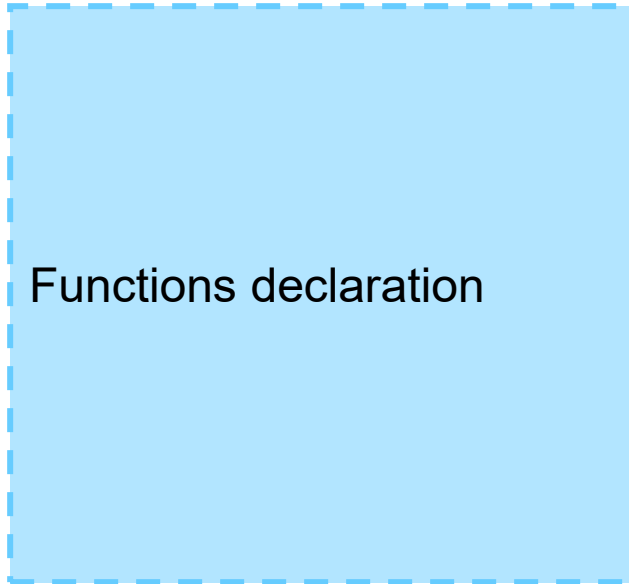
    if (C >= A && C >= B)
        printf("%d is the largest number.", C);

    return 0;                    //return to OS (0=successful completion)
}
```

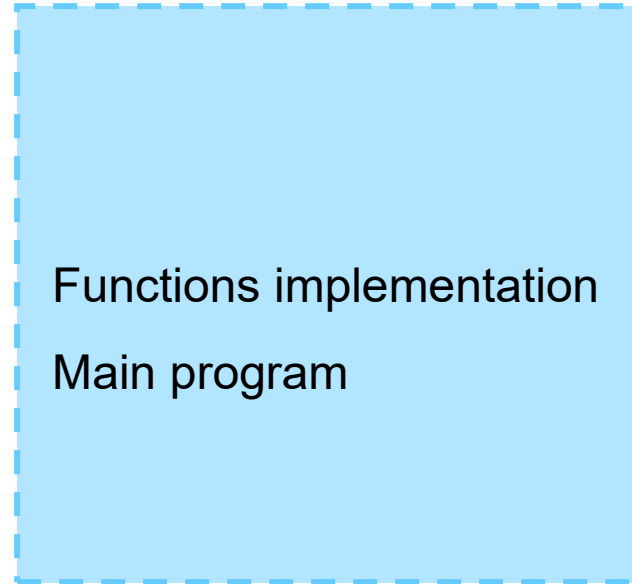
What is the purpose of this program?

C++ File Structure

Header file (.h)



Program file (.cpp)



A header file commonly contains forward declarations of subroutines. Programmers who wish **to declare functions in more than one source file** can place such declaration in a single header file, which other code can then **include** whenever the header contents are required.

Example 2 (self-defined header file)

```
#include <stdio>

/*
 * Demonstrate forward declaration of a function.
 */

int main(int argc, char** argv) {

    sayHello();
    return(0);
}

void sayHello() {
    printf("Welcome to EE2331!\n");
}
```

Can the above code compile successfully? If not, how to fix?

```
hello.cpp:11:5: error: use of undeclared identifier 'sayHello'
    sayHello();
    ^
1 error generated.
```

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

/*
 * Demonstrate forward declaration of a function.
 */

int main(int argc, char** argv) {

    sayHello();
    return(0);
}

void sayHello() {
    printf("Welcome to EE2331!\n");
}

hello.cpp (END)
```

```
// forward declaration
void sayHello();

hello.h (END)
```

Main Function

- There are two declarations of main that must be allowed:
 - `int main()` // without arguments
 - `int main(int argc, char** argv)` // with arguments
- The **return type** of main must be **int**.
 - Return zero to indicate success and non-zero to indicate failure.
 - You are not required to explicitly write a return statement in `main()`. If you let `main()` return without an explicit return statement, it's the same as if you had written `return 0;`.
 - `int main() { }` // equivalent to the next line
 - `int main() { return 0; }`
 - There are two macros, **EXIT_SUCCESS** and **EXIT_FAILURE**, defined in `<cstdlib>` that can also be returned from `main()` to indicate success and failure, respectively.

Command Line Arguments

 `C:\> assign1.exe dat1.txt data2 ... xxx`

Where's the
location of
your
compiled
program?

	↑	↑	↑	↑
	Your compiled program	1 st argument	2 nd argument	... n^{th}
	<code>argv[0]</code>	<code>argv[1]</code>	<code>argv[2]</code>	... <code>argv[n]</code>

Total no. of arguments (i.e. `argc` = $n + 1$)

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

`argc`: count
`argv`: value

Example 3

```
#include <stdio>

int main(int argc, char* argv[])
{
    if(argc!=3)
    {
        printf("Enter two integers\n!");
        return 0;
    }

    for (int i = 0; i < argc; i++)
        printf("argv[%d] = %s\n", i, argv[i]);

    return 0;
}
```

A useful method to remind your users of the input format!

After I compile this program, I got the executable **program ex3**.
Show the output of the following three commands:

`./ex3`



Enter two integers

`./ex3 4 9 10`



Enter two integers

`./ex3 4 9`



argv[0] = ./ex3
argv[1] = 4
argv[2] = 9

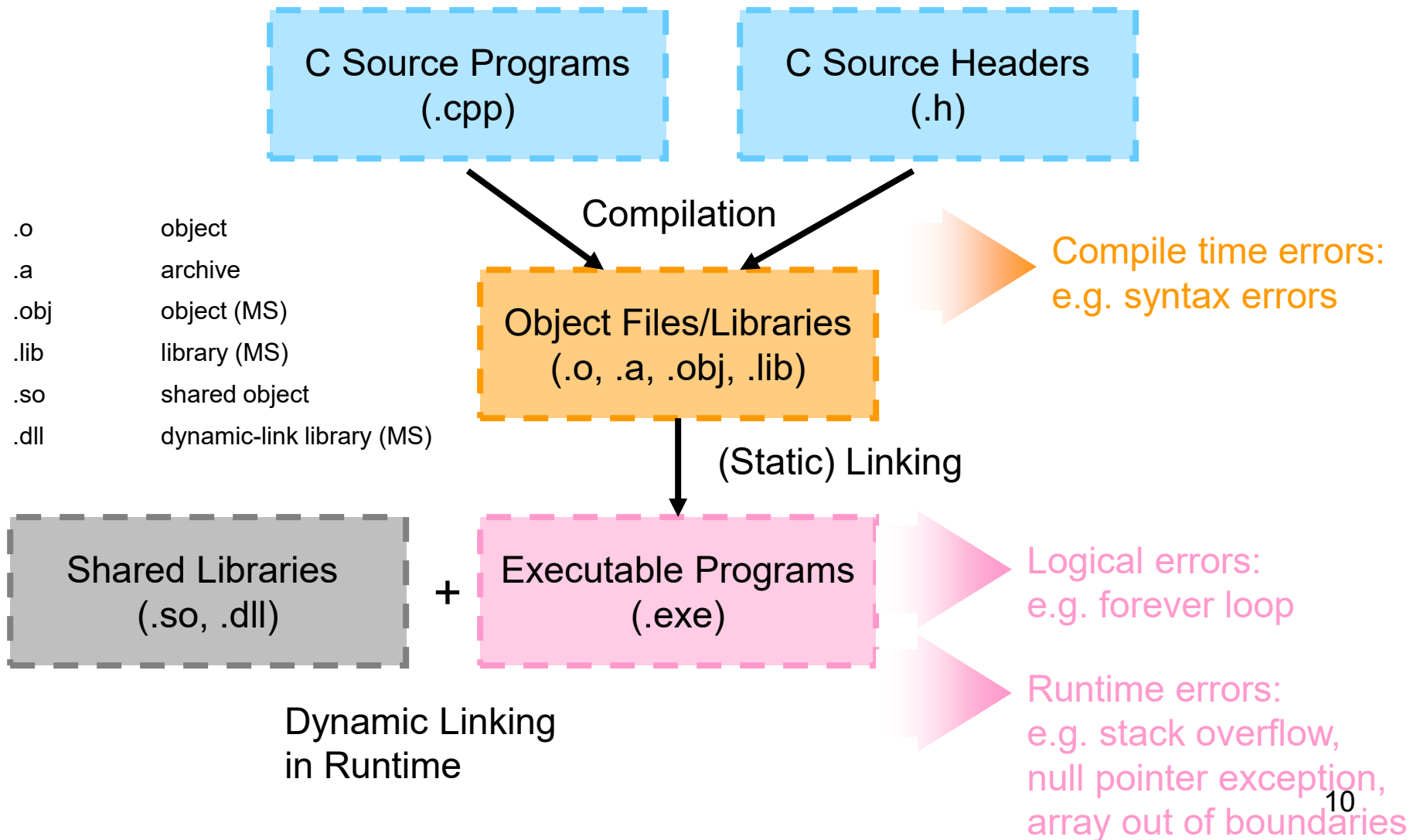
Command Line Arguments

```
int main(int argc, char *argv[]) {  
    printf("argc = %d\n", argc);  
    for (int i = 0; i < argc; i++)  
        printf("argv[%d] = %s\n", i, argv[i]);  
}
```

```
>ex1_2.exe 123 abc
```

```
argc = 3  
argv[0] = ex1_2.exe           //name of the program  
argv[1] = 123                 //string, not integer  
argv[2] = abc
```

The Building Process



Common Standard Library Header

■ `<cstdio>`

- Standard I/O facilities: `printf()`, `scanf()`, `getchar()`, `fopen()`, `fclose()`, etc

■ `<cstdlib>`

- Standard utility functions: `malloc()`, `free()`, `rand()`, etc

■ `<cstring>`

- String functions: `strcpy()`, `strcmp()`, `memset()`, etc

■ `<iostream>`

- Perform both input and output operations with the stream objects: **`cin`** and **`cout`**

Comments

```
/* Block comment 1 */
```

```
/*  
 * Block comment 2  
 */
```

```
// Line comment
```

Primitive Data Types in C++

Data type	Size (byte)	Interpretation/representation	Range of values
bool	1	Boolean (not available in C)	false or true
char	1	signed number (2's complement)	-128 to 127
unsigned char		unsigned number	0 to 255
int	4	signed number (2's complement)	-2^{31} to $2^{31}-1$
unsigned int		unsigned number	0 to $2^{32}-1$
short	2	signed number (2's complement)	-2^{15} to $2^{15}-1$
unsigned short		unsigned number	0 to $2^{16}-1$
long	4	signed number (2's complement)	-2^{31} to $2^{31}-1$
unsigned long		unsigned number	0 to $2^{32}-1$
long long	8	signed number (2's complement)	-2^{63} to $2^{63}-1$
unsigned long long		unsigned number	0 to $2^{64}-1$
float	4	IEEE 32-bit floating point number	$\pm 1.4 \times 10^{-45}$ to $\pm 3.4 \times 10^{38}$
double	8	IEEE 64-bit floating point number	$\pm 5 \times 10^{-324}$ to $\pm 1.798 \times 10^{308}$
pointer	4	memory address	0 to $2^{32}-1$

pointer's size is 4 bytes for 32-bit machine; 8 bytes for 64-bit machine

Operators in C++

Operator	Symbol	Description
Assignment	=	
Arithmetic	+, -, *, /, %	
Increment, decrement	++, --	
Unary minus	-	
Comparison	==, !=, <, <=, >, >=	
Logical	!, &&,	
Bitwise	~, &, , ^, <<, >>	
insertion, extraction	cout << s cin >> i	insertion to an output stream extraction from an input stream
Member and pointer	x[i]	subscript (x is an array or a pointer)
	*x	indirection, dereference (x is a pointer)
	&x	reference (address of x)
	x->y	structure dereference (x is a pointer to object/struct; y is a member of the object/struct pointed to by x)
	x.y	structure reference (x is an object or struct; y is a member of x)

Use of Variables

■ Declaration

- Given an identifier (variable name), you specify the data type of it and hence implicitly reserve the required memory space.

■ Initialization

- Variables should be initialized before being used.

```
int a;  
cout << a;    // prints dummy value
```

Arithmetic Operators

■ Addition

```
int a, b, c;  
a = 1;  
b = 2;  
c = a + b;  
printf("%d\n", c);
```

■ Mind the **overflow** problem

```
int a, b, c;  
a = b = 2147483647; //the largest value of signed int  
c = a + b;  
printf("%d\n", c);
```


Arithmetic Operators

■ Subtraction

```
int a, b, c;  
a = 1;  
b = 2;  
c = a - b;  
printf("%d\n", c);
```

■ Mind the **underflow** problem

```
int a, b, c;  
a = -2147483648; //the smallest value of signed int  
b = 2147483647;  //the largest value of signed int  
c = a - b;  
printf("%d\n", c);
```

Arithmetic Operators

■ Division

```
int a, b, c;  
a = 5;  
b = 2;  
c = a / b;  
printf("%d\n", c);    // output is 2
```

■ Integer truncation occurs

Arithmetic Operators

■ Remainder (Modulus Operator)

```
int a, b, c;  
a = 5;  
b = 2;  
c = a % b;  
printf("%d\n", c);
```

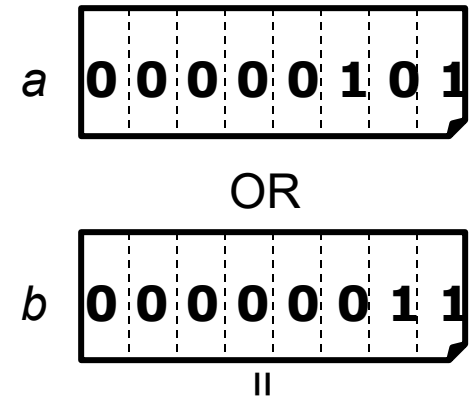
■ When to use it?

- Generate **periodic values**
- To wrap around the array index (in Queue)
- To determine the hash key (in Hash table)

Bitwise & Logical Operators

■ Bitwise OR

```
int a, b, c;  
a = 5;  
b = 3;  
c = a | b;  
printf("%d\n", c);
```



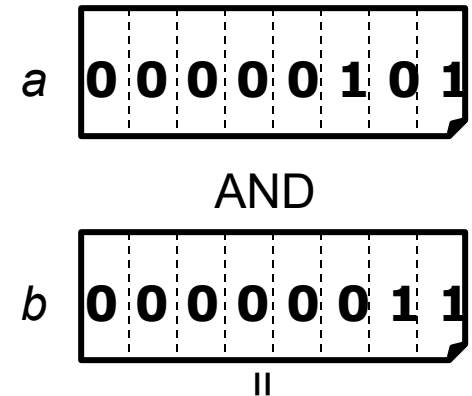
■ Logical OR

```
int a, b, c;  
a = 5;  
b = 3;  
c = a || b;  
printf("%d\n", c);
```

Bitwise & Logical Operators

■ Bitwise AND

```
int a, b, c;  
a = 5;  
b = 3;  
c = a & b;  
printf("%d\n", c);
```



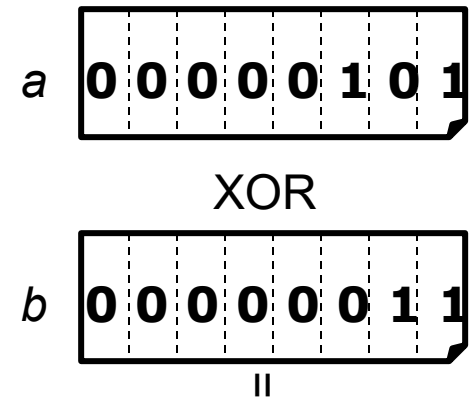
■ Logical AND

```
int a, b, c;  
a = 5;  
b = 3;  
c = a && b;  
printf("%d\n", c);
```

Bitwise Operators

■ Exclusive OR

```
int a, b, c;  
a = 5;  
b = 3;  
c = a ^ b;  
printf("%d\n", c);
```



■ When to use it?

- Interchange two variables

Bitwise Operators

■ Left Shift (x2)

```
int a, b;  
a = 5;  
b = a << 1;  
printf("%d\n", b);
```

a

0	0	0	0	0	1	0	1
---	---	---	---	---	---	---	---

b

0	0	0	0	1	0	1	0
---	---	---	---	---	---	---	---

■ Right Shift (/2)

```
int a, b;  
a = 5;  
b = a >> 1;  
printf("%d\n", b);
```

b

0	0	0	0	0	0	1	0
---	---	---	---	---	---	---	---

Variable Assignments

■ Example 1

```
int a, b, c;  
a = b = c = 5;  
printf("%d\n", a);
```

■ Example 2

```
int a = 5, b = 5, c = 5;  
a = b == c;  
printf("%d\n", a);
```

What are the outputs of the two examples?

Typecasting

■ Example 1 - Implicit

```
int a;  
float b = 10.5;  
a = b; // precision loss with warning  
printf("%d %f\n", a, b); // 10 10.5
```

■ Example 2 - Explicit

```
int a;  
float b = 10.5;  
a = (int) b; // still precision loss but NO warning  
printf("%d %f\n", a, b); // 10 10.5
```

Typecasting

■ Example 3

```
int a = 3;  
int b = 2;  
int c = 4;  
cout << a / b * c << endl; // output is 4 !!  
cout << a * c / b << endl; // output is 6
```

- The resultant type of an arithmetic operation will be promoted to the type of the operators with larger precision.
 - $\text{int} / \text{int} \rightarrow \text{int}$
 - $\text{float} / \text{int} \rightarrow \text{float}$

Control Structures

If-then-else

- **?** : (ternary operator)
 - equivalent to if-then-else
 - *expression ? true instruction : false instruction;*

```
if (a < b)
    min = a;
else
    min = b;
```

```
min = a < b ? a : b;
```

For-Loop and While-Loop

- for-loop and while-loop are interchangeable

```
for (initialization; loop_test; loop_counting) {  
    //loop-body  
}
```

```
initialization;  
while (loop_test) {  
    //loop-body  
    loop_counting;  
}
```

Loop head is executed one more time than loop body. But we won't care about this slight difference.

Jump Statements

- Jump statements allow the early termination of loops
- These cause unconditional branches
 - `goto` is bad practice and will not be dealt with
 - `break` will exit the inner most loop
 - `continue` will force the next iteration
 - `return` will return to the calling function
 - `exit` will quit the program

Breaking Out Loops Early

```
for (i = 0; i < n; i++) {  
    ...  
    if (...) break;           //to break out the for-loop  
    ...  
}
```

```
while (...) {  
    ...  
    if (...) continue;       //to skip the rest part of current iteration,  
                             //and continue for next iteration  
    ...  
}
```

Bad Styles of Loop

// DON'T use != (Not equal) to test the end of a range

```
for (i = 1; i != n; i++) {  
    //loop body  
}
```

// How does the loop behave if n happens to be zero or negative?

// DON'T modify the value of the loop-counter inside the loop body of a for-loop.

```
for (i = 1; i <= n; i++) {  
    //main body of the loop  
    if (testCondition)  
        i = i + displacement;
```

//i++ is executed before going back to top of the loop

```
}
```


Breaking Out Functions Early

```
void func(...) {  
    ...  
    if (...) return;           //to break out the function  
    ...  
}
```

```
int func(...) {  
    ...  
    if (...) return 0;        //to break out the function, and  
                               //return a value to the calling function  
    ...  
}
```

Breaking Out Programs Early

```
void func(...) {  
    ...  
    if (...) exit(0);           //to terminate the program, and  
                                //return normal exit value 0 to operating  
    ...                         //system!  
}
```

```
int main(...) {  
    ...  
    if (...) exit(1);           //to terminate the program, and  
                                //return abnormal exit value 1 to  
    ...                         //operating system!  
    return 0;                   //normal completion of the program  
}
```

Loop Design

- Find the maximum value in an array of integers.
- In-class exercise: any mistake in this program?

```
int max(int a[], int n) {           //n = no. of elements in a[]
    int m = 0;                      // variable to store the max value
    for (int i = 0; i < n; i++)
        if (a[i] > m)
            m = a[i];
    return m;
}
```

Pointers and Arrays

Pointers

Note: The actual size of integers and pointers are 4-byte long

```
① int a, *p;  
② a = 5;  
③ p = &a;
```

a: value of *a* (i.e. 5)

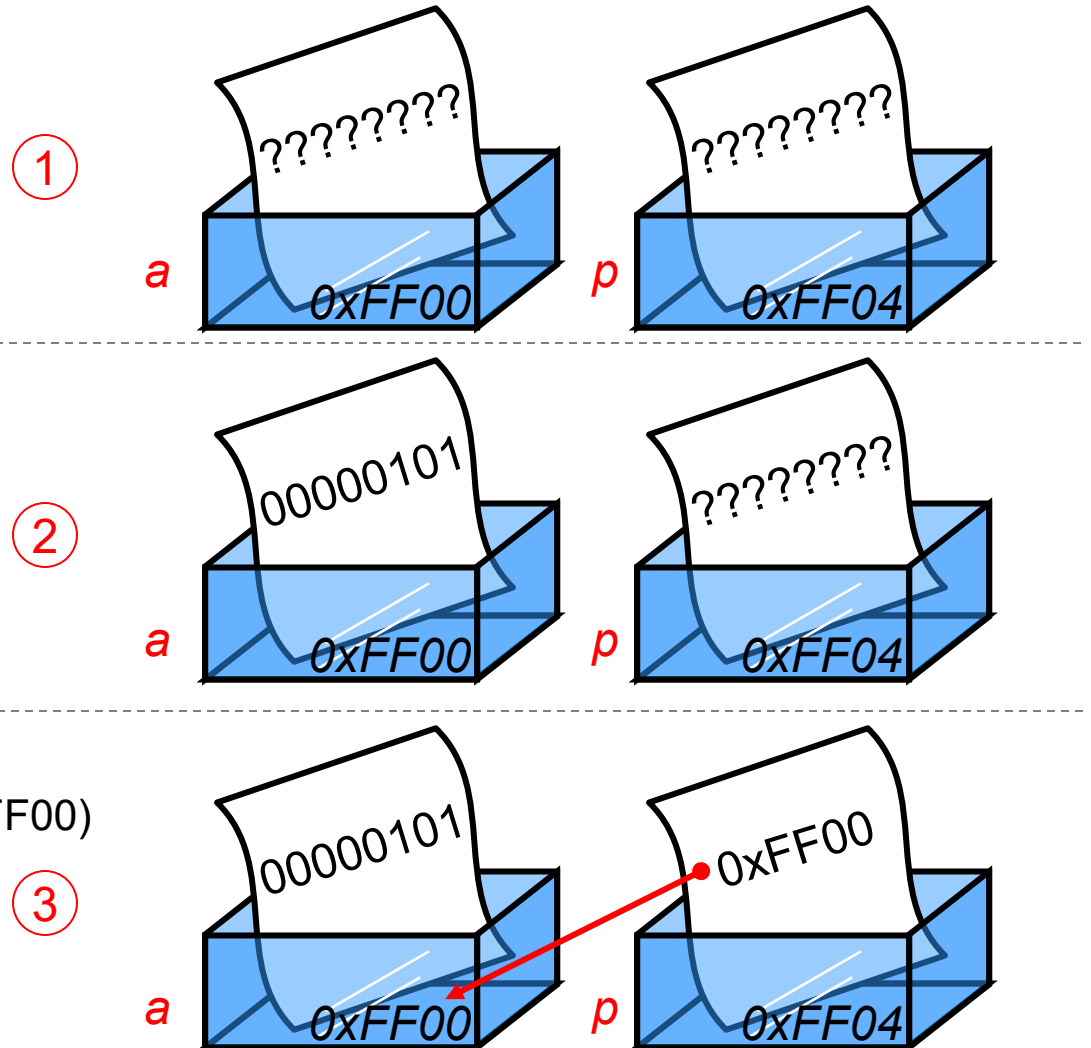
&a: address of *a* (i.e. 0xFF00)

*a: ?

p: value of *p* == address of *a* (i.e. 0xFF00)

&p: address of *p* (i.e. 0xFF04)

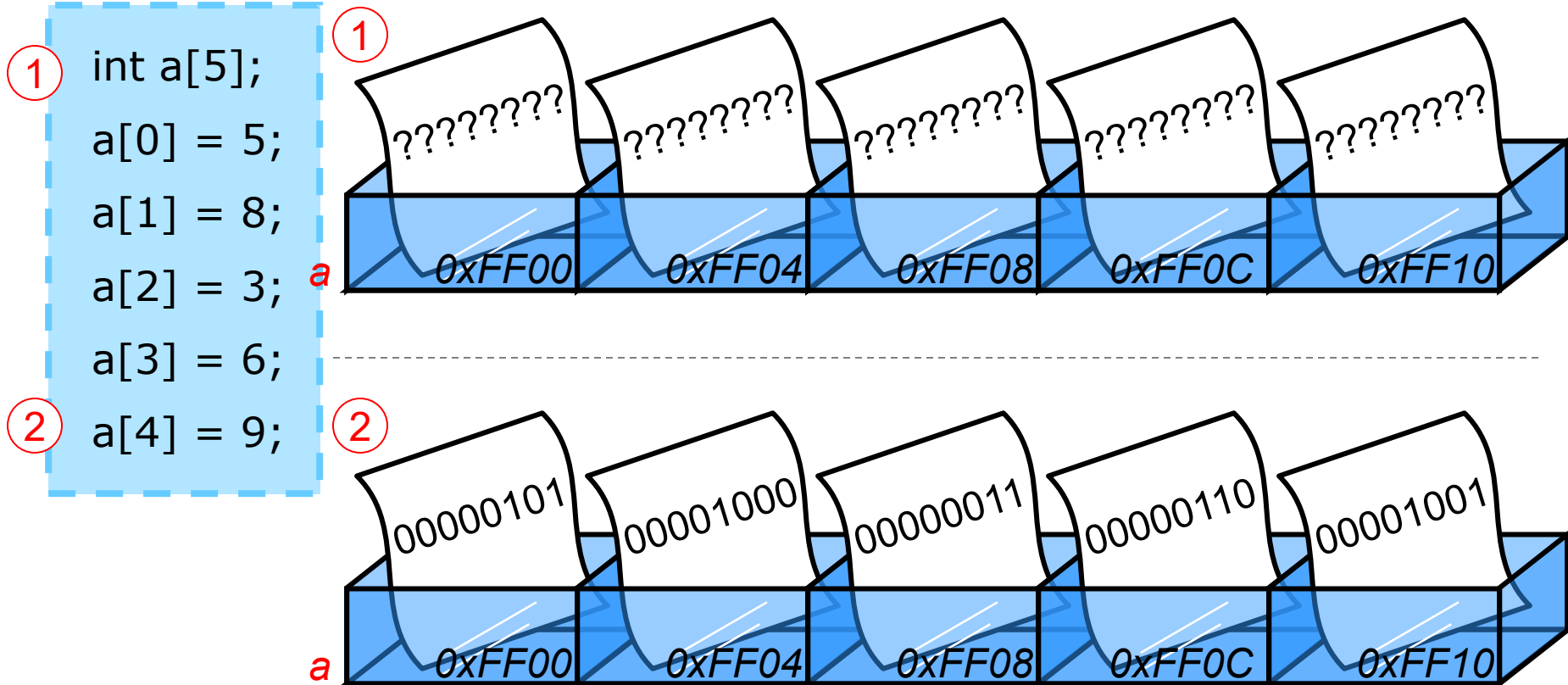
*p: value pointed by *p* (i.e. 5)



Pointers Example

```
int x = 1, y = 2;  
int *a, *b, *c;  
  
a = &x;  
b = &y;  
printf("%d %d %d %d\n", x, y, *a, *b);  
  
c = a;           // swap a with b  
a = b;  
b = c;  
printf("%d %d %d %d\n", x, y, *a, *b);
```

Creation of Array



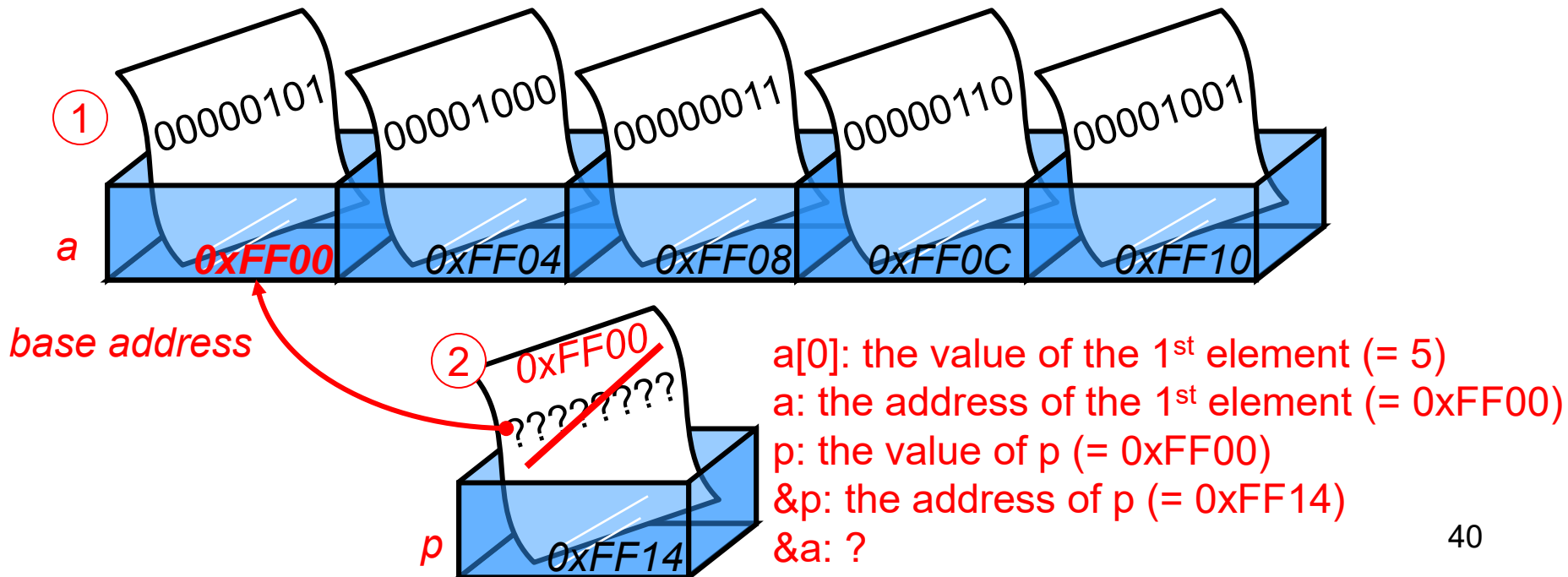
Note: the elements of integer array should be 4-byte long.

Base Address of Arrays

Initialization, set size implicitly

```
① int a[] = {5, 8, 3, 6, 9};  
   int *p;  
② p = a; //why not p = &a; ??
```

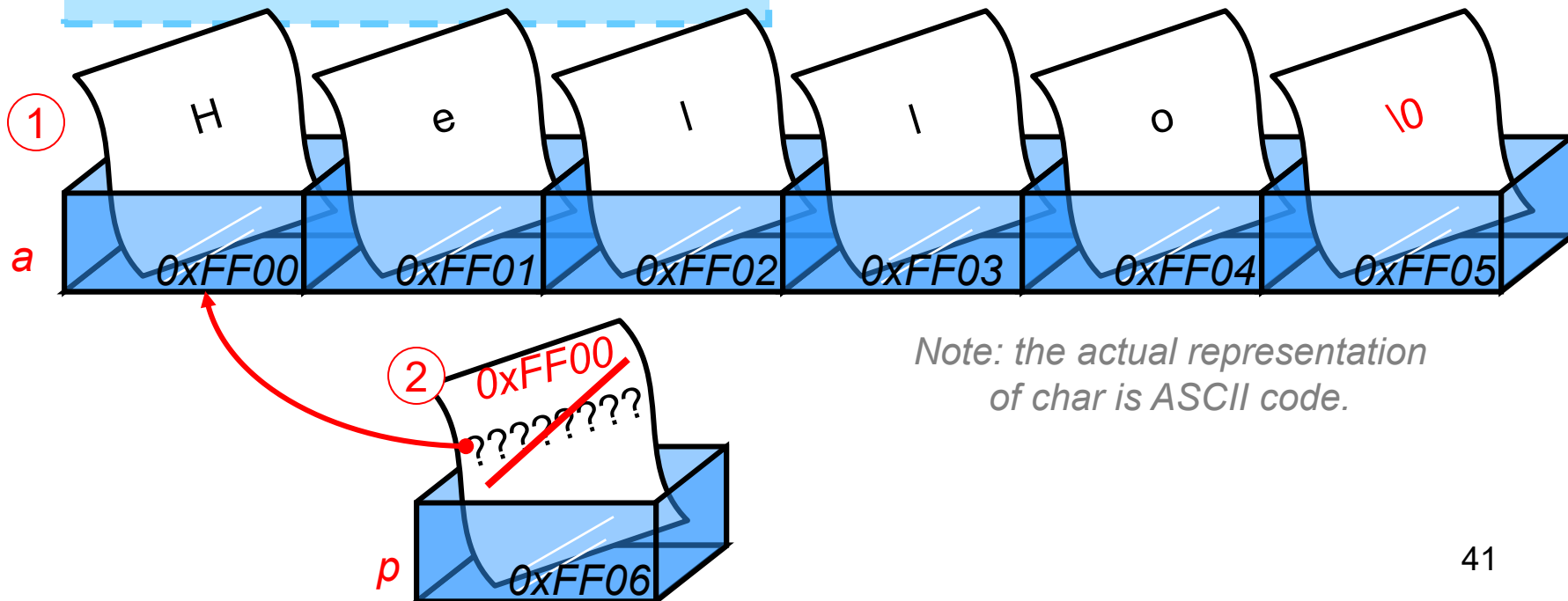
The array variable 'a' is interpreted as a pointer pointing to the first element (base address) of the array.



C-String (Character Array)

```
① char a[] = "Hello";  
  char *p;  
② p = a;  
  printf("%d\n", sizeof(a));
```

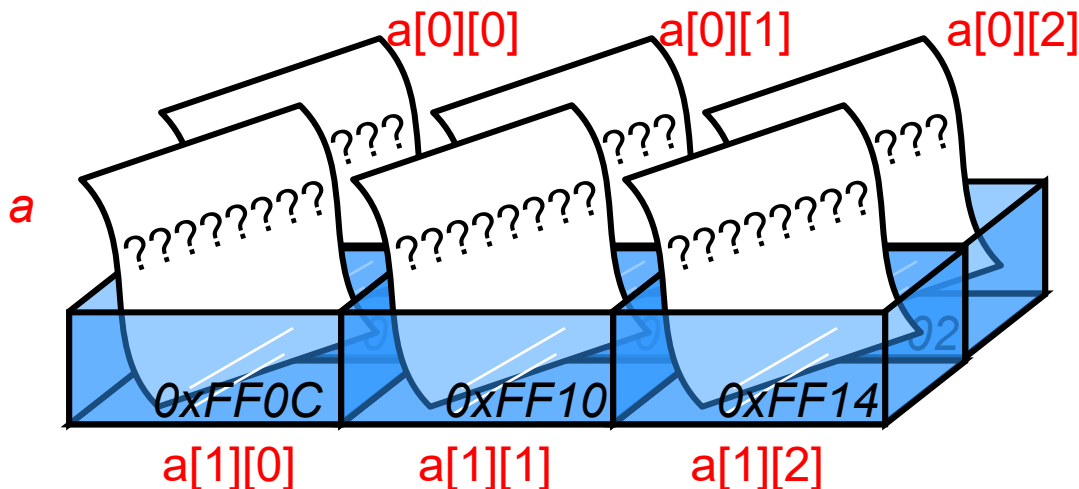
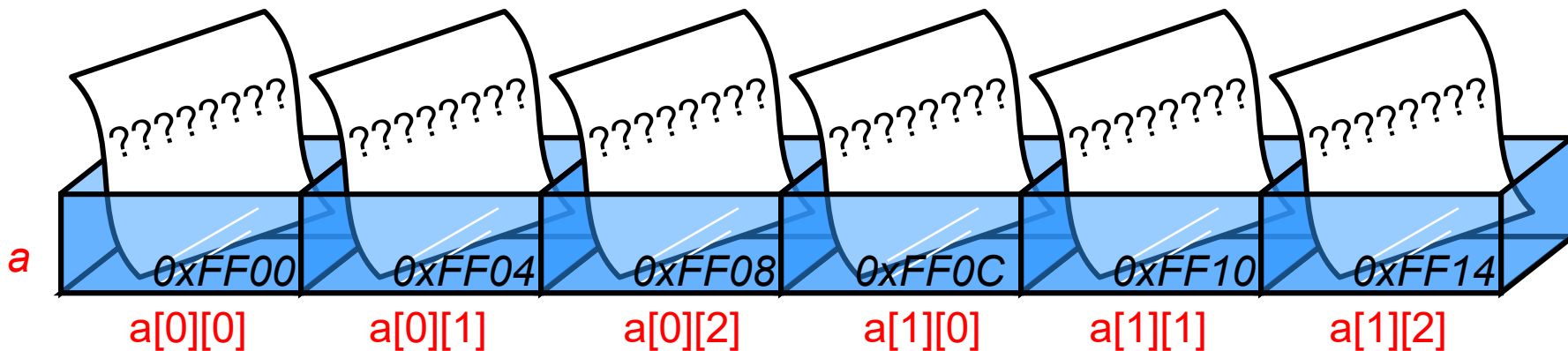
Null character ('\0') filled at the end
of character array (string)



2D Arrays

```
int a[2][3]; //2 rows, 3 columns
```

Multi-dimensional arrays are mapped to the linear address space of the computer system.



*In C/C++, elements of a multi-dimensional array are arranged in **row-major order**.*

Size of Array

- The size of array is **fixed** and **predetermined**
- Cannot declare an array with variable size

```
#define n 10    //n is a macro  
int i, a[n];    //ok, n is substituted by 10 during compilation  
for (i = 0; i < n; i++)  
    a[i] = i;
```

```
int n=100;      // n is a variable  
int i, a[n];    // compilation error, a commonly seen mistake  
for (i = 0; i < n; i++)  
    a[i] = i;
```

Boundaries of Array

- C/C++ will not check the boundaries of array

```
int a[10];  
a[11] = 0;    //allow to run (dangerous!)  
              //but result is unpredictable!
```

- It is the responsibility of programmers to ensure not going out the boundaries

```
int a[10];  
int i = 11;  
if (i >= 0 && i < 10) a[i] = ...; //boundaries checking
```

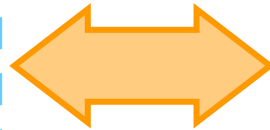
Composite Structures

Typedef

- To rename a type to a new name

```
int func(int x) {  
    return x*x;  
}  
int main(...) {  
    int a, b;  
    a = 1;  
    b = func(a);  
    ...  
}
```

equivalent



```
typedef int NUM;  
NUM func(NUM x) {  
    return x*x;  
}  
int main(...) {  
    NUM a, b;  
    a = 1;  
    b = func(a);  
    ...  
}
```

Structures

- To define a composite structure

```
struct name{  
    data_type1 member1;  
    data_type2 member2;  
    ...  
};
```

- To refer to this structure, use

```
struct name           // C  
name                 // C++
```

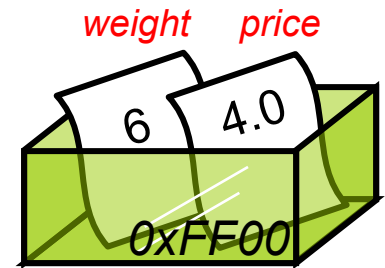
Structure

```
struct Product{  
    int weight;  
    float price;  
};
```

```
int main(...) {  
    ① Product orange = {6, 4.0};  
    Product apple;  
    apple.weight = 5;  
    ② apple.price = 3.5;  
    printf("%d\n", apple.weight);  
    ...  
}
```

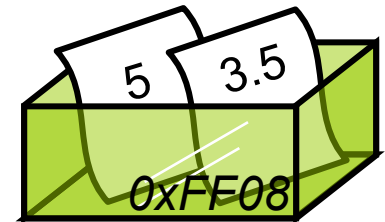
①

orange



②

apple



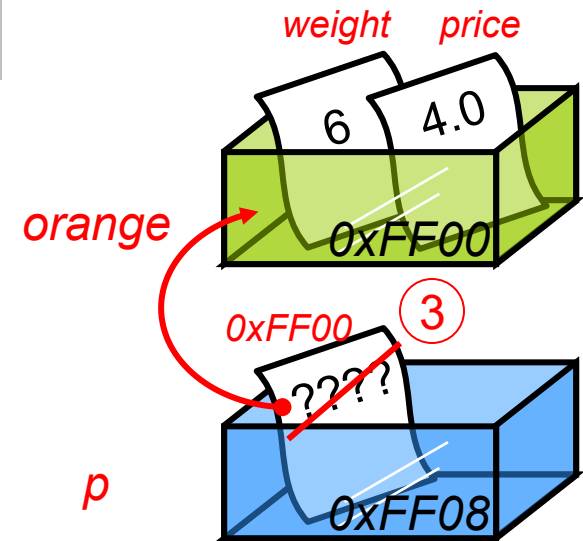
→ A structure can be initialized by using {}

→ Or use the . (dot) operator to access the member of a structure

Pointer to Structure

```
struct Product{  
    int weight;  
    float price;  
};
```

```
int main(...) {  
    ① Product orange = {6, 4.0};  
    ② Product *p;  
    ③ p = &orange;  
    printf("%d\n", p->weight);  
    printf("%d\n", (*p).weight);  
    ...  
}
```



Use the arrow `->` operator to access the member of pointer-to-structure

Parameter Passing in Functions

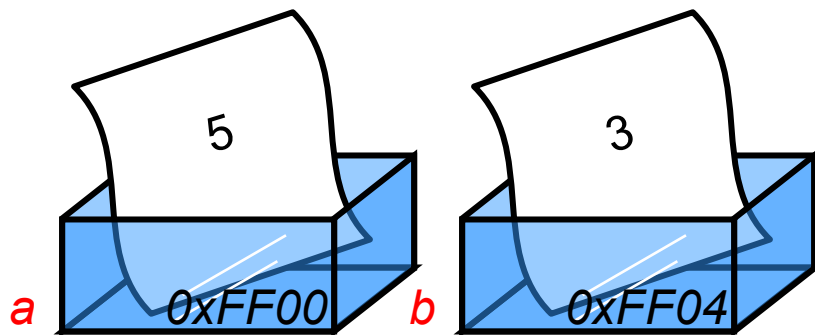
Parameter Passing in Functions

- Pass by value
 - Involve copying the value of parameters
- Pass by pointer
 - Just pass the **address** of the parameters, without copying the value of them
 - Usually used in passing large-size data structures, e.g. arrays, structures, objects, lists, etc
- Pass by reference
 - C++ reference is similar to pass-by-pointer but without the hassles of pointers' (&)reference/ (*)dereference syntax
 - You can specify a formal parameter in the function signature as a **reference parameter**

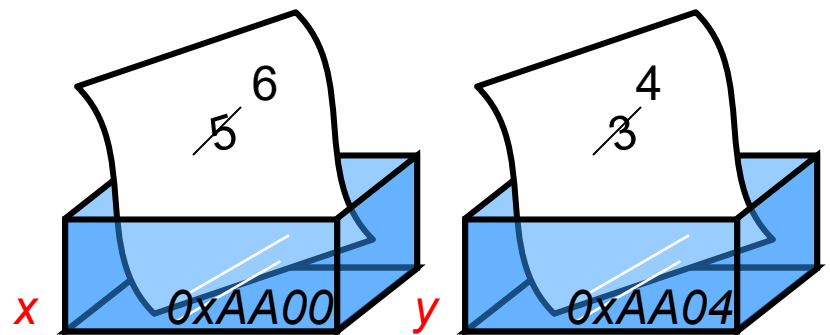
Pass by Value

```
void plus_one(int x, int y) {  
    x++; y++;  
}
```

```
int a = 5, b = 3;  
plus_one(a, b);
```



The values of *a*, *b* have not been modified



A new set of variables is **duplicate**d in function *plus_one*

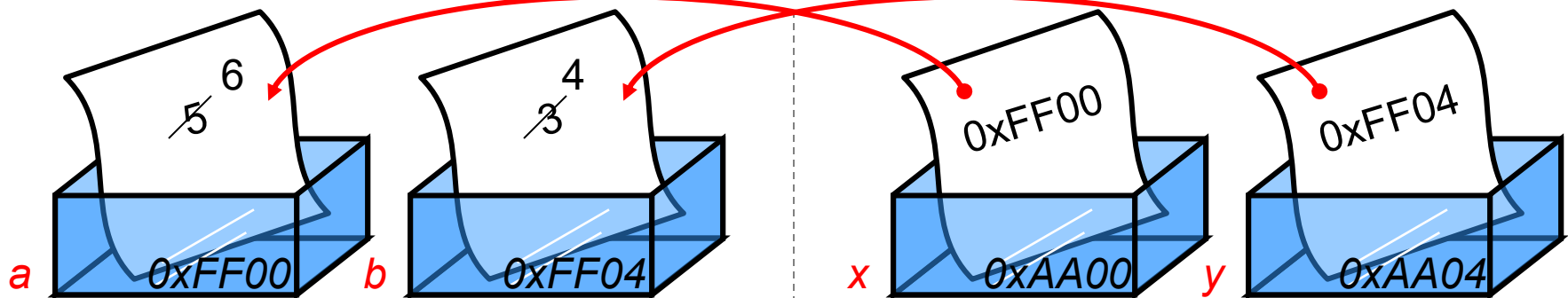
Pass by Pointer

```
void plus_one(int *x, int *y) {  
    (*x)++; (*y)++;  
}
```

pointers

```
int a = 5, b = 3;  
plus_one(&a, &b);
```

addresses



The values of *a*, *b* have been modified!

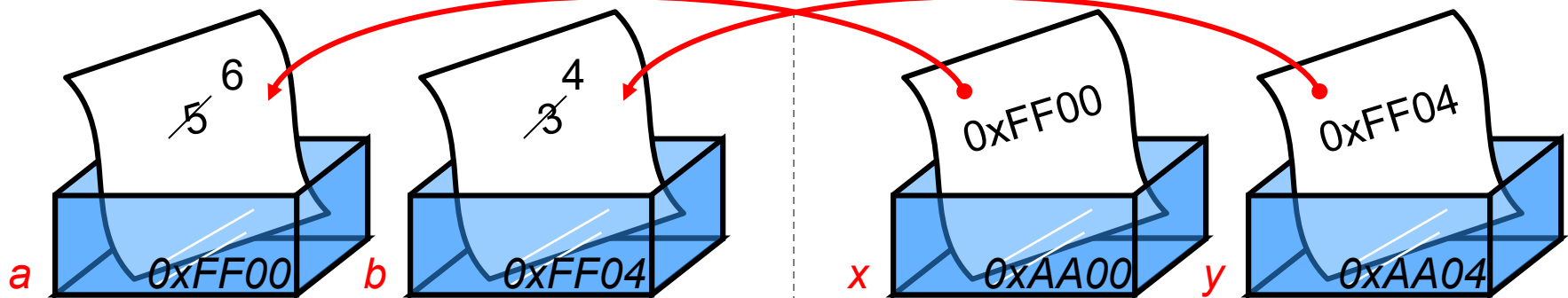
The new set of variables is actually pointing to *a*, *b*

Pass by Reference

```
void plus_one(int &x, int &y) {  
    x++; y++;  
}
```

reference parameters

```
int a = 5, b = 3;  
plus_one(a, b);
```



The values of `a`, `b` have been modified!

The new set of variables is actually referencing to `a`, `b`

C++ Reference Example

```
int i = 2;  
//an initial value must be provided in the declaration of r  
int &r = i;      //r is a reference to an integer  
int *p = &i;     //p is a pointer to an integer  
  
printf("%d %d %d %d\n", i, r, p, *p);  
// output: 2 2 001AF9C0 2  
  
r = 4;  
printf("%d %d\n", i, r);  
// output: 4 4
```

Reference vs. Pointer

1. Pointers can point nowhere (NULL), whereas reference always refers to an object.
2. References **must be initialized as soon as they are created**.
3. A pointer can be re-assigned any number of times while a reference **cannot be re-seated** after binding.
4. You cannot take the address of a reference like what you can do with pointers. Any occurrence of its name refers directly to the object it references.
5. There is no **reference arithmetic** but you can take the address of an object pointed by a reference and do **pointer arithmetic** on it (because of #4).

Pseudo Code

- We need a language to express program development
 - English is **too verbose** and imprecise.
 - The target language, e.g. C/C++, requires too much details.
- Pseudo code resembles the target language in that
 - it is a sequence of steps (each step is precise and unambiguous)
 - it has similar control structure of C/C++
- Pseudo code is a kind of **structured English** for describing algorithms. It allows the designer to focus on the logic of the algorithm **without being distracted by details of language syntax**.

```
x = max{a, b, c}
```

Pseudo code

```
x = a;  
if (b > x) x = b;  
if (c > x) x = c;
```

C++ code

Pseudo Code Example

- An $m \times n$ matrix is said to have a saddle point if some entry $A[i][j]$ is the smallest value on row i and the largest value in column j .

An 6×8 matrix with a saddle point

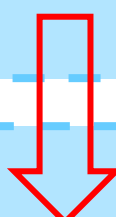
11	33	55	16	77	99	10	40
29	87	65	20	45	60	90	76
50	53	78	44	60	88	77	81
46	72	71	23	88	26	15	21
65	83	23	36	49	57	32	14
70	22	34	19	54	37	26	93

- Problem:
- Given an $m \times n$ matrix, determine if there exists one or more saddle points.

Pseudo Code Solutions

```
// high-level pseudo code solution
for each row {
    j = index of the smallest element on row i;
    if (A[i][j]) is the largest element in column j)
        A[i][j] is a saddle point;
}
```

```
// refined pseudo code
for (i = 0; i < m; i++) {
    j = index of the smallest element on row i;
    for (k = 0; k < m; k++)
        if there does not exist A[k][j] > A[i][j]
            A[i][j] is a saddle point;
}
```



Suggestions for Good Style

- Use informative and meaningful variable names
- Insert useful comments (i.e. assertions) in the source program
- Format the source file with **proper indentation** of statements and align the braces so that the control structures can be read easily
- Do not use **goto** statement, especially backward jump
- Use **single-entry single-exit** control blocks, or at most one break statement inside a loop
- Avoid ambiguous statements e.g. `x[i] = i++;`
- **Minimize direct accesses to global variables**, especially you should avoid modifying the values of global variables in a function
- Always make a **planning** of the program organization and data structures before start writing program codes
- Should avoid using the **trial-and-error** approach without proper understanding of the problem to be solved

Standard Input / Output

cin & cout

- Default input/output stream objects
- A stream is a sequence of bytes (characters) that can be read from or written to
 - cin is a stream on the keyboard input
 - cout is a stream on the screen output
- The extractor (>>) / insertor (<<) is used to read/write from/to the input/output stream

Standard Output

```
#include <cstdio>
#include <iostream>
using namespace std;

...

int x = 1;
float y = 2.5;
char z = 'a';
char w[80] = "xxxxxx";

printf("%d %f %c %s\n", x, y, z, w);
std::cout << x;
cout << endl;
cout << y << " " << z << " " << w;
```

How to output the values to standard output (screen)?

Use `printf()` in `<cstdio>`:

- integer: `%d`
- float: `%f`
- character: `%c`
- string: `%s`

Use `cout` in `<iostream>`:

- `cout` is defined in the `std` namespace
- Use insertion operator to insert values to output stream.
- Multiple insertions can be chained.
- Use `endl` to set a new line.

Standard Input

```
#include <cstdio>
#include <iostream>
using namespace std;

...

int x;
float y;
char z;
char w[80];

cin >> x;
scanf("%f", &y);
cin >> z;
scanf("%s", w);
```

How to read the values from standard input (console)?

Use `scanf()` in `<cstdio>`:

- integer: `%d`
float: `%f`
character: `%c`
string: `%s`

Use `cin` in `<iostream>`:

- `cin` is defined in the `std` namespace
- Use extraction operator to extract values from input stream.

scanf()

- *scanf* can only read a “word”, but not a sentence. It stops reading if meets **whitespace** characters.
- What are whitespace characters?
 - Blank space: ‘ ’
 - Newline: ‘\r’ ‘\n’
 - Tab: ‘\t’
- Visual Studio compiler will tell you the function *scanf* is not safe.
 - Add this code to the beginning of your program to suppress this MS secure warning


```
#ifdef _MSC_VER  
#define _CRT_SECURE_NO_WARNINGS  
#endif
```

scanf() Examples

scanf() will stop reading when it meets enter, space or tab (whitespace)

```
scanf("%s", w);  
printf("##%s##\n", w);
```

```
abc<enter>  
##abc##
```





The newline character has been ignored by scanf()

```
scanf("%s", w);  
printf("##%s##\n", w);
```

Space

```
abc def<enter>  
##abc##
```



The space and following characters have been ignored by scanf()

More on Input

- When looking for the input value in the stream, the `>>` operator **skips any leading whitespace characters** and stops reading at the first character that is inappropriate for the data type (whitespace or otherwise).
- You can use the **`get()`** function to input the very next character in the input stream **without skipping any whitespace characters**:

```
char someChar;  
cin.get(someChar);
```

- The **`ignore()`** function is used to skip characters in the input stream:

```
cin.ignore(200, '\n');
```

- The first parameter is an int expression; the second, a char value. This **skips the next 200 characters or until a newline character is read**, whichever comes first

Output Manipulators

- Manipulators change the output format of your data. To use them, you will need to include this header in your C++ source code.

```
#include <iomanip>
```

- **setw()** sets the width of the field to be printed to the screen

```
■ cout << 5 << setw(4) << 6 << 7;    // output:5    67
```

- **setprecision()** sets the *decimal precision* to be used to format floating-point values:

```
■ cout << setprecision(5) << 3.14159;    // 3.1416
```

```
■ cout << setprecision(1) << 3.14159;    // 3
```

- To specify the number of digits after the decimal point:

```
■ cout << setiosflags(ios::fixed);    // not use scientific notation
```

```
■ cout << setprecision(2) << 12.1234; // 12.12
```

- Other floating point output flags:

```
■ setiosflags(ios::scientific);    // use scientific notation
```

```
■ resetiosflags(ios::floatfield)    // restores default (use fixed  
// or scientific notation based  
// on the precision)
```

File Input/Output

- In a similar way C++ provides **streams** which can manipulate **files**
- C++ provides **2 file streams**

ifstream input file stream

ofstream output file stream

Must `#include <fstream>` to use them

- Example:

```
#include <fstream>
```

```
int number;
```

```
ifstream in("in.dat");
```

```
ofstream out("out.dat");
```

```
in >> number;
```

```
out << number;
```

Input File Streams (ifstream)

- Allows data to be read from a file
- An input file stream can be defined as follows:

```
ifstream stream_var(filename);
```

Example:

```
ifstream inFile("test.dat");
```

- If stream opened successfully, inFile evaluates to **positive** and the stream becomes attached to the file test.data
- If stream open failed (e.g. file does not exist) inFile evaluates to **zero**
- **Important:** Effects of reading data from file which has failed to open is undefined

Input File Streams (ifstream)

- When file opened successfully, data can be read using normal **extractor** functions

```
int n;  
char c;  
ifstream inFile("test.dat");  
inFile >> n;  
inFile.get(c);  
inFile.close();
```

- **Note:** When a file stream goes out of scope it will automatically close the file it is attached to

File Input Failure/End

- To check if the file has been **opened or not**, you can use:

```
if (inFile) // testing if the file opened successfully
{ ... }
```

- To test for **end of file**, you can use:

```
while (!inFile.eof())
{ ... }
```

For instance:

```
int number;
inFile >> number; // reading number from a file
while (!inFile.eof())
{
    cout << number; // print number on screen
    inFile >> number;
}
```


Output File Stream (ofstream)

- Allows data to be written to a file

An output file stream can be defined as follows:

```
ofstream stream_var(filename);
```

Example:

```
ofstream outFile("temp.data");
```

- If stream opened successfully, outFile evaluates to **positive** and the stream becomes attached to the file temp.data
- If stream open failed (e.g. no disk space) outFile evaluates to **zero**

■ Note:

- If the file already exists its contents will be deleted
- If the file does not exist, a file with the same name is created
- Data can be **appended** to a file by using constructor with two arguments

```
ofstream outFile("temp.data", ios::app);
```

Example on How to Write to a File

```
#include <iostream>
#include <fstream>
#include <iomanip>

using namespace std;

int main ()
{
    float first, second, sum;           // Declaring variables
    ofstream outFile("out.dat");        // Opening file for output

    cout << "Enter two numbers" << endl;
    cin >> first >> second;             // Reading in the two numbers
    sum = first + second;
    outFile << setiosflags(ios::fixed); // Formatting the output
    outFile << setprecision(2);
    outFile << sum << endl;             // Writing into the file

    return 0;
}
```