EE2331 Data Structures and Algorithms

C++ Programming Review

Outline

- 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

C++ File Structure

Header file (.h)

Functions declaration

Program file (.cpp)

Functions implementation

Main program

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.

A Basic C++ Program

```
#include <cstdio>          //include directive(s)

int z = 0;                 //global variable(s) declaration & initialization

void hello(int a) {        //function(s) declaration & implementation
    printf("%d\n", a + z);
}

int main(int argc, char *argv[]) {
    int x = 10;            //local variable(s) declaration & initialization
    hello(x);              //function call
    return 0;              //return to O.S. (0 = successful completion)
}
```

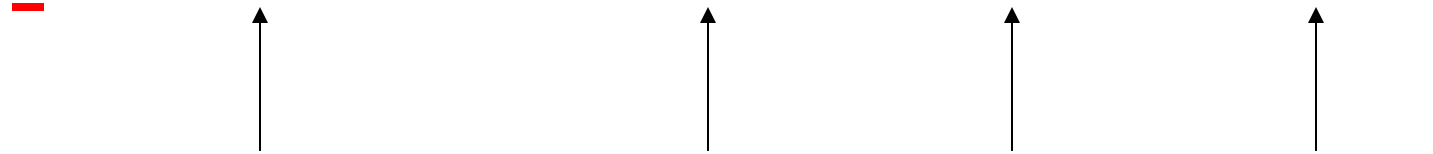
Main Function

- 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 | 1st argument | 2nd argument | … | *n*th

argv[0] argv[1] argv[2] … argv[n]

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

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

argc: count

argv: value

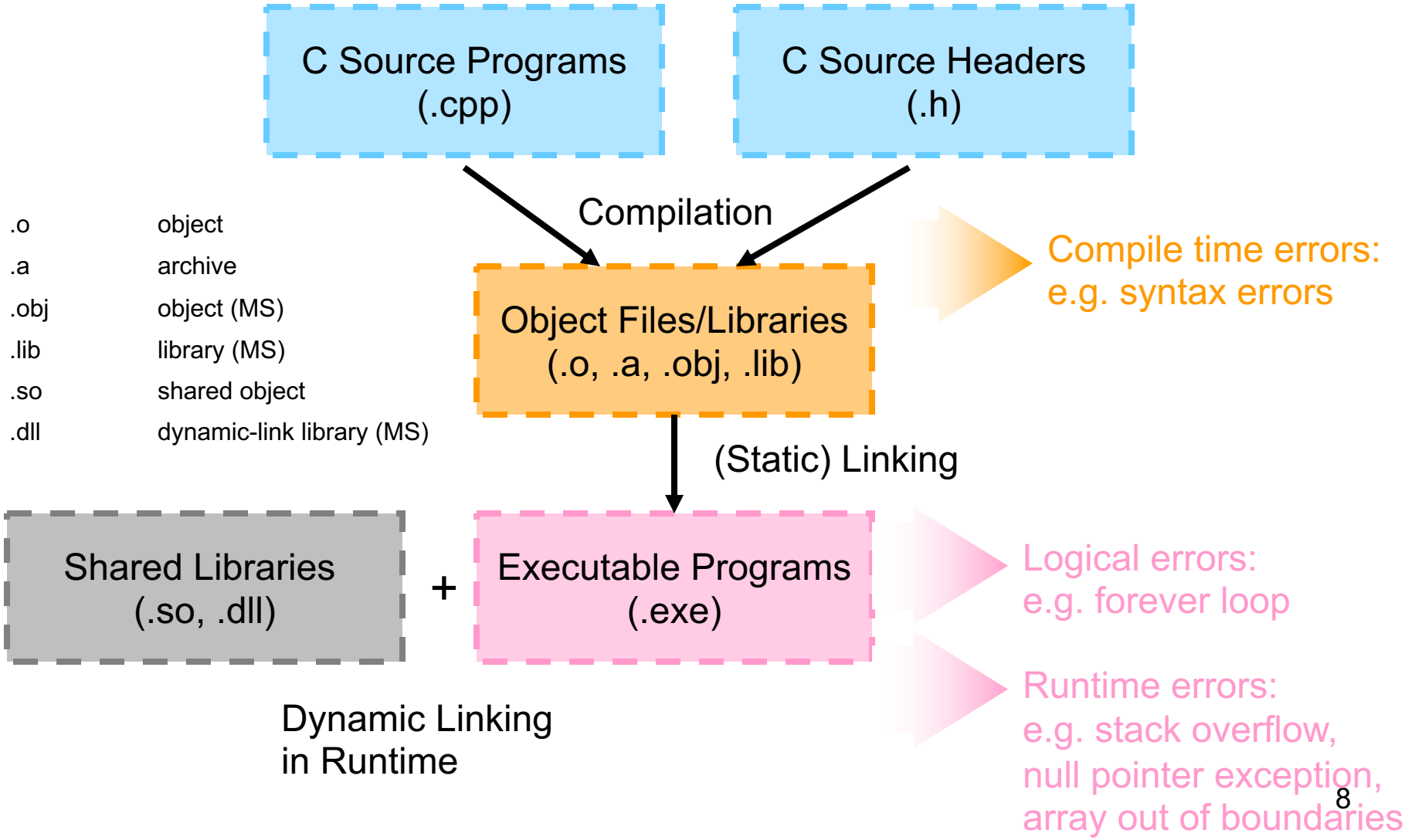
Command Line Arguments


```
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**

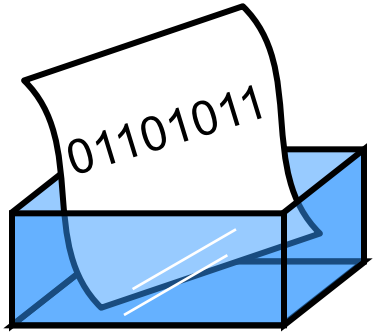
Comments

```
/* Block comment 1 */


/*
 * Block comment 2
 */
```

```
// Line comment
```

Basic Data Type

- Data itself does not have meaning. Its meaning depends on how you interpret the data.
- Char
  - 1 Byte (8 bits)

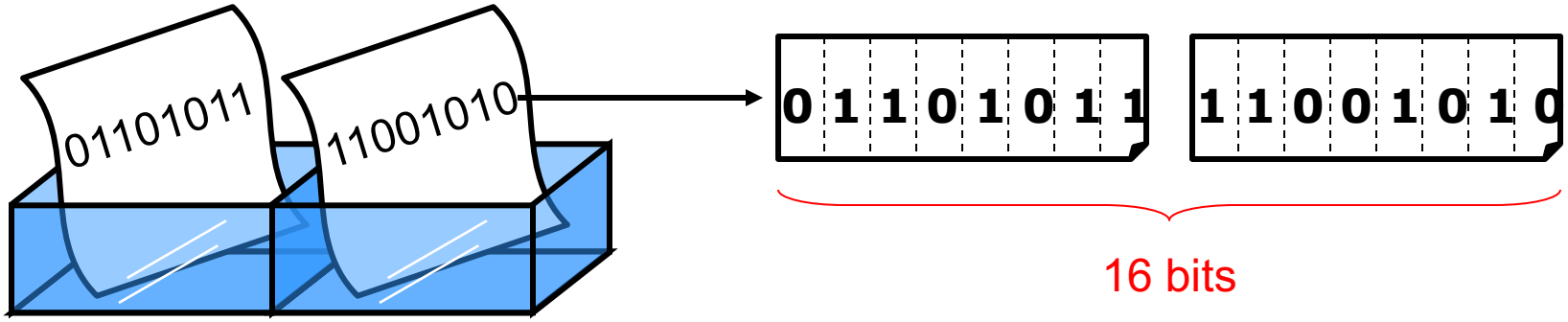


Unsigned	Signed (2's complement)	
0	0	0 0 0 0 0 0 0 0
1	1	0 0 0 0 0 0 0 1
⋮	⋮	⋮
255	-1	1 1 1 1 1 1 1 1

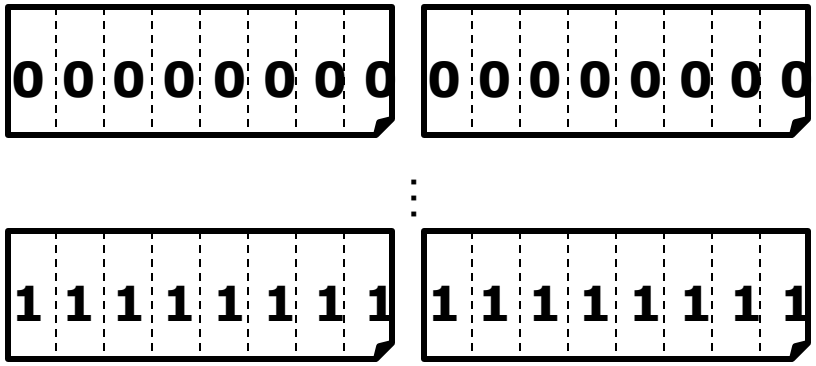
8 bits

Basic Data Type

- Short Int
  - 2 Bytes (16 bits)

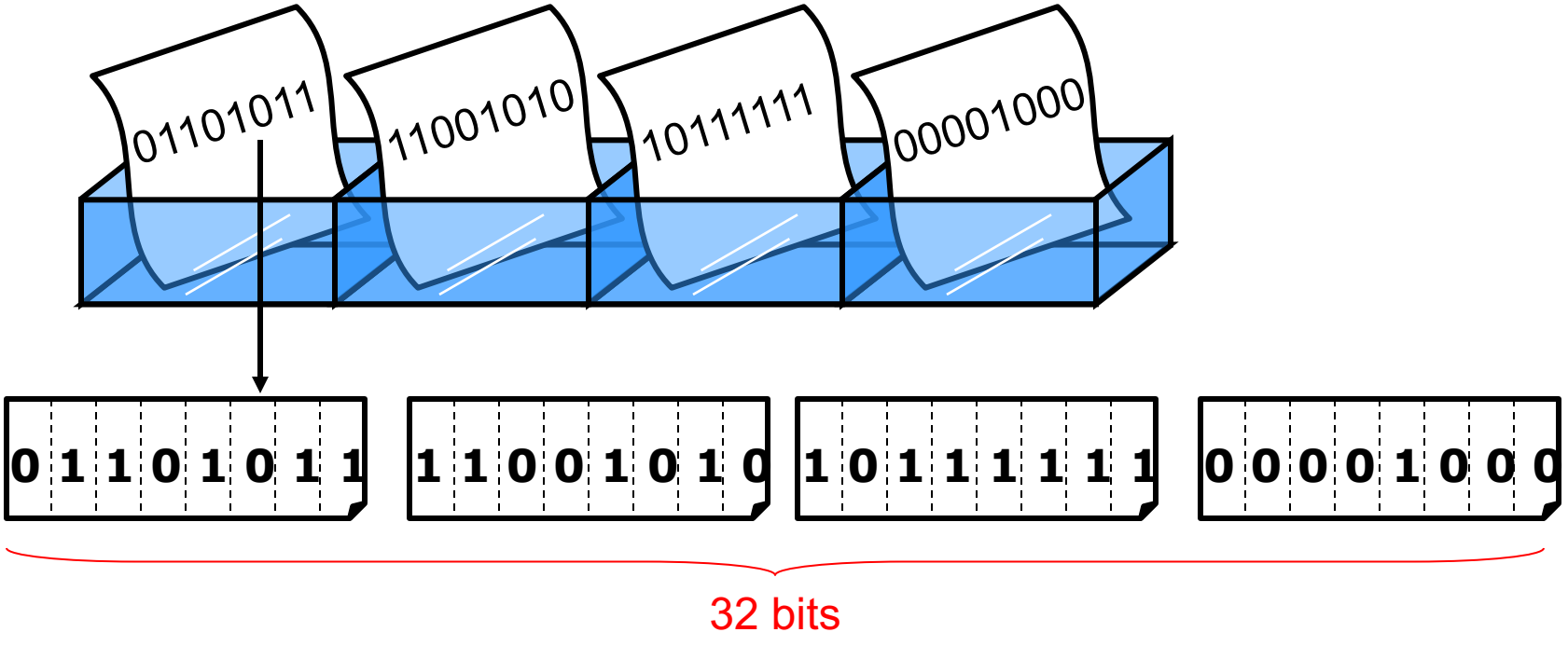


Unsigned	Signed (2's complement)
0	0
⋮	⋮
65535	-1



Basic Data Type

- Int / Long Int
  - 4 Bytes (32 bits)



What are the largest and smallest numbers can an “int” be represented?

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	$\pm 1.4\times10^{-45}$ to $\pm 3.4\times10^{38}$
double	8	IEEE 64-bit floating point number	$\pm 5\times10^{-324}$ to $\pm 1.798\times10^{308}$
pointer	**4**	**memory address**	**0 to $2^{32}-1$**

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
  - What is the resulted of a float divided by an int?

Arithmetic Operators

- Remainder (Modulus Operator)

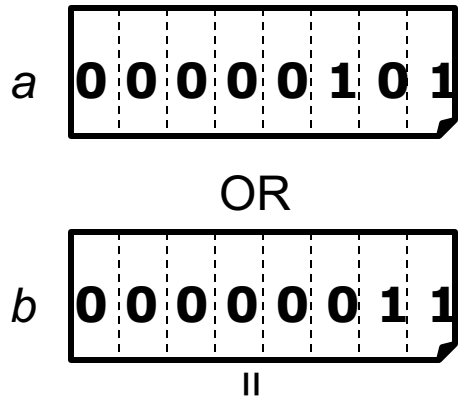
```
int a, b, c;
a = 5;
b = 2;
c = a % b;
printf("%d\n", c);
```

  - 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);
```



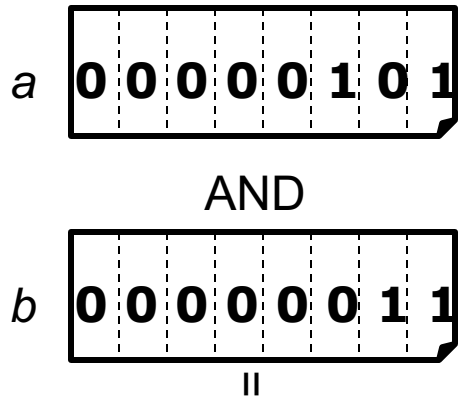
- Logical OR

```
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);
```



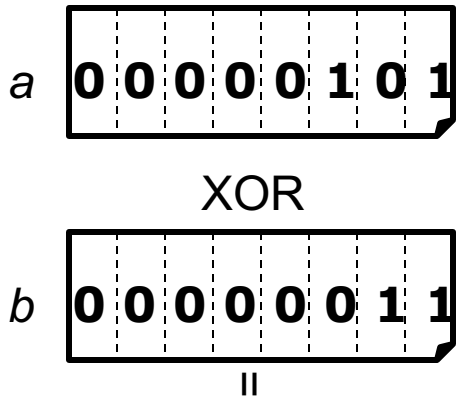
- Logical AND

```
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);
```

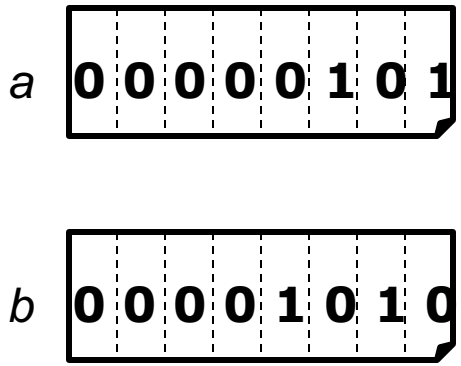


- When to use it?
  - Interchange two variables (in Bubble Sort)

Bitwise Operators

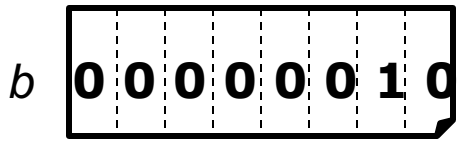
- Left Shift (x2)

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



- Right Shift (/2)

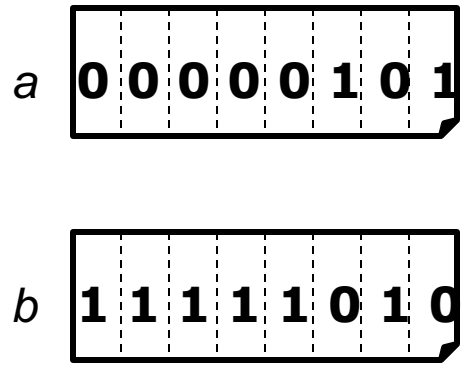
```
int a, b;
a = 5;
b = a >> 1;
printf("%d\n", b);
```



Bitwise Operators

- 1's complement

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



Note: both a and b should be 4-byte long

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);
```

Variable Assignments

- Example 3

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

- Example 4

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

- Example 5

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

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.
  - int / int → int
  - float / int → float

Octal and Hex. Assignment

- Example 1 - Octal

```
int a;
a = 022;                    // leading zero
printf("%d\n", a);          // 18
```

- Example 2 - Hex

```
int a;
a = 0x22;
printf("%d\n", a);          // 34
```

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;
}
```

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.
- 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;
}
```

Loop Design

- **Precondition/Postcondition** is a condition (predicate) that must always be true just prior/after to the execution of some section of code
  - Often, preconditions/postconditions are simply included in the documentation of the affected section of code.
  - If a precondition is violated, the effect of the section of code becomes **undefined** and thus may or may not carry out its intended work.
- **Loop invariant** is a condition that is necessarily true immediately before and after each iteration of a loop.
  - An appropriate invariant should also **present the goal** of the loop such that it is used to help prove the correctness of an algorithm.

Loop Design

- Find the maximum value in an array of integers.

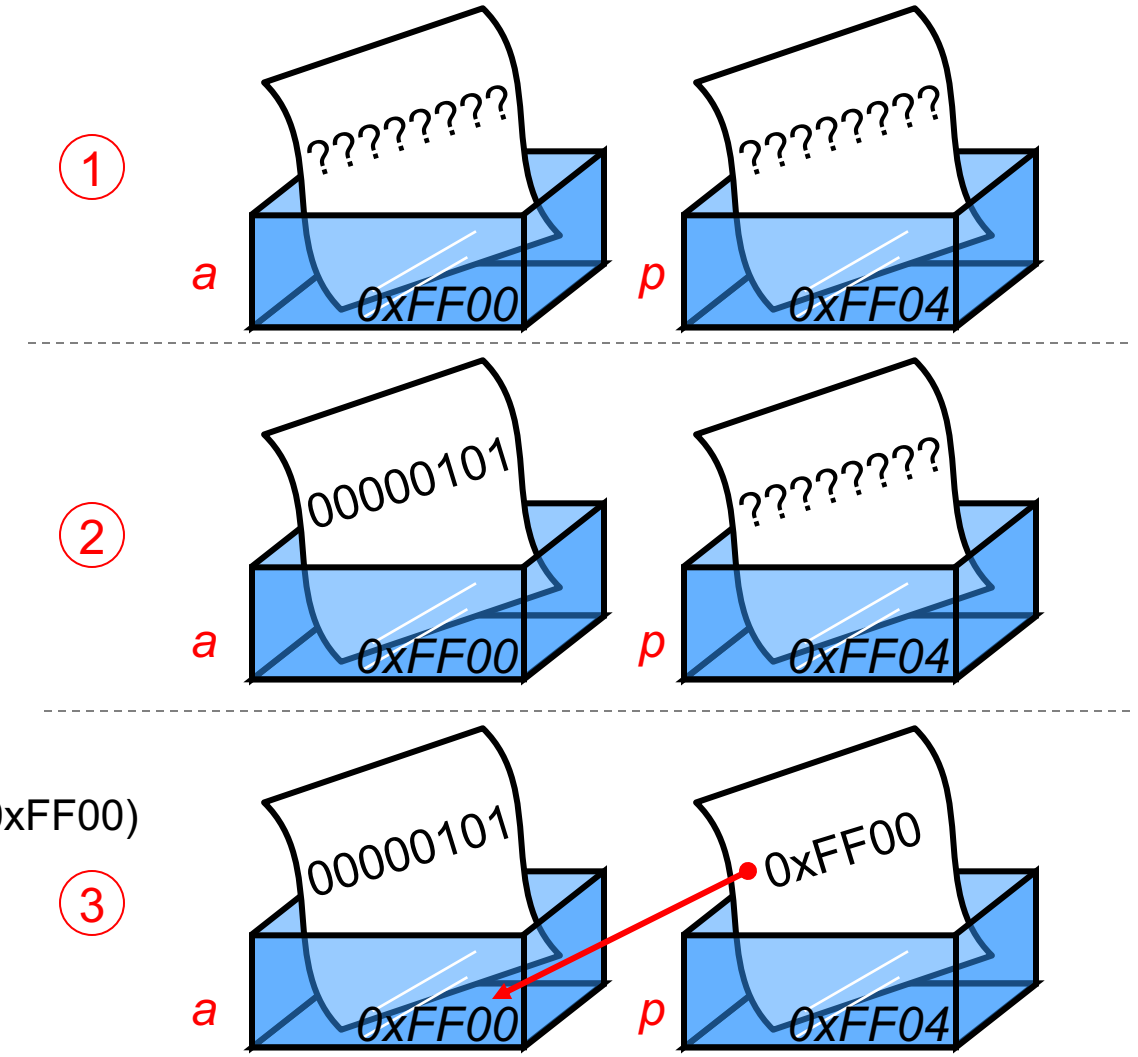
```
//  precondition: n > 0 and a[] is unordered
int max(int a[], int n) {
    int m = a[0];
    // m equals the maximum value in a[0...0]
    int i = 1;
    while (i < n) {
        // invariant: m equals the maximum value in a[0...i-1]
        if (m < a[i])
            m = a[i];        // m equals the maximum value in a[0...i]
        i++;
        // invariant: m equals the maximum value in a[0...i-1]
    }
    // postcondition: m equals the maximum value in a[0...i-1], and i==n
    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: ?

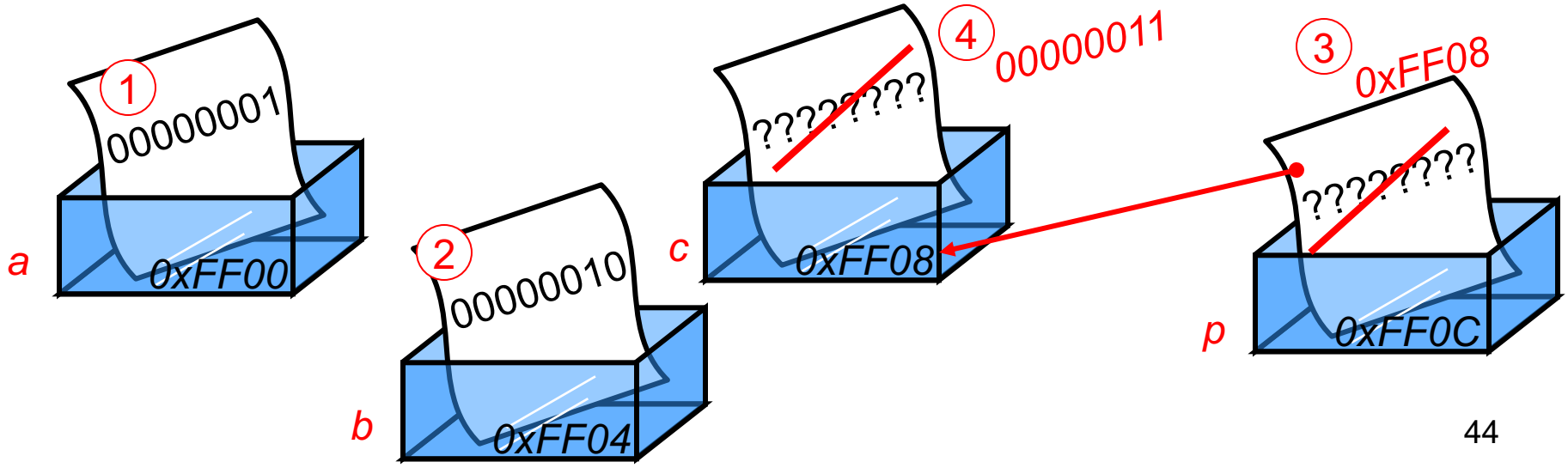
p: value of *p* == address of *a* (i.e. 0xFF00)

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

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

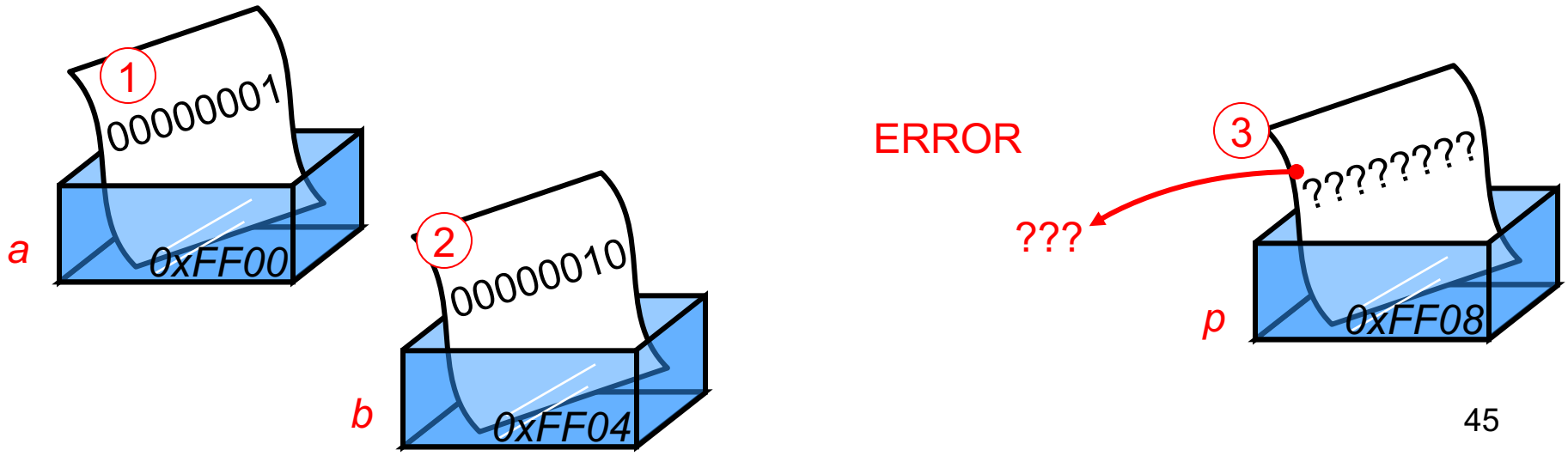
Pointers

```
int a, b, c, *p;
1 a = 1;
2 b = 2;
3 p = &c;
4 *p = a + b;
  printf("%d %d\n", c, *p);
```



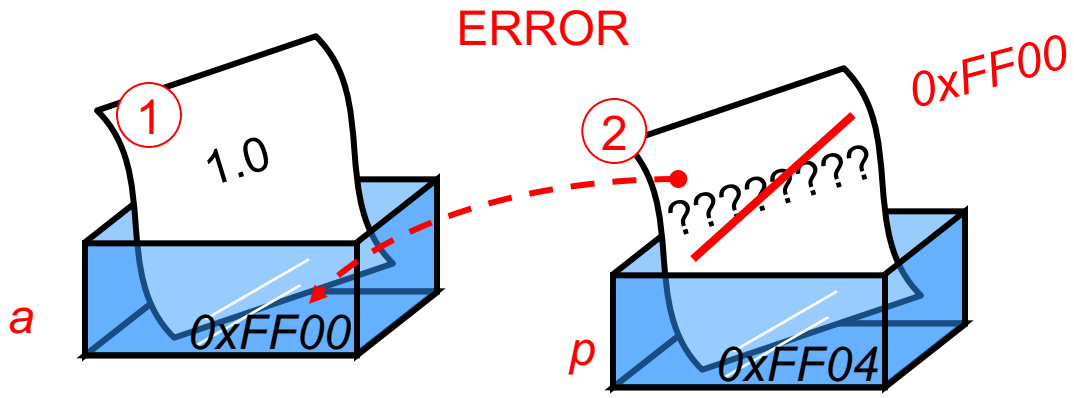
Pointers

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



Pointers

```
float a;
int *p;
1 a = 1.0;
2 p = &a;
3 printf("%d\n", *p);
```



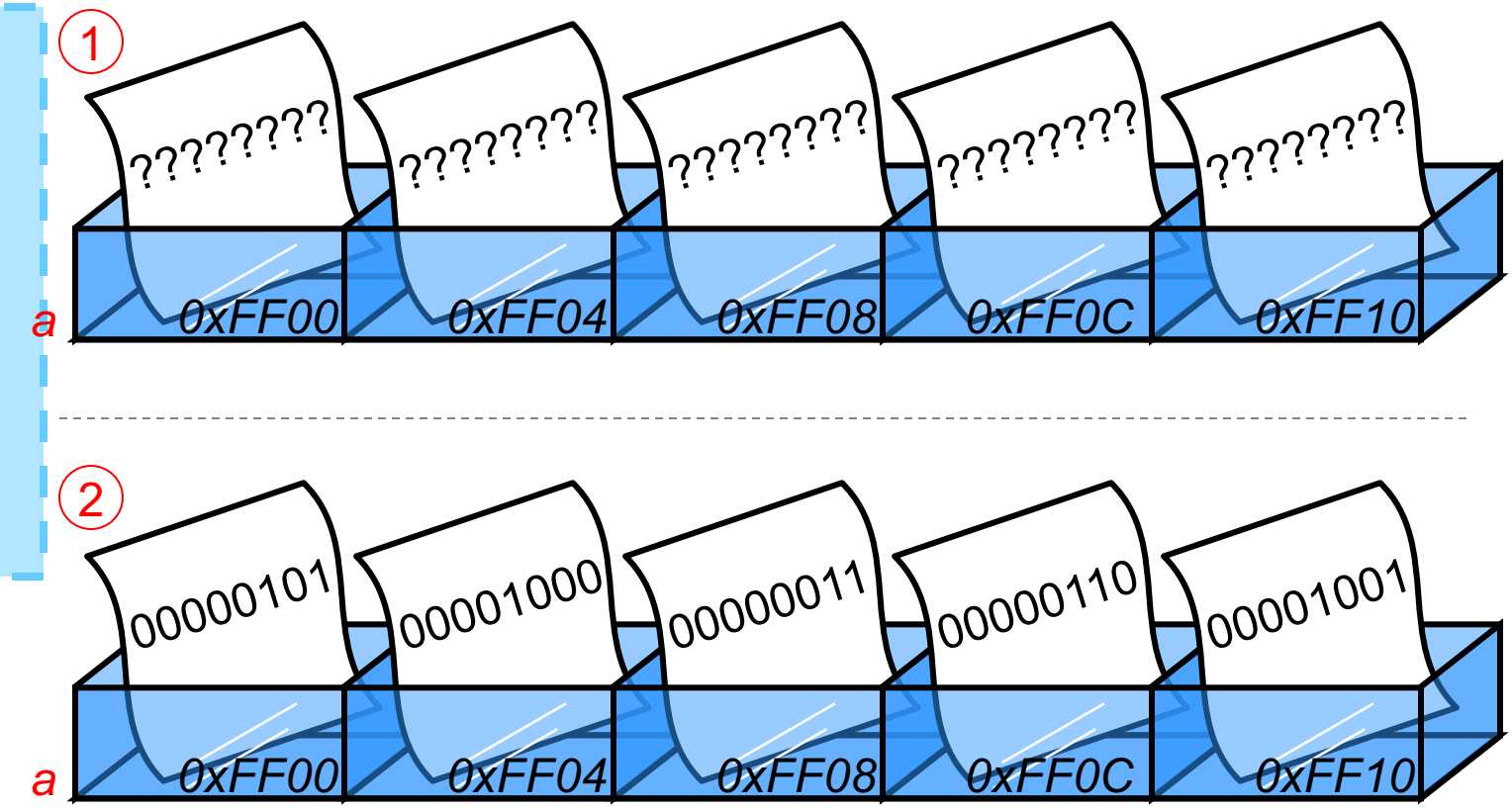
Note: this is not the actual bit representation of floating numbers. It is simplified for easy drawing

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

```
1  int a[5];
   a[0] = 5;
   a[1] = 8;
   a[2] = 3;
   a[3] = 6;
2  a[4] = 9;
```



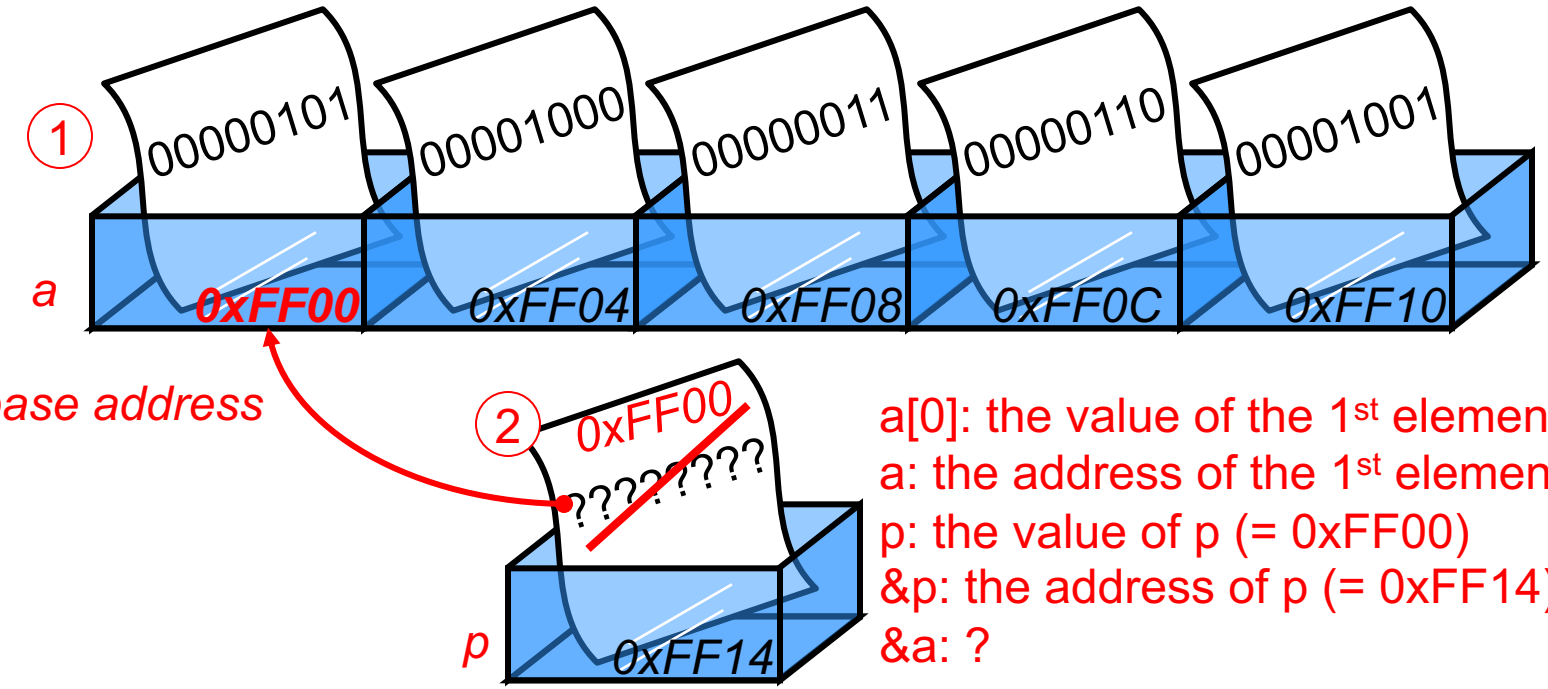
Note: the elements of integer array should be 4-byte long.

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.

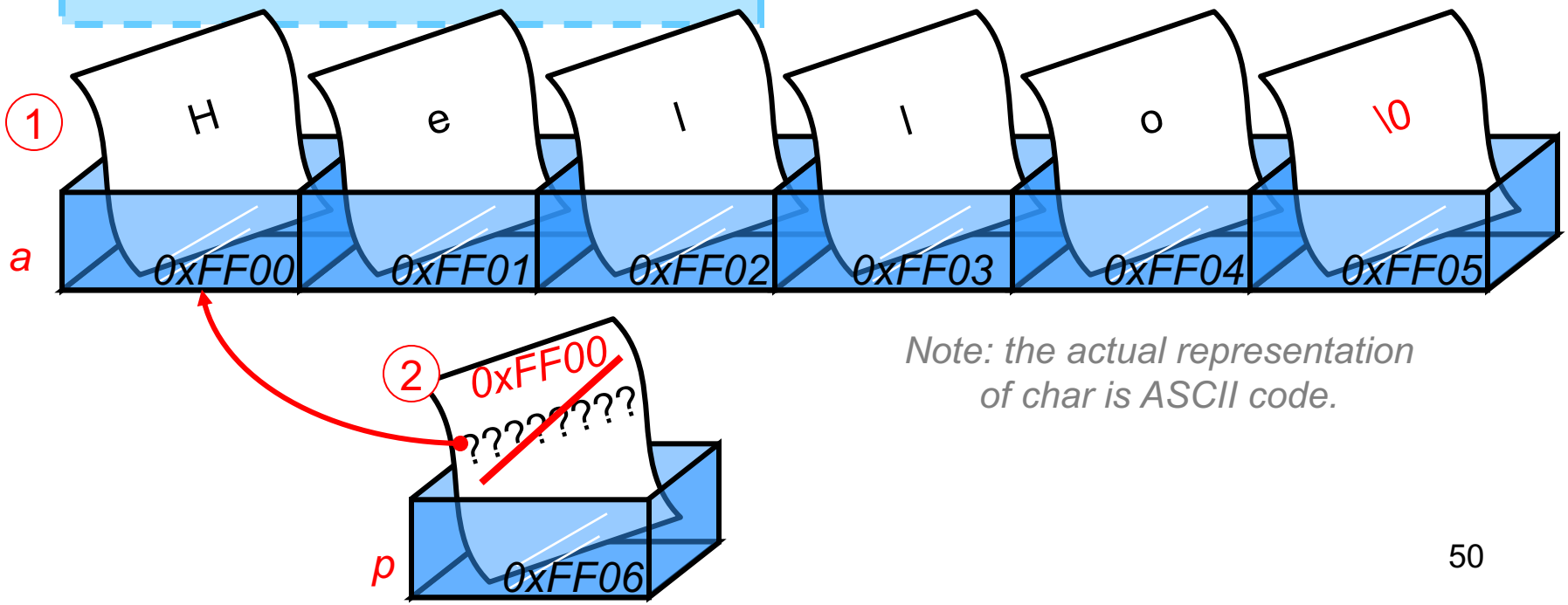


a[0]: the value of the 1st element (= 5)
a: the address of the 1st element (= 0xFF00)
p: the value of p (= 0xFF00)
&p: the address of p (= 0xFF14)
&a: ?

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)

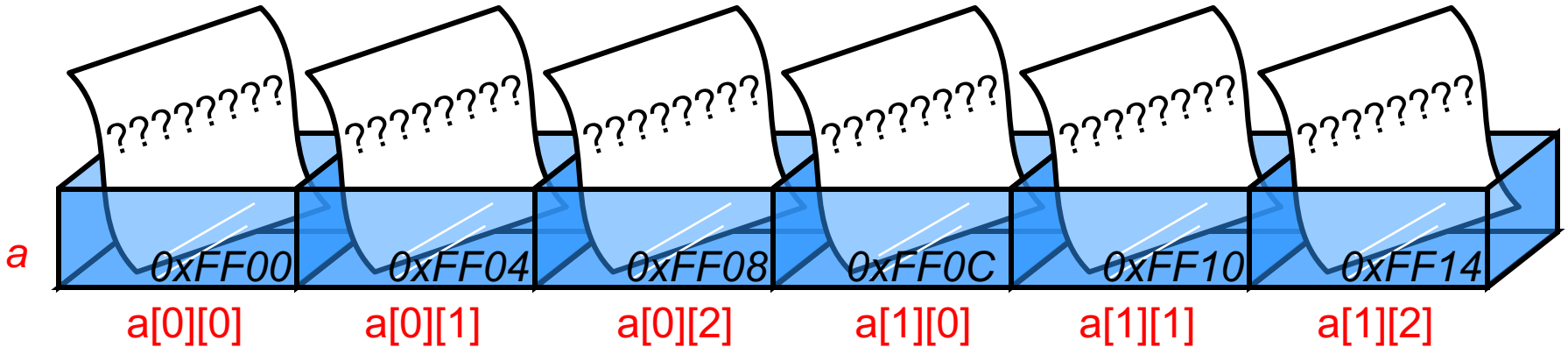


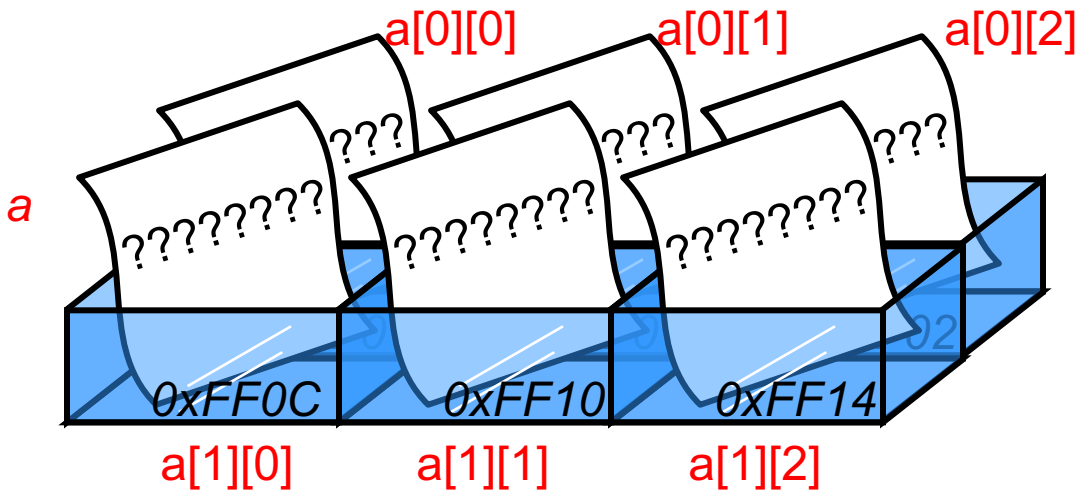
Note: the actual representation of char is ASCII code.

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
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
```

Array Mapping Functions

- Today's PCs are byte-addressable
- Let
  - i = row index
  - j = column index
  - cols = number of columns in a row
  - esize = size of an element (no. of bytes) e.g. 4 for integer
- address of b[i] = base(b) + i * esize
  - base(b) = address of b[0]
- address of a[i][j] = base(a) + (i * cols + j) * esize
  - base(a) = address of a[0][0]

Treat Array as Pointer

- The 2 implementations are equivalent:

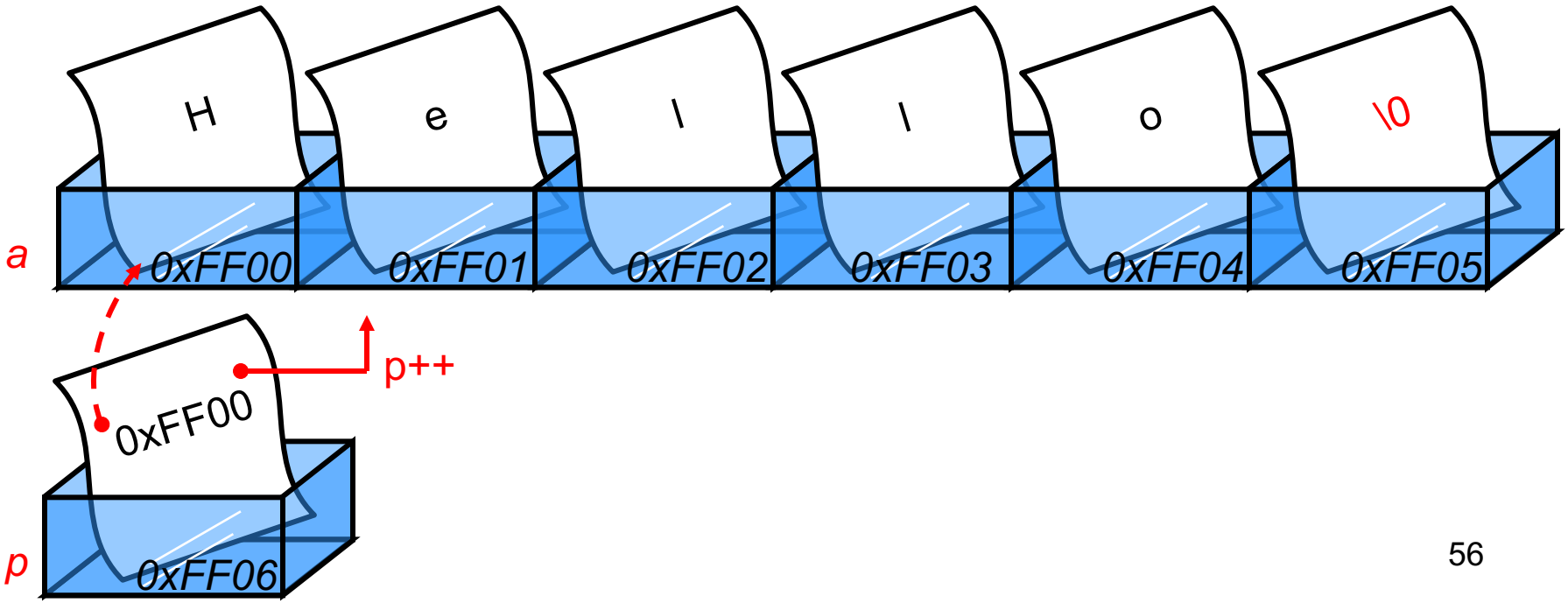
```
int sum1(int a[], int n) {
    int t = 0;
    for (int i = 0; i < n; i++)
        t += a[i];
    return t;
}

int sum2(int *a, int n) {
    int t = 0;
    for (int i = 0; i < n; i++)
        t += *(a+i);
    return t;
}
```

Because esize is implied by the data type, the arithmetic operation of pointer implicitly takes esize into account.

So, (a+i) = physical address of a+i*esize

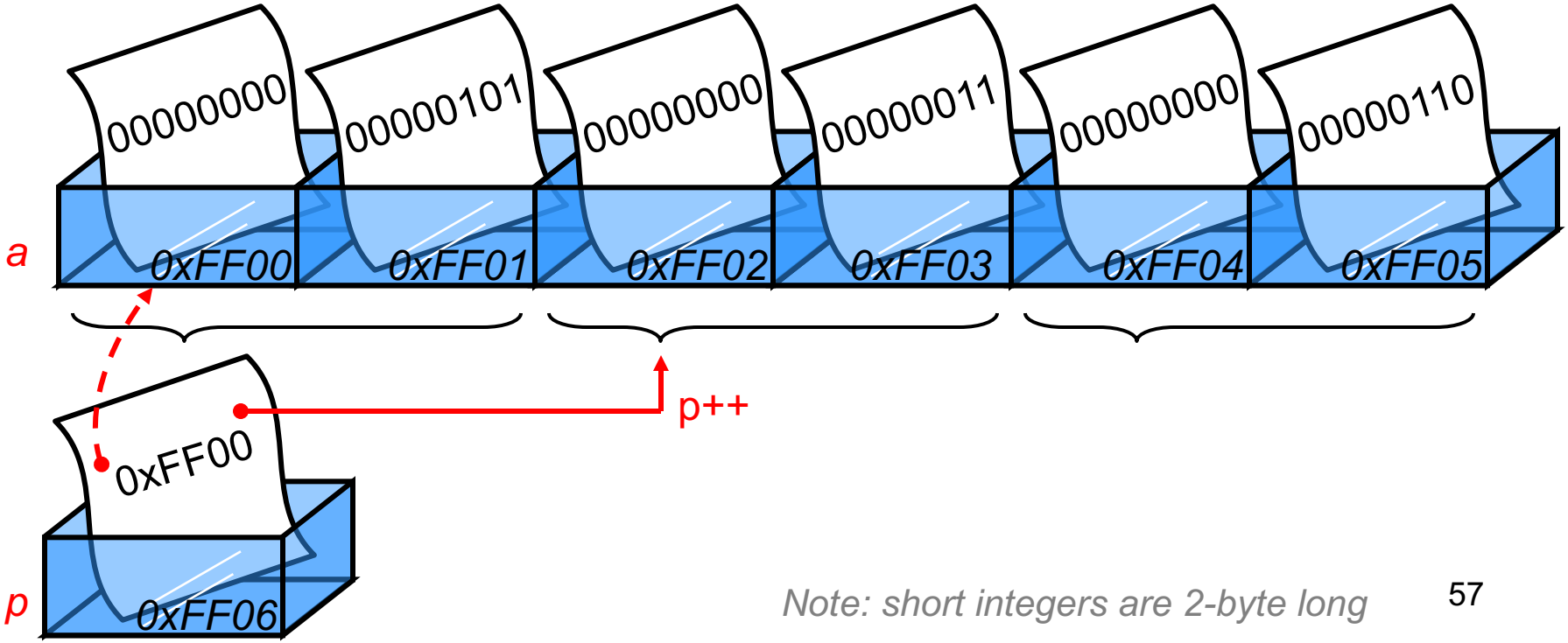
Arrays and Pointers

```
char a[] = "Hello";
char *p;
p = a;
```



Arrays and Pointers

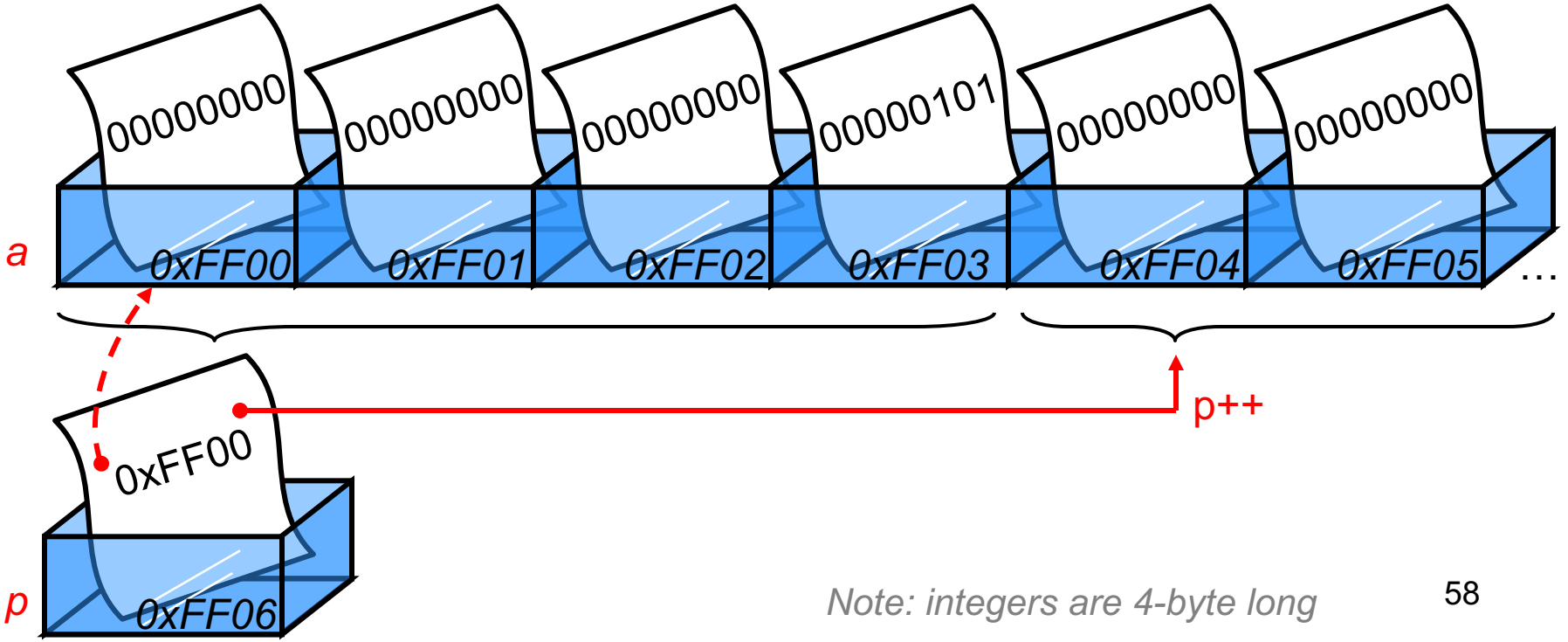
```
short a[] ={5, 3, 6};
short *p;
p = a;
```



Note: short integers are 2-byte long

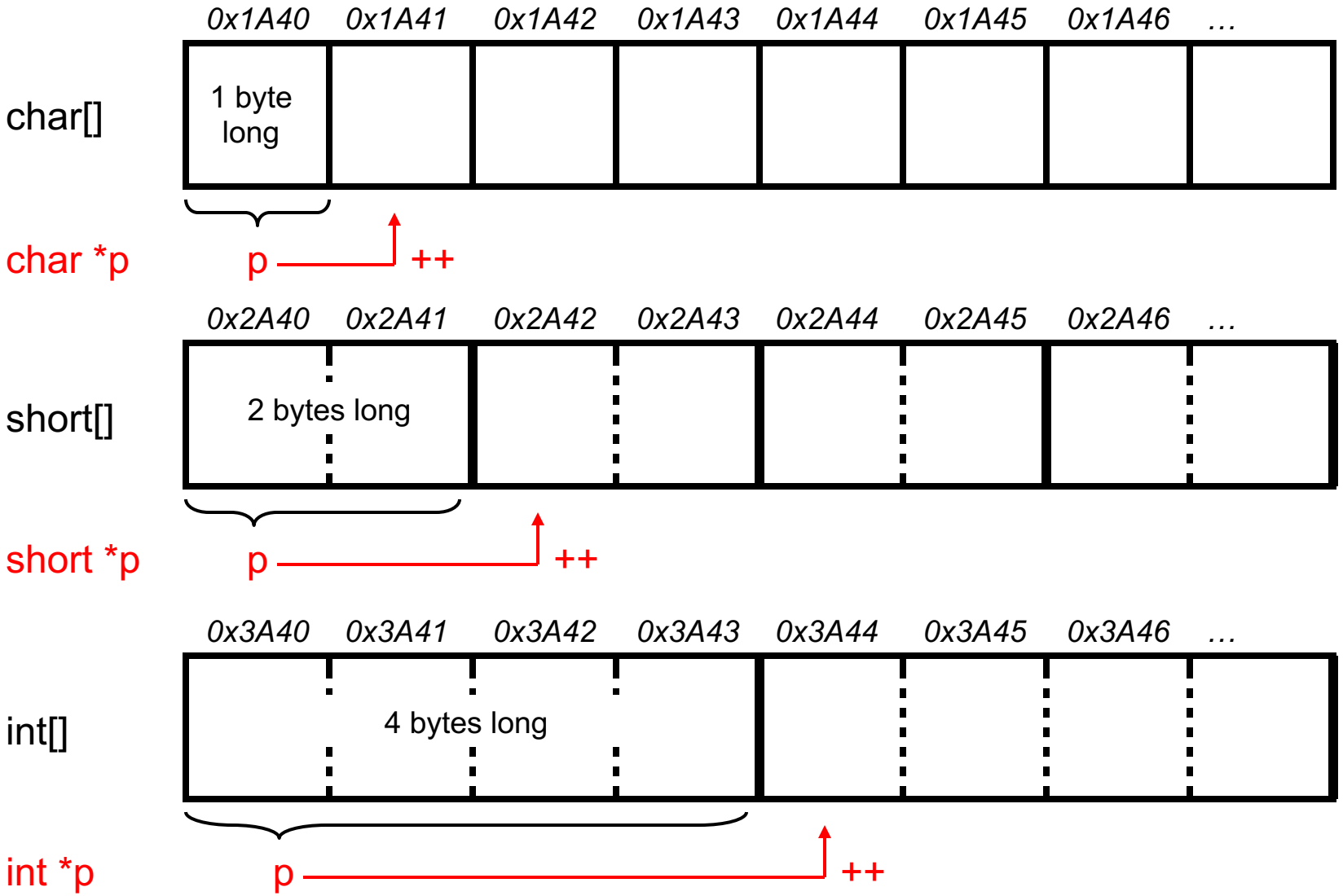
Arrays and Pointers

```
int a[] ={5, 3, 6};
int *p;
p = a;
```



Note: integers are 4-byte long

Arrays and Pointers



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

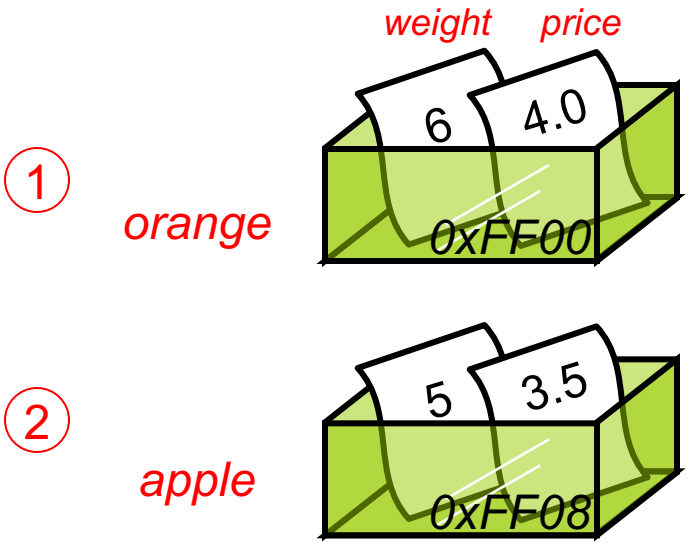
```
struct name{
    data_type1 member1;
    data_type2 member2;
    …
};
```

- To refer to this structure, use

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

Structure

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



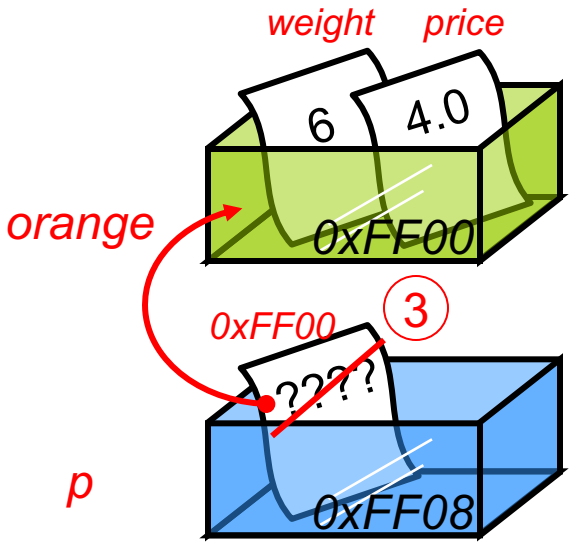

```
int main(…) {
1   Product orange = {6, 4.0};
    Product apple;
    apple.weight = 5;
2   apple.price = 3.5;
    printf("%d\n", apple.weight);
    …
}
```

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

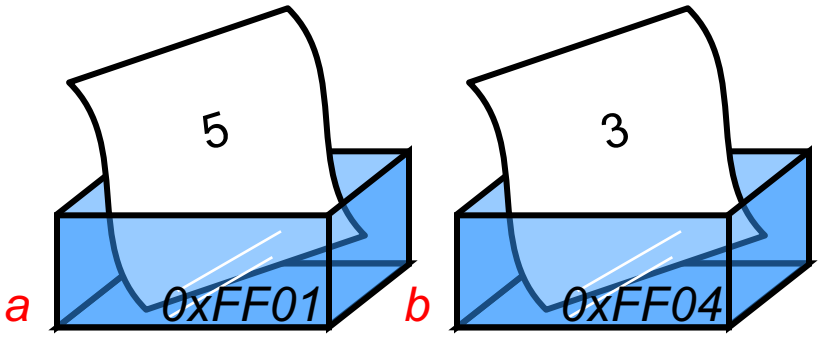
Parameter Passing in Functions

- 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 a syntactic sugar to C pointer
  - 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

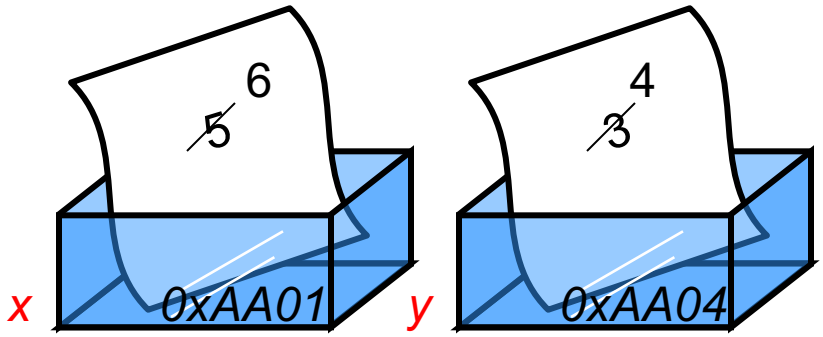
Pass by Value

```
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 **duplicated** in function *plus_one*

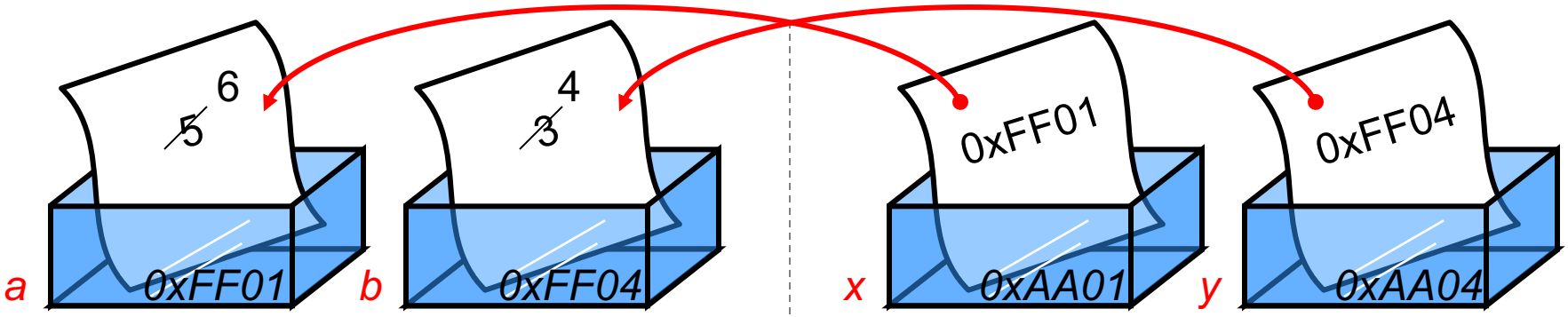
Pass by Pointer

```
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!

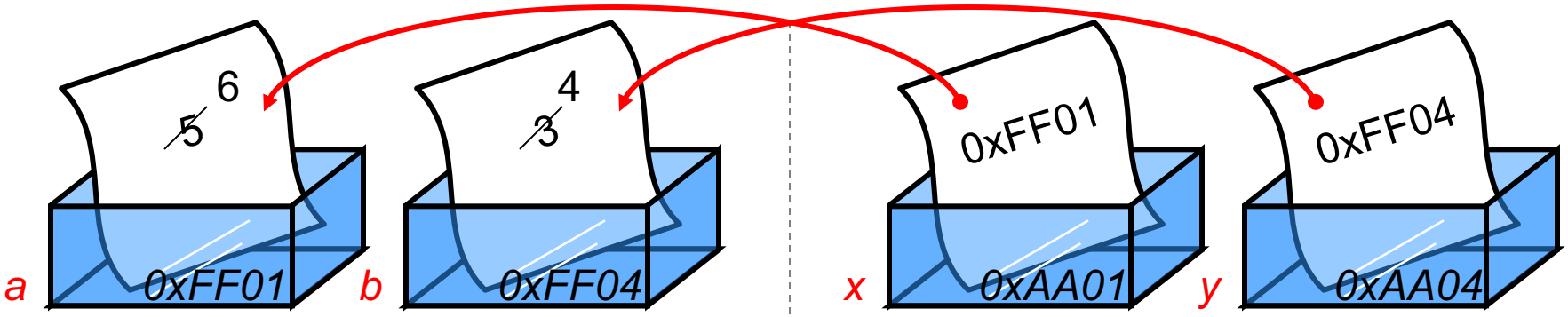
The new set of variables is actually **pointing** to *a*, *b*

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).

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()

Space

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

```
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.ignore(100, 'A');
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;
}
```

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*×*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*.

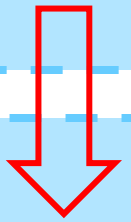
An 6×8 matrix with a saddle point

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*×*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++) {                  //for each row
   j = index of the smallest element on row i;
   for (k = 0; k < m; k++)                 //for each element in column j
      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
- Avoid side effects (see example in next page)

Side Effect

- In computer science, a function or expression is said to have a side effect if, in addition to returning a value, it also modifies some state or has an observable interaction with calling functions or the outside world.

```
int x = 0;   //global variable

int f(int n) {
    x += 1;  //side effect: modify the value of x which is not a formal parameter of function f()
    return n + x;
}

int g(int n) {
    x *= 2;  //side effect
    return n * x;
}

void main() {
    int t;
    t = f(1) + g(2);        // logically the same as t = g(2) + f(1) but the results will be totally different.
}
```