



# Advanced Programming

## Lab 5. Precautions for pointer , Memory Management(1)

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# Topic

- Precautions for pointer
  - DON'TS
  - Suggestion
    - ✓ Coding specification
    - ✓ Tool: valgrind
- Memory Management(1)
  - Stack vs Heap
    - ✓ compiler+system vs programmer
  - C/C++ vs Python
    - ✓ compiler vs interpreter
    - ✓ compiler+system+programmer vs interpreter+programmer



# Precautions for Pointer

- DON'TS

- 1. wild pointer
- 2. memory leak
- 3. free less or free more
- 4. free stack
- 5. dangling pointer

- Suggestion

- Coding specification
- Tools



# DON'TS : 1. wild pointer

```
#include<stdio.h>    //wild_pointer.c
#include<stdlib.h>
int main(intargc, char* argv[]){
    int*p1;
    *p1=0x12345678;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    return0;
}
```

```
#include<stdio.h>    //wild_pointer.c
#include<stdlib.h>
int main(int argc, char* argv[]){
    int *p1=NULL;
    *p1=0x12345678;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    return0;
}
```

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ gcc wild_pointer.c
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out
Segmentation fault (core dumped)
```

**Wild pointers** refer to pointers that have not been initialized or have been released but are still in use. The positions pointed to by these pointers are uncertain, random, and have no clear limitations.

**Wild pointers may cause program crashes or unpredictable results**, as the memory addresses they point to may already be occupied by other objects or programs, or reclaimed by the operating system



# DON'TS : 2. memory leak

```
#include<stdio.h>    //demo1.c
#include<stdlib.h>
int main(intargc, char* argv[]){
    int *p1=(int*)malloc(sizeof(int));
    *p1=0x12345678;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    return0;
}
```

```
#include<stdio.h>    //demo2.c
#include<stdlib.h>
int main(intargc, char* argv[]){
    int d1=0x12345678;
    int *p1=&d1;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    return0;
}
```

**Memory leak** refers to the waste of system memory **caused by dynamically allocated heap memory** in a program that is not released or cannot be released for some reason, resulting in **serious consequences such as slow program running speed or even system crashes**.

Q: Which piece(s) of code would lead to memory leak? demo1.c, demo2.c or both ?



# DON'TS : 3. free more or free less

```
#include <stdio.h> //free less
#include <stdlib.h>
int main(int argc, char*argv[]){
    int *p1 = malloc(sizeof(int)*1);
    int *p2 = malloc(sizeof(int)*1);
    *p1=0x12345678;
    *p2=*p1;
    printf("p1:%p\tdata:0x%x\n
           p2:%p\tdata:0x%x\n",p1,*p1,p2,*p2);
    free(p1);
    return 0;
}
```

```
#include <stdio.h> //free more
#include <stdlib.h>
int main(int argc, char*argv[]){
    int *p1 = malloc(sizeof(int)*1);
    *p1=0x12345678;
    int *p2 = p1;
    printf("p1:%p\tdata:0x%x\n
           p2:%p\tdata:0x%x\n",p1,*p1,p2,*p2);
    free(p1);
    free(p2);
    return 0;
}
```

```
ww2@DESKTOP-4NIH4UK: /mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out
p1:0x55c8cd4132a0    data:0x12345678
p2:0x55c8cd4132c0    data:0x12345678
```

```
ww2@DESKTOP-4NIH4UK: /mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out
p1:0x562895d2e2a0    data:0x12345678
p2:0x562895d2e2a0    data:0x12345678
free(): double free detected in tcache 2
Aborted (core dumped)
```

Q. Which piece of code would lead to memory leak, which piece of code would lead to program abort with error?



# DON'TS : 4. free stack

```
#include <stdio.h>
#include <stdlib.h>
int main(int argc, char*argv[]){
    int *p1=NULL;
    int d1=0x12345678;
    p1 = &d1;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    free(p1);
    return 0;
}
```

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out
address: 0x7ffe8aa8477c data: 0x12345678
free(): invalid pointer
Aborted (core dumped)
```

```
✓ WATCH
  ✓ p1: 0x7fffffffdd9c
    *p1: 305419896
  ✓ &d1: 0x7fffffffdd9c
    *&d1: 305419896
```

- Q1. What's the value of p1 after finish the assignment "`p1 = &d1;`"?
- Q2. Is the address of P1 belongs to stack or heap?
- Q3. While using free/del to release the space on stack, what would happen?



# DON'TS : 5. dangling pointer

```
#include <stdio.h> //dangling_pointer
#include <stdlib.h>
int main(int argc, char*argv[]){
    int *p1 = (int*) malloc(sizeof(int)*1);
    *p1 = 0x12345678;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    free(p1);
    *p1 = 0x78563421;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    return 0;
}
```

```
#include <stdio.h> //dangling_pointer
#include <stdlib.h>
int main(int argc, char*argv[]){
    int *p1 = (int*) malloc(sizeof(int)*1);
    *p1 = 0x12345678;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    free(p1);
    p1=NULL;
    *p1 = 0x78563421;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    return 0;
}
```

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ gcc dangling_pointer.c
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out
address: 0x55afc6f8a2a0 data: 0x12345678
address: 0x55afc6f8a2a0 data: 0x78563421
```

Seems Ok But Dangerous!!

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ gcc dangling_pointer.c
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out
address: 0x5630898572a0 data: 0x12345678
Segmentation fault (core dumped)
```





# Tools: valgrind(1)

step1. using “-g” option along with gcc/g++ to generate the executable file.  
step2. invoke valgrind with “--leak-check=full” as option, the executable file as parameter to check the memory leak on the executable file.

```
#include<stdio.h>    //memory_leak.c
#include<stdlib.h>

int main(int argc, char*argv[]){
    int *p1=(int*)malloc(sizeof(int));
    *p1=0x12345678;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    return0;
}
```

**Valgrind** is an instrumentation framework for building dynamic analysis tools. There are Valgrind tools that can **automatically detect many memory management and threading bugs, and profile your programs in detail**. You can also use Valgrind to build new tools.

<https://valgrind.org/>

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ gcc -g memory_leak.c
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ valgrind --leak-check=full ./a.out
==9103== Memcheck, a memory error detector
==9103== Copyright (C) 2002-2017, and GNU GPL'd, by Julian Seward et al.
==9103== Using Valgrind-3.15.0 and LibVEX; rerun with -h for copyright info
==9103== Command: ./a.out
==9103==
address: 0x4a48040      data: 0x12345678
==9103==
==9103== HEAP SUMMARY:
==9103==    in use at exit: 4 bytes in 1 blocks
==9103==   total heap usage: 2 allocs, 1 frees, 1,028 bytes allocated
==9103==
==9103== 4 bytes in 1 blocks are definitely lost in loss record 1 of 1
==9103==    at 0x483B7F3: malloc (in /usr/lib/x86_64-linux-gnu/valgrind/vgpreload_memcheck-amd64-linux.so)
==9103==    by 0x109185: main (memory_leak.c:4)
==9103==
==9103== LEAK SUMMARY:
==9103==    definitely lost: 4 bytes in 1 blocks
==9103==    indirectly lost: 0 bytes in 0 blocks
==9103==    possibly lost: 0 bytes in 0 blocks
==9103==    still reachable: 0 bytes in 0 blocks
==9103==    suppressed: 0 bytes in 0 blocks
==9103==
==9103== For lists of detected and suppressed errors, rerun with: -s
==9103== ERROR SUMMARY: 1 errors from 1 contexts (suppressed: 0 from 0)
```

program running results

details about the memory leak



# Tools: valgrind(2)

```
#include <stdio.h> //dangling_pointer
#include <stdlib.h>

int main(int argc, char*argv[]){
    int *p1 = (int*) malloc(sizeof(int)*1);
    *p1 = 0x12345678;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    free(p1);
    *p1 = 0x78563421;
    printf("address: %p\tdata: 0x%x\n",p1,*p1);
    return 0;
}
```

## NOTES:

The program can be executed and the results appear correct, but it brings greater risks!!!

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ gcc -g dangling_pointer.c
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out
address: 0x56089bdb12a0 data: 0x12345678
address: 0x56089bdb12a0 data: 0x78563421
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ valgrind --tool=memcheck ./a.out
==37617== Memcheck, a memory error detector
==37617== Copyright (C) 2002-2017, and GNU GPL'd, by Julian Seward et al.
==37617== Using Valgrind-3.15.0 and LibVEX; rerun with -h for copyright info
==37617== Command: ./a.out
==37617==
address: 0x4a48040      data: 0x12345678
==37617== Invalid write of size 4
==37617==    at 0x1091E2: main (dangling_pointer.c:8)
==37617==    Address 0x4a48040 is 0 bytes inside a block of size 4 free'd
==37617==    at 0x483CA3F: free (in /usr/lib/x86_64-linux-gnu/valgrind/vgpreload_memcheck-amd64-linux.so)
==37617==    by 0x1091DD: main (dangling_pointer.c:7)
==37617==    Block was alloc'd at
==37617==    at 0x483B7F3: malloc (in /usr/lib/x86_64-linux-gnu/valgrind/vgpreload_memcheck-amd64-linux.so)
==37617==    by 0x1091A5: main (dangling_pointer.c:4)
==37617==
invalid write/read on memory
==37617== Invalid read of size 4
==37617==    at 0x1091EC: main (dangling_pointer.c:9)
==37617==    Address 0x4a48040 is 0 bytes inside a block of size 4 free'd
==37617==    at 0x483CA3F: free (in /usr/lib/x86_64-linux-gnu/valgrind/vgpreload_memcheck-amd64-linux.so)
==37617==    by 0x1091DD: main (dangling_pointer.c:7)
==37617==    Block was alloc'd at
==37617==    at 0x483B7F3: malloc (in /usr/lib/x86_64-linux-gnu/valgrind/vgpreload_memcheck-amd64-linux.so)
==37617==    by 0x1091A5: main (dangling_pointer.c:4)
==37617==
address: 0x4a48040      data: 0x78563421
==37617==
==37617== HEAP SUMMARY:
==37617==    in use at exit: 0 bytes in 0 blocks
==37617==    total heap usage: 2 allocs, 2 frees, 1,028 bytes allocated
==37617==
==37617== All heap blocks were freed -- no leaks are possible
==37617==
==37617== For lists of detected and suppressed errors, rerun with: -s
==37617== ERROR SUMMARY: 2 errors from 2 contexts (suppressed: 0 from 0)
```



# Coding specification

- Tips1:
  - ✓ check if malloc/new is successful
- Tips2:
  - ✓ don't forget to free/del the space
- Tips3:
  - ✓ assign NULL to the pointer after del/free the related space

```
#include<stdio.h>    //demo.c
#include<stdlib.h>
int main(int argc, char*argv[]){
    int *p1=(int*)malloc(sizeof(int));
    if(NULL!=p1){
        *p1=0x12345678;
        printf("address: %p\tdata: 0x%x\n",p1,*p1);
        free(p1);
        p1=NULL;
    }
    return 0;
}
```

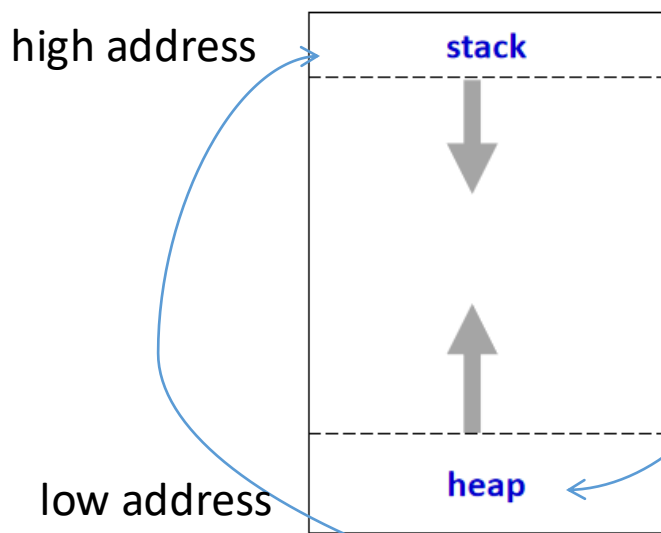
```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ gcc -g demo.c
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ valgrind --leak-check=full ./a.out
==57150== Memcheck, a memory error detector
==57150== Copyright (C) 2002-2017, and GNU GPL'd, by Julian Seward et al.
==57150== Using Valgrind-3.15.0 and LibVEX; rerun with -h for copyright info
==57150== Command: ./a.out
==57150==
address: 0x4a48040      data: 0x12345678
==57150==
==57150== HEAP SUMMARY:
==57150==      in use at exit: 0 bytes in 0 blocks
==57150==    total heap usage: 2 allocs, 2 frees, 1,028 bytes allocated
==57150==
==57150== All heap blocks were freed -- no leaks are possible
==57150==
==57150== For lists of detected and suppressed errors, rerun with: -s
==57150== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
```



# Memory Management-Stack vs Heap(1)

Both Stack and heap belongs to dynamic memory area.

- Stack: LIFO, expand from high address to low address.
- heap: expand from low address to high address.



```
lab5 > C demo.c > main(int, char * [])
3 int main(int argc, char*argv[]){
4     int *p1=(int*)malloc(sizeof(int));
5     if(NULL!=p1){
6         *p1=0x12345678;
7         printf("address: %p\data: 0x%x\n",p1,*p1);
8         free(p1);
9         p1=NULL;
10    }
```

PROBLEMS OUTPUT **DEBUG CONSOLE** PORTS 1 MEMORY TERMINAL endian

→ -exec info proc mapping  
process 69522  
Mapped address spaces:

Start Addr	End Addr	Size	Offset	objfile
0x55555554000	0x55555555000	0x1000	0x0	/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5/demo
0x55555555000	0x55555556000	0x1000	0x1000	/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5/demo
0x55555556000	0x55555557000	0x1000	0x2000	/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5/demo
0x55555557000	0x55555558000	0x1000	0x2000	/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5/demo
0x55555558000	0x55555559000	0x1000	0x3000	/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5/demo
0x55555559000	0x5555557a000	0x21000	0x0	[heap]
0x7ffff7dcc000	0x7ffff7dee000	0x22000	0x0	/usr/lib/x86_64-linux-gnu/libc-2.31.so
0x7ffff7dee000	0x7ffff7f66000	0x178000	0x22000	/usr/lib/x86_64-linux-gnu/libc-2.31.so
0x7ffff7f66000	0x7ffff7fb4000	0x4e000	0x19a000	/usr/lib/x86_64-linux-gnu/libc-2.31.so
0x7ffff7fb4000	0x7ffff7fb8000	0x4000	0x1e7000	/usr/lib/x86_64-linux-gnu/libc-2.31.so
0x7ffff7fb8000	0x7ffff7fba000	0x2000	0x1eb000	/usr/lib/x86_64-linux-gnu/libc-2.31.so
0x7ffff7fba000	0x7ffff7fc0000	0x6000	0x0	
0x7ffff7fc9000	0x7ffff7fcd000	0x4000	0x0	[vvar]
0x7ffff7fcd000	0x7ffff7fcf000	0x2000	0x0	[vdso]
0x7ffff7fcf000	0x7ffff7fd0000	0x1000	0x0	/usr/lib/x86_64-linux-gnu/ld-2.31.so
0x7ffff7fd0000	0x7ffff7ff3000	0x23000	0x1000	/usr/lib/x86_64-linux-gnu/ld-2.31.so
0x7ffff7ff3000	0x7ffff7ffb000	0x8000	0x24000	/usr/lib/x86_64-linux-gnu/ld-2.31.so
0x7ffff7ffc000	0x7ffff7ffd000	0x1000	0x2c000	/usr/lib/x86_64-linux-gnu/ld-2.31.so
0x7ffff7ffd000	0x7ffff7ffe000	0x1000	0x2d000	/usr/lib/x86_64-linux-gnu/ld-2.31.so
0x7ffff7ffe000	0x7ffff7fff000	0x1000	0x0	
0x7ffff7ffe000	0x7ffff7fff000	0x21000	0x0	[stack]



# Memory Management-Stack vs Heap(2)

```
lab5 > C mm_stack_demo.c > main(int, char * [])
```

```
1 #include <stdio.h>
2 #include <stdlib.h>
3 int main(int argc, char*argv[]){
4     char str[]="I'm here.";
5     char p[1024*1024*10] = {};
6     return 0;
7 }
```

PROBLEMS

OUTPUT

DEBUG CONSOLE

PORTS

1

MEMORY

TERMINAL

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ gcc -g -O0 -o mm_stack_demo mm_stack_demo.c
```

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ valgrind --tool=memcheck ./mm_stack_demo
```

```
==91562== Memcheck, a memory error detector
```

```
==91562== Copyright (C) 2002-2017, and GNU GPL'd, by Julian Seward et al.
```

```
==91562== Using Valgrind-3.15.0 and LibVEX; rerun with -h for copyright info
```

```
==91562== Command: ./mm_stack_demo
```

```
==91562==
```

```
==91562== Stack overflow in thread #1: can't grow stack to 0x1ffe801000
```

```
==91562==
```

```
==91562== Process terminating with default action of signal 11 (SIGSEGV)
```

```
==91562== Access not within mapped region at address 0x1FFE801D30
```

```
==91562== Stack overflow in thread #1: can't grow stack to 0x1ffe801000
```

```
==91562== at 0x109180: main (mm_stack_demo.c:3)
```

```
==91562== If you believe this happened as a result of a stack
```

```
==91562== overflow in your program's main thread (unlikely but
```

```
==91562== possible), you can try to increase the size of the
```

```
==91562== main thread stack using the --main-stacksize= flag.
```

```
==91562== The main thread stack size used in this run was 8388608.
```

```
==91562== Stack overflow in thread #1: can't grow stack to 0x1ffe801000
```

```
==91562==
```

```
==91562== Process terminating with default action of signal 11 (SIGSEGV)
```

```
==91562== Access not within mapped region at address 0x1FFE801D28
```

```
==91562== Stack overflow in thread #1: can't grow stack to 0x1ffe801000
```

```
==91562== at 0x4831134: _vgnU_freeres (in /usr/lib/x86_64-linux-gnu/valgrind/vgpreload_core-amd64-linux.so)
```

```
==91562== If you believe this happened as a result of a stack
```

```
==91562== overflow in your program's main thread (unlikely but
```

```
==91562== possible), you can try to increase the size of the
```

```
==91562== main thread stack using the --main-stacksize= flag.
```

```
==91562== The main thread stack size used in this run was 8388608.
```

```
==91562==
```

```
==91562== HEAP SUMMARY:
```

```
==91562== in use at exit: 0 bytes in 0 blocks
```

```
==91562== total heap usage: 0 allocs, 0 frees, 0 bytes allocated
```

stack overflow

```
#include <stdio.h>
#include <stdlib.h>
int main(int argc, char*argv[]){
    char str[]="I'm here.";
    char p[1024*1024*10] = {};
    return 0;
}
```

Requesting a large space in the **stack** space may lead to stack overflow.

In this demo, the size of the space is 1024\*1024\*10 sizeof char.

The space on stack for C/C++ is managed by Compiler and the system.

Q. Smaller the size of char array “p”, such as 1024\*10, generate the executable file and use valgrind again, what’s the result?





# Memory Management-Stack vs Heap(3)

```
1 #include <stdio.h>
2 #include <stdlib.h>
3 int main(int argc, char*argv[]){
4     char str[]="I'm here.";
5     char *p = (char*)malloc(sizeof(char)*1024*1024*10);
6     if(p!=NULL){
7         free(p);
8         p=NULL;
9     }
10    return 0;
11 }
```

PROBLEMS OUTPUT DEBUG CONSOLE PORTS 1 MEMORY TERMINAL

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ gcc -g -O0 -o mm_heap_demo mm_heap_demo.c
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ valgrind --tool=memcheck ./mm_heap_demo
==91012== Memcheck, a memory error detector
==91012== Copyright (C) 2002-2017, and GNU GPL'd, by Julian Seward et al.
==91012== Using Valgrind-3.15.0 and LibVEX; rerun with -h for copyright info
==91012== Command: ./mm_heap_demo
==91012==
==91012== HEAP SUMMARY:
==91012==   in use at exit: 0 bytes in 0 blocks
==91012==   total heap usage: 1 allocs, 1 frees, 10,485,760 bytes allocated
==91012==
==91012== All heap blocks were freed -- no leaks are possible
==91012==
==91012== For lists of detected and suppressed errors, rerun with: -s
==91012== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$
```

it's ok to apply for  
a large space on  
heap.

DO remember to  
free it.

```
#include <stdio.h>
#include <stdlib.h>
int main(int argc, char*argv[]){
    char str[]="I'm here.";
    char *p =
(char*)malloc(sizeof(char)*1024*1024*10);
    if(p!=NULL){
        free(p);
        p=NULL;
    }
    return 0;
}
```

Requesting a large space in the **heap** space would not lead to heap overflow.

In this demo, the size of the space is 1024\*1024\*10 sizeof char.

The space on heap for C/C++ is managed by programmer.



# Memory Management-C/C++ VS Python(1)

	C/C++	Python
Language Type	Compiled	Interpreted
Operating efficiency	Faster, real time	Slower
Static/dynamic type	Static type languages determine variable types at compile time	Dynamic type languages determine variable types at runtime.
Memory Mangment	1. Compiler + System for non-heap space  2. programmer for heap	1. interpreter for most situation  2. garbage collector used by programmer for very few situation
others	...	...

```
C:\Users\sustech>python
Python 3.11.4 (tags/v3.11.4:
Type "help", "copyright", "c
>>> a=123
>>> type(a)
<class 'int'>
>>> a='123'
>>> type(a)
<class 'str'>
>>> a=b'123'
>>> type(a)
<class 'bytes'>
>>> a=[123,'123',b'123']
>>> a
[123, '123', b'123']
>>>
```

<https://docs.python.org/3/c-api/memory.html>



# Exercise 1

```
#include<stdio.h>
int main()
{
    int numbers1[] = {2,4,6,8,10};
    int sum = 0;
    int *p1 = &numbers1[1];
    printf("numbers1 = %p\n", numbers1);
    printf("p1      = %p\n", p1);
    for(int i = 0; i < 3; i++)
        sum += *(p1+i);
    printf("sum      = %d\n",sum);

    int numbers2[5]={1,2,3,4,5};
    int *p2 = (int*)(&numbers2 + 1);
    printf("numbers2  = %p\n", numbers2);
    printf("numbers2 + 4 = %p\n", numbers2 + 4);
    printf("p2          = %p\n", p2);
    printf("*(numbers2+1)= %d\n",*(numbers2+1));
    printf("(p2-1)      = %d\n",*(p2-1));
    return 0;
}
```

Run the program and explain the result to SA.





# Exercise 2

```
#include <iostream>
using namespace std;
int main()
{
    int matrix[][4] = {1,3,5,7,9,11,13,15,17,19};
    int *p = *(matrix + 1);
    p += 3;
    cout << "*p++ = " << *p++ << endl;

    const char *str = "Welcome to programming.";
    long *q = (long *)str;
    q++;
    char *r = (char *)q;
    cout << r << endl;

    unsigned int num = 0x3E56AF67;
    unsigned short *pshort = (unsigned short *) &num;
    cout << "*pshort = 0x" << hex << *pshort << endl;
    return 0;
}
```

Run the program and explain the result to SA.



# Exercises 3

- 3-1. Complete the code on the right to finish the following task:
  - 1. Determine whether the current system is in big-endian(BE) or little-endian(LE) based on the storage location of byte0 in numA.
  - 2. Store each byte in numA to a new space (numB or pointed by pnumB) in reverse order.
    - ✓ If the command-line parameter of the program is 'H', use heap mode to implement swapping.
    - ✓ If the command-line parameter of the program is 'S', use stack mode to implement swapping.
    - ✓ Print out the value of numB (or pointed by pnumB) in hexadecimal.
- 3-2. Use the tool valgrind to check if there is memory problem on the code.

```
#include <stdio.h>
#include <stdlib.h>
int main(int argc, char *argv[]){
    int numA = 0x11223344;
    if(argc==2){
        if((argv[1][0] == 'H')){
            int *pnumB = (int*)malloc(sizeof(int));
            if(pnumB != NULL){
                /*complete code here*/
            }
        }
        else if((argv[1][0] == 'S')){
            /*complete code here*/
        }
    }
    return 0;
}
```

```
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out H
Data A_addr: 0x0x7ffed47fb3f8, A_data: 0x11223344, This is LE
Data B_addr: 0x0x562d6f40a2a0, B_data: 0x44332211
ww2@DESKTOP-4NIH4UK:/mnt/c/Users/sustech/Desktop/C_CPP_CODE/lab5$ ./a.out S
Data A_addr: 0x0x7ffdd4954cc8, A_data: 0x11223344, This is LE
Data B_addr: 0x0x7ffdd4954ccc, B_data: 0x44332211
```



# Tips on Big-Endian and Little-Endian

**BE** stores the big-end first, the lowest memory address is the biggest.

**LE** stores the little-end first, the lowest memory address is the littlest.

## Big-Endian

2003	44
2002	33
2001	22
2000	11

## Little-Endian

2003	11
2002	22
2001	33
2000	44

```
#include<stdio.h>
union data
{
    int a;
    char c;
};

int main()
{
    union data endian;
    endian.a = 0x11223344;

    if(endian.c == 0x11)
        printf("Big-Endian\n");
    else if(endian.c == 0x44)
        printf("Little-Endian\n");

    return 0;
}
```

Q: Run the demo on your system, is your system Big-Endian or Little-Endian?