Chapter 13. The Abstraction: Address Space

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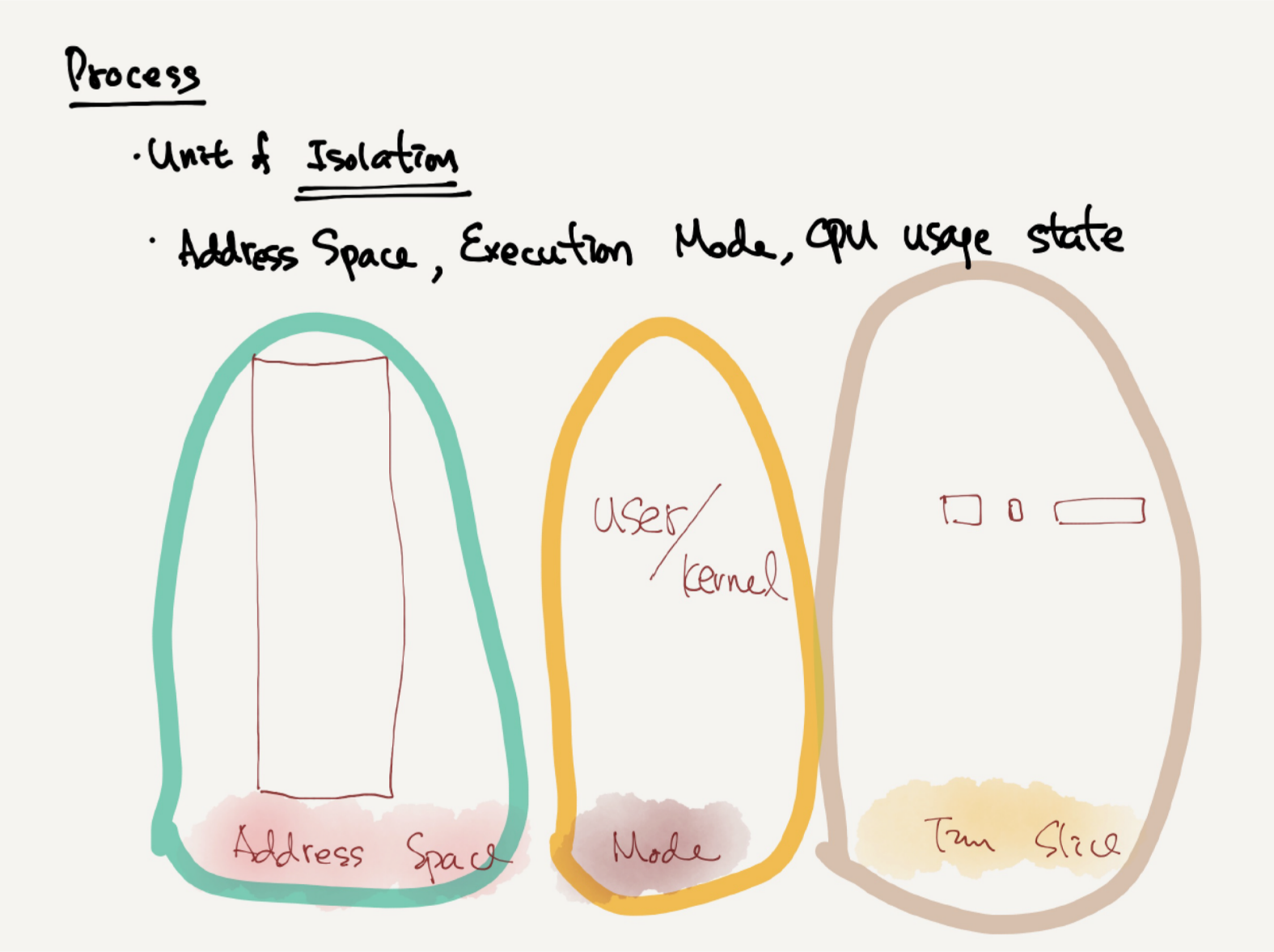
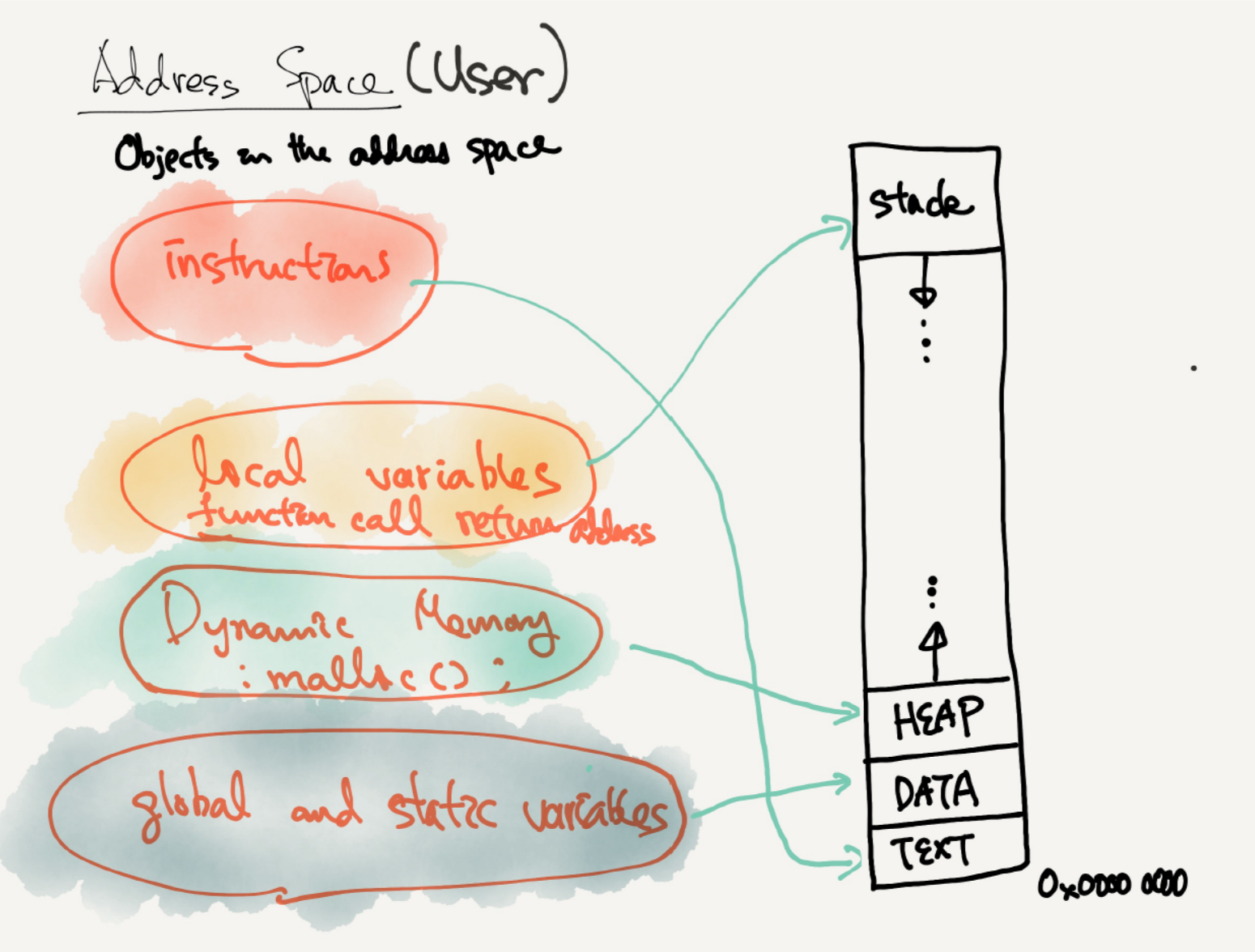
Slides adapted from Dr. Youjip Won

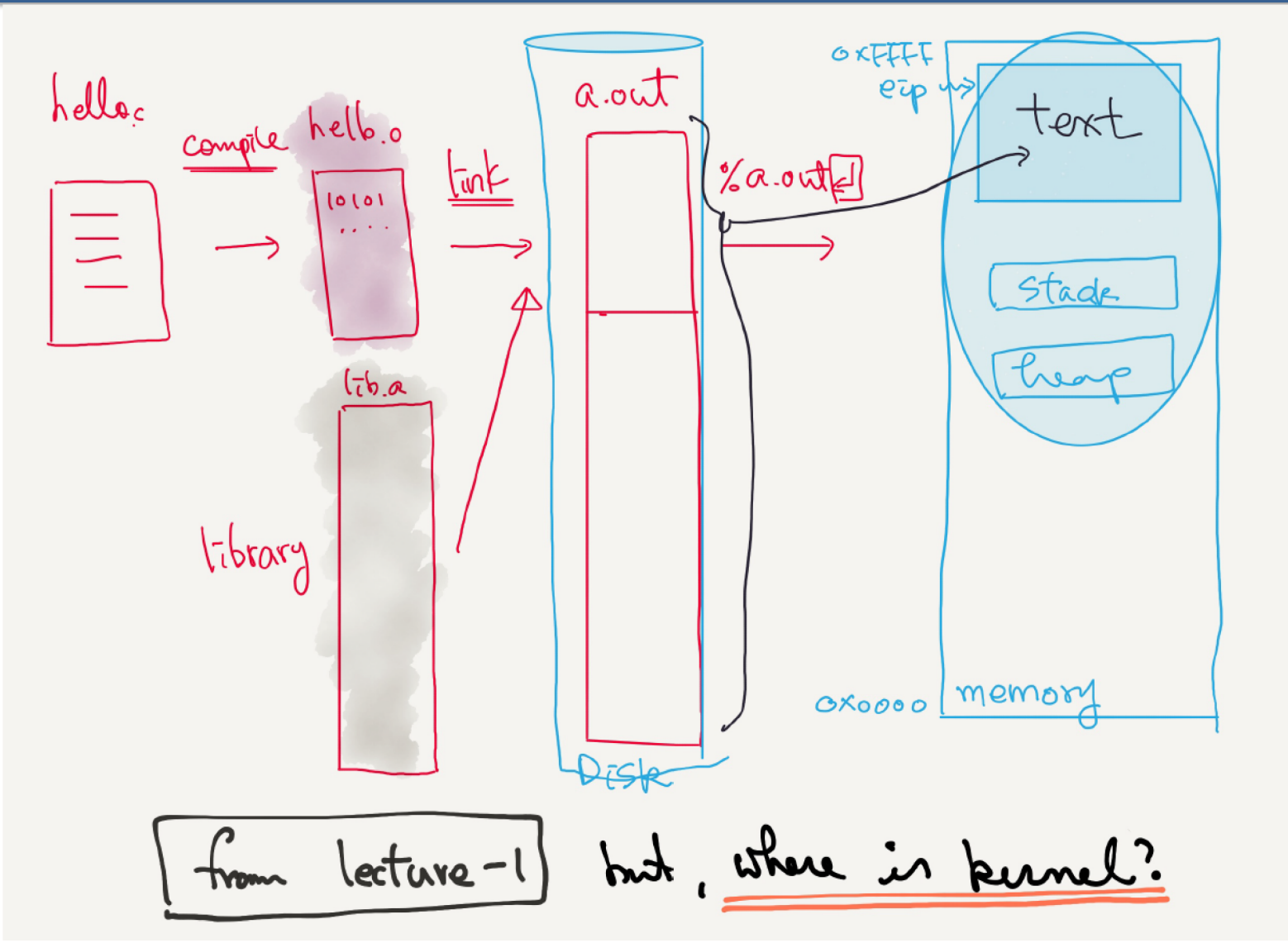
Memory Virtualization

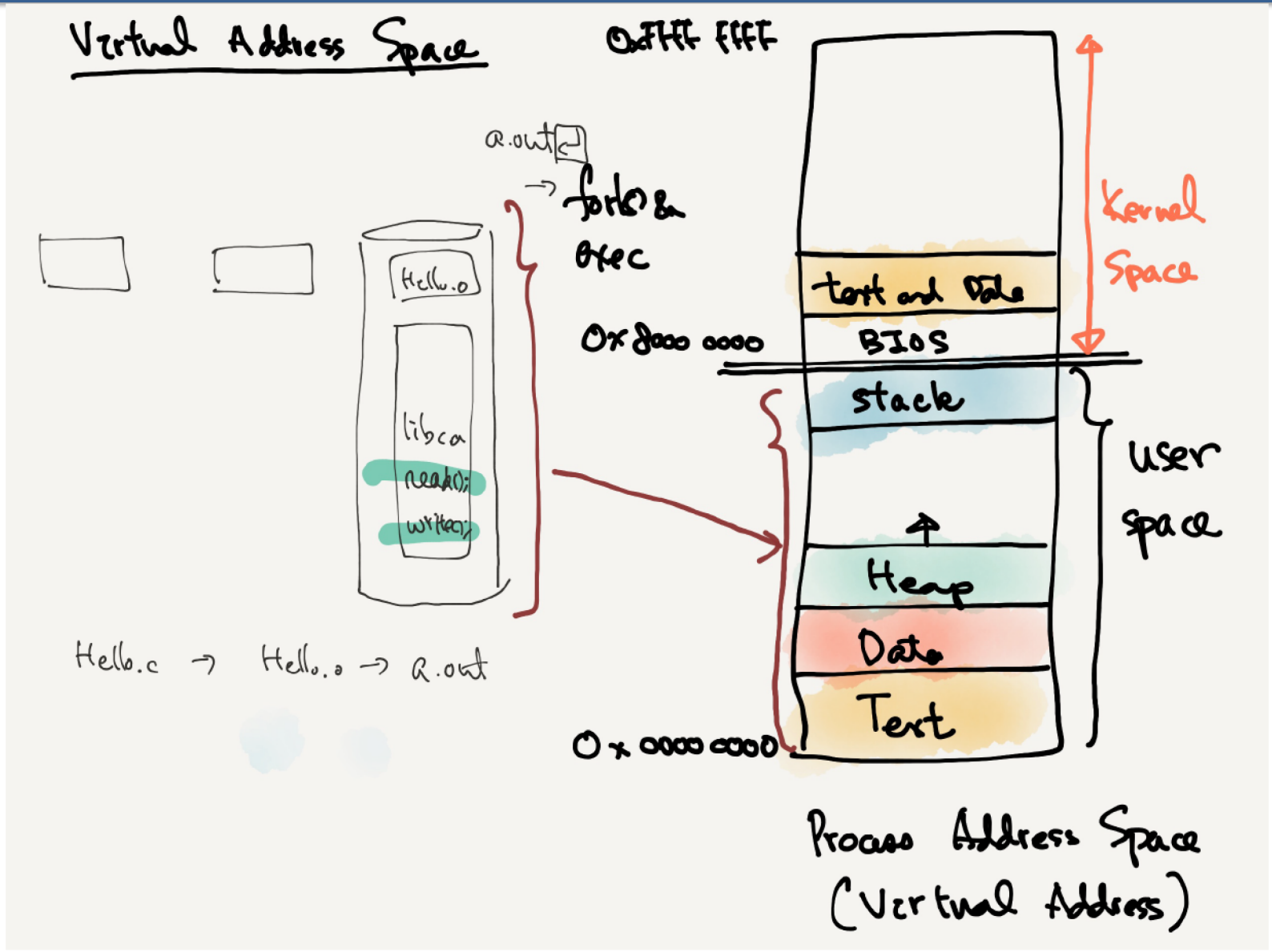
- What is **memory virtualization**?
  - OS virtualizes its physical memory.
  - OS provides an illusion memory space per each process.
  - It seems to be seen like each process uses the whole memory .

Isolation


Process
· Unit of Isolation
· Address Space, Execution Mode, CPU usage state
User/kernel
Address Space
Mode
Time Slice


Address Space (User)
Objects in the address space
instructions
local variables
function call return address
Dynamic Memory
: malloc();
global and static variables
stack
HEAP
DATA
TEXT
0x0000 0000


hello.c
compile
hello.o
10101
link
a.out
%a.out
0xFFFF
eip
text
stack
heap
memory
0x0000
lib.a
library
Disk
from lecture-1
but, where is kernel?


Virtual Address Space
0xFFFF FFFF
a.out
fork() &
exec
Hello.o
libca
read();
write();
Kernel
Space
text and Data
BIOS
0x8000 0000
stack
user
space
Heap
Data
Text
0x 0000 0000
Hello.c → Hello.o → a.out
Process Address Space
(Virtual Address)

Process structure: `struct thread`

pintos/src/threads/thread.h

```
struct thread
{
    /* Owned by thread.c. */
    tid_t tid;                          /* Thread identifier. */
    enum thread_status status;          /* Thread state. */
    char name[16];                      /* Name (for debugging purposes). */
    uint8_t *stack;                     /* Saved stack pointer. */
    int priority;                       /* Priority. */
    struct list_elem allelem;           /* List element for all threads list. */

    /* Shared between thread.c and synch.c. */
    struct list_elem elem;              /* List element. */

#ifdef USERPROG
    /* Owned by userprog/process.c. */
    uint32_t *pagedir;                  /* Page directory. */
#endif

    /* Owned by thread.c. */
    unsigned magic;                     /* Detects stack overflow. */
};
```

```
enum thread_status
  {
    THREAD_RUNNING,     /* Running thread. */
    THREAD_READY,       /* Not running but ready to run. */
    THREAD_BLOCKED,     /* Waiting for an event to trigger. */
    THREAD_DYING        /* About to be destroyed. */
  };
```

Process : `struct thread`

- page table

`p->pagedir`

- kernel stack

`p->stack`

- run state

`p->status`

process: unit of isolation
- page table

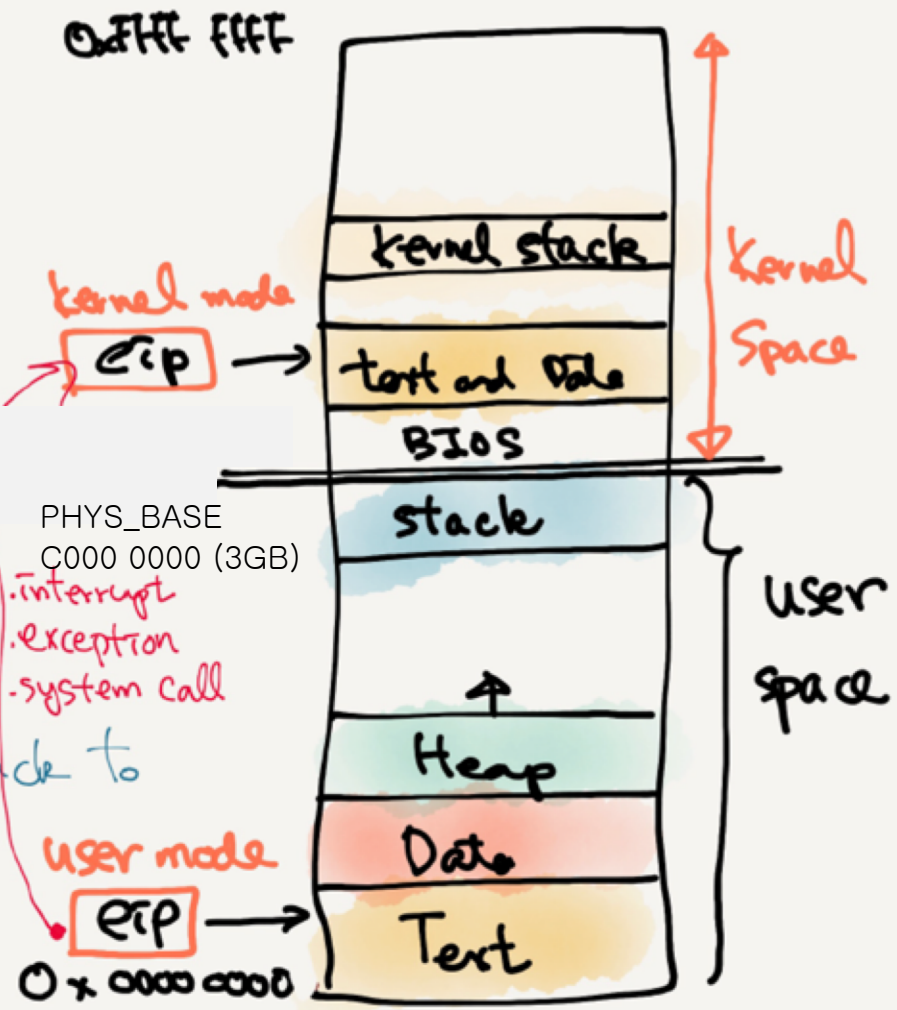
thread: unit of execution
- registers
- stacks
  - local variables
  - function call return address

User stack vs. kernel stack

Executing in User Mode
- User stack

executing in the kernel
- use kernel stack

- System Call
  - entering the kernel
  1. switch from user stack to kernel stack
  2. raise privilege level

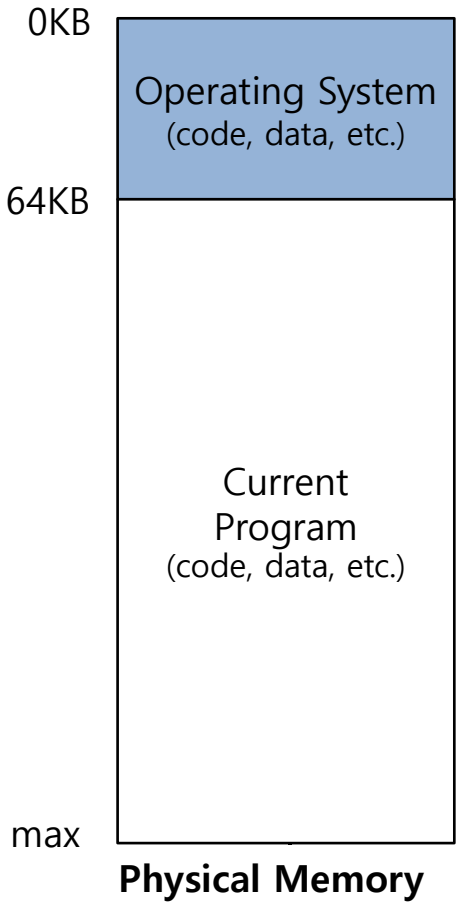


Benefit of Memory Virtualization

- Ease of use in programming
- Memory efficiency in terms of times and space
- The guarantee of isolation for processes as well as OS
  - Protection from errant accesses of other processes

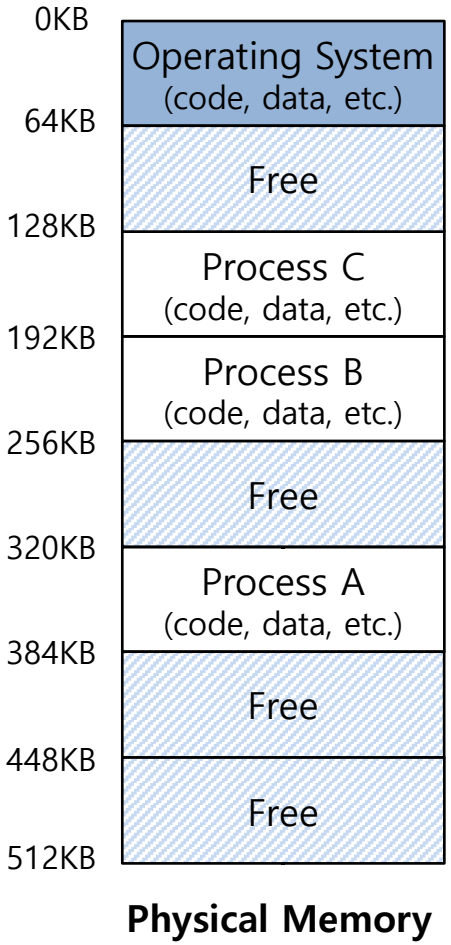
OS in The Early System

- Load only one process in memory.
  - Poor utilization and efficiency



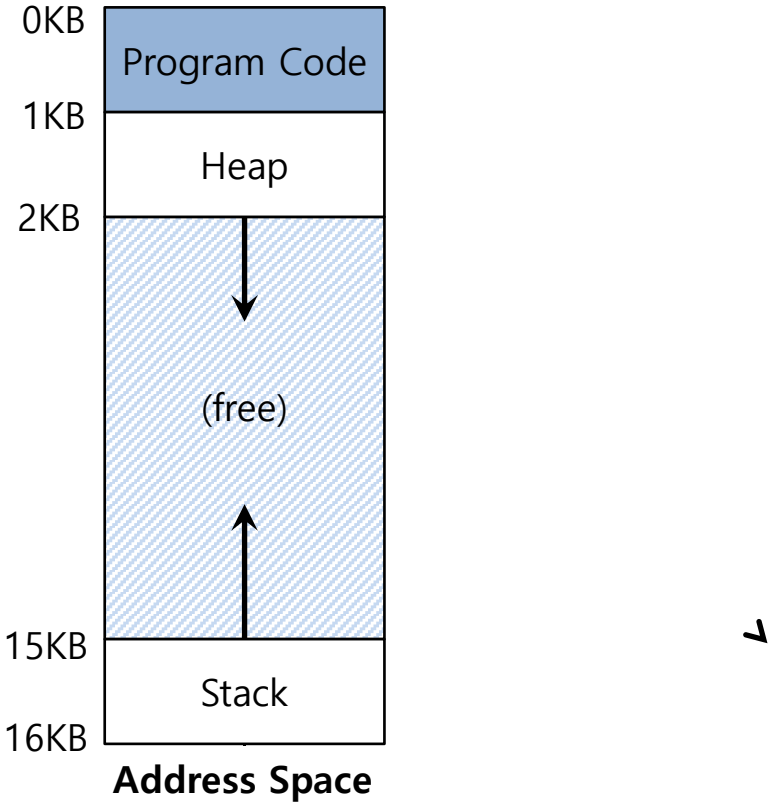
Multiprogramming and Time Sharing

- **Load multiple processes** in memory.
  - Execute one for a short while.
  - Switch processes between them in memory.
  - Increase utilization and efficiency.
- Cause an important **protection issue**.
  - Errant memory accesses from other processes



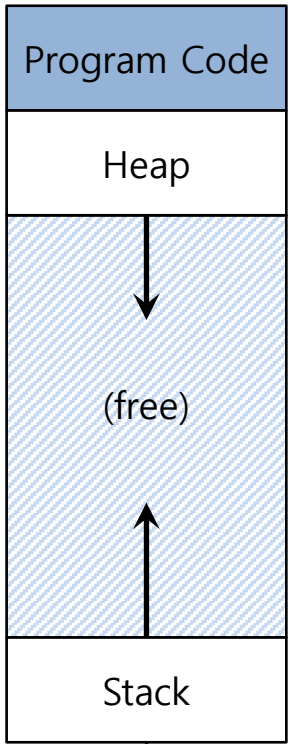
Address Space

- OS creates an **abstraction** of physical memory.
  - The address space contains all about **a** running process.
  - That consists of program code, heap, stack and etc.



Address Space(Cont.)

- Code
  - Where instructions live
- Heap
  - Dynamically allocate memory.
    - `malloc` in C language
    - `new` in object-oriented language
- Stack
  - Store return addresses or values.
  - Contain local variables arguments to routines.



Address Space

Virtual Address

- **Every address** in a running program is virtual.
  - OS translates the virtual address to physical address

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

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

    printf("location of code  : %p\n", (void *) main);
    printf("location of heap  : %p\n", (void *) malloc(1));
    int x = 3;
    printf("location of stack : %p\n", (void *) &x);

    return x;
}
```

A simple program that prints out addresses

Virtual Address(Cont.)

- The output in 64-bit Linux machine

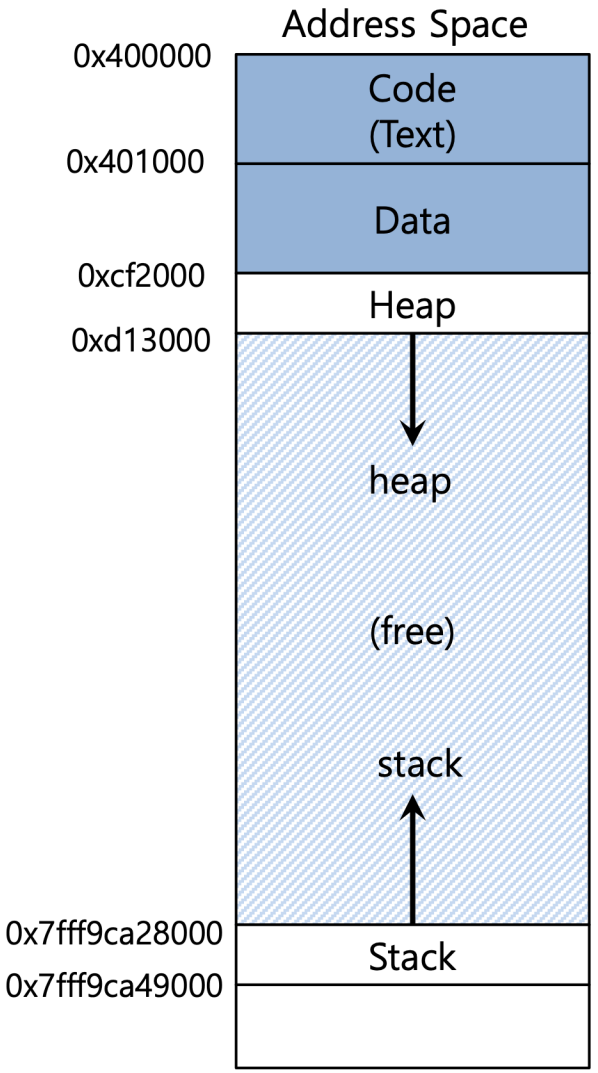
```
location of code  : 0x40057d
location of heap  : 0xcf2010
location of stack : 0x7fff9ca45fcc
```

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

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

    printf("location of code  : %p\n", (void *) main);
    printf("location of heap  : %p\n", (void *) malloc(1));
    int x = 3;
    printf("location of stack : %p\n", (void *) &x);

    return x;
}
```



Components of Virtual Address Space

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

int InitializedGlobal[1024] = {0,};
int UnintGlobal[1024];

int main() {
    int localVar1;
    int localVar2;
    int *dynamicLocalVar1;
    int *dynamicLocalVar2;

    dynamicLocalVar1 = malloc(sizeof(int));
    dynamicLocalVar2 = malloc(sizeof(int));

    printf("code                 : 0x%x\n", main);
    printf("Data                 : 0x%x\n", &InitializedGlobal);
    printf("BSS(Uninit Data)     : 0x%x\n", &UnintGlobal);

    printf("stack localVar1      : 0x%x\n", &localVar1);
    printf("stack localVar2      : 0x%x\n", &localVar2);
    printf("heap dynamicLocalVar1: 0x%x\n", dynamicLocalVar1);
    printf("heap dynamicLocalVar2: 0x%x\n", dynamicLocalVar2);
    return 0;
}
```

Block Starting Symbol (BSS): statically-allocated variables that are declared but have n ot been assigned a value yet

Components of Virtual Address Space

```
husky:~ $ ./a.out
code                    : 0xdffde0
Data                    : 0xe01020
BSS(Uninit Data)        : 0xe02020
stack localVar1         : 0xeee00a88
stack localVar2         : 0xeee00a84
heap dynamicLocalVar1: 0xc4c01700
heap dynamicLocalVar2: 0xc4c01710
```

Minimum heap allocation unit: 16 Byte