CS310 Operating Systems

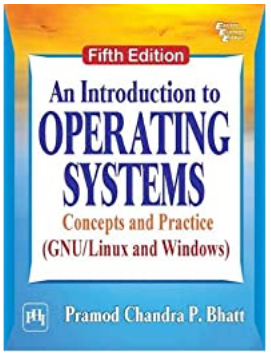
Lecture 18: Inter Process Communication – Shared Memory

Ravi Mittal

IIT Goa

Reading

- Book: An introduction to Operating System: Concepts and Practices, Pramod Chandra Bhatt, 5th Edition,
  - Chapter 7, Section 7.3.4

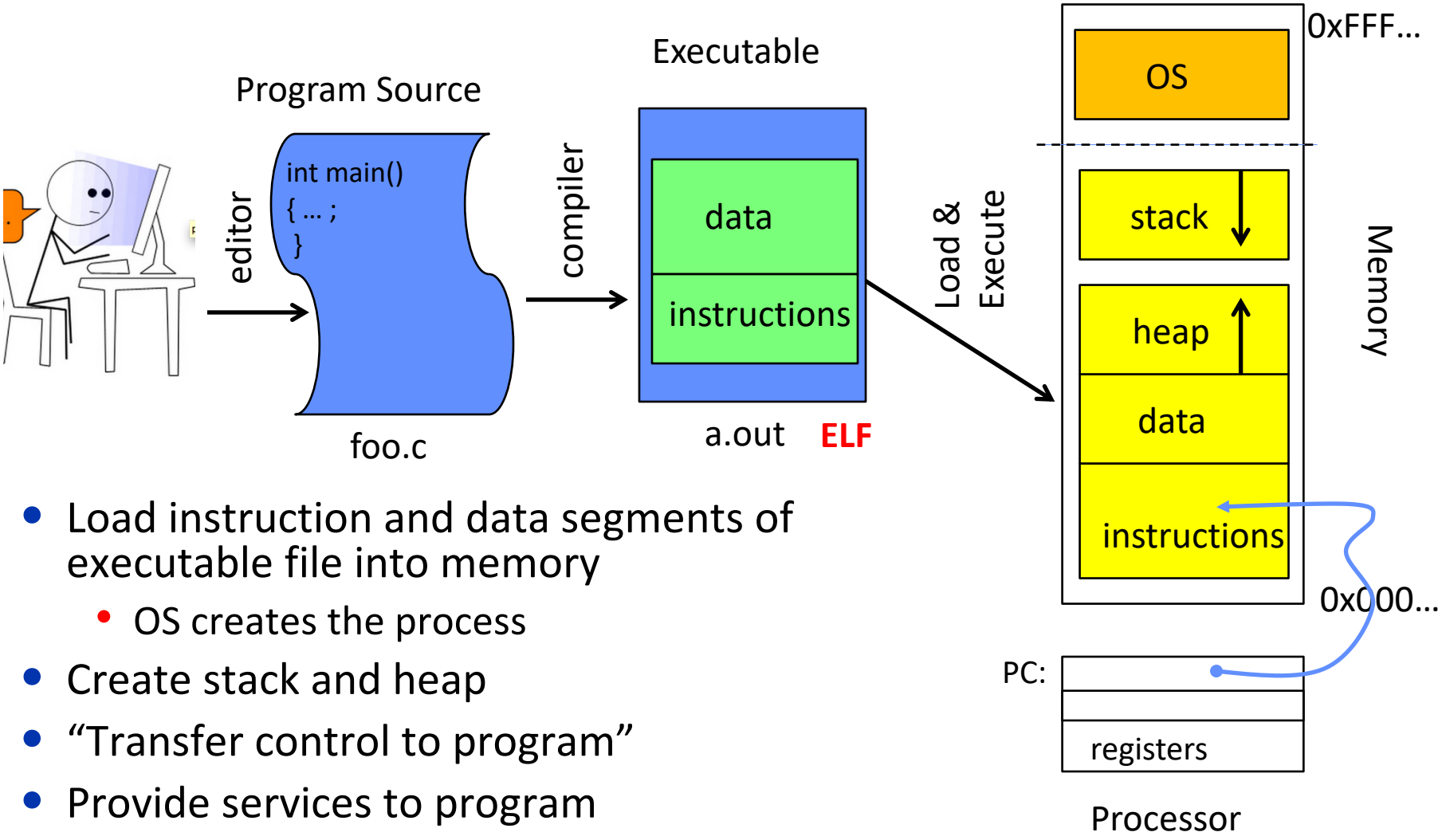


Today we will study

- Where are we in CS310?
- Shared Memory Concept
- Garbage Collection

Where are we in CS310?

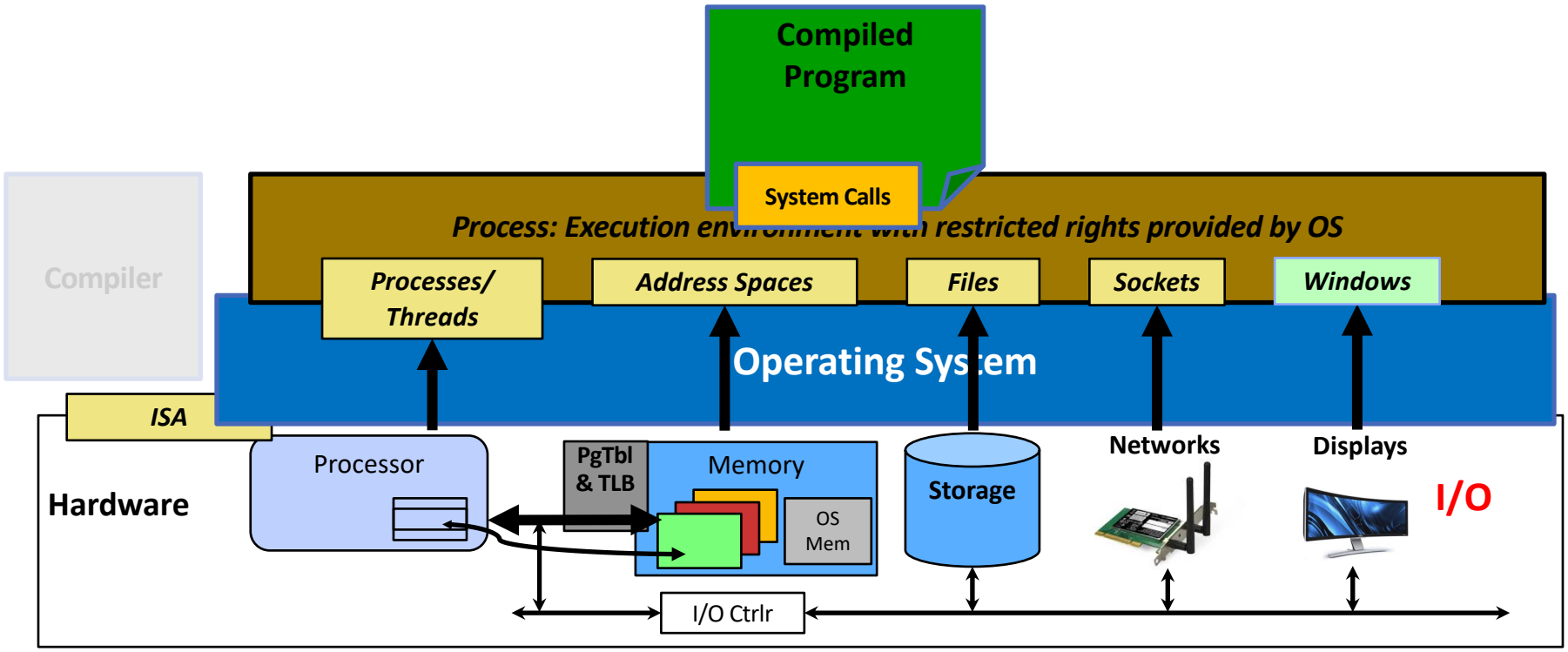
Recall: OS Bottom Line: Run Programs



- Load instruction and data segments of executable file into memory
  - OS creates the process
- Create stack and heap
- "Transfer control to program"
- Provide services to program
- While protecting OS and program

ELF: Executable and Linking Format

Recall: Operating System



Topics

- OS Concepts: Top Level view
  - How does the OS work?
  - Multiprogramming Concept
- Process Concept, PCB, Context Switching
- How processes interact with OS for use of hardware – System Calls
- Threads
  - Concept
- Inter-process Communication
  - Message Passing and Shared Memory
- Concurrency Management
- File System, I/O
- Security
- Cloud Infrastructure

Two important Requirements

- When processes/threads interact with each other, they must satisfy the following requirements:
- Synchronization
  - Processes may need to be synchronized to enforce mutual exclusion
- Communication
  - Cooperating processes may need to exchange information

Concurrent Execution of Processes / Threads

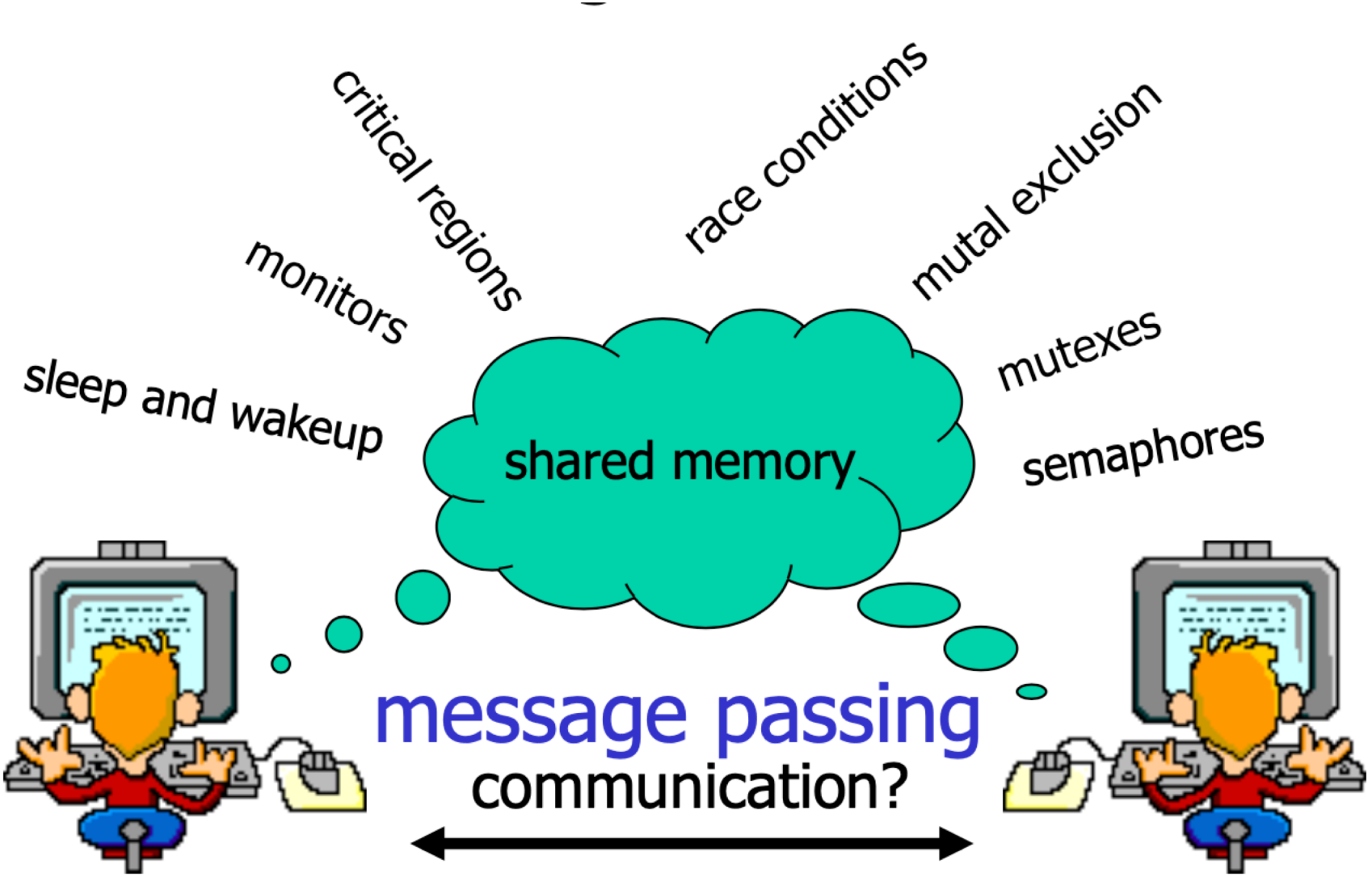
- Concurrency is inherent feature of multiprogramming, multiprocessing, distributed systems, and client-server model of computation
- Implementation of systems using concurrent Threads/Processes require
  - Communication between Processes/Threads
  - Synchronization among processes/Threads
  - Sharing of common resources

Interactions among processes

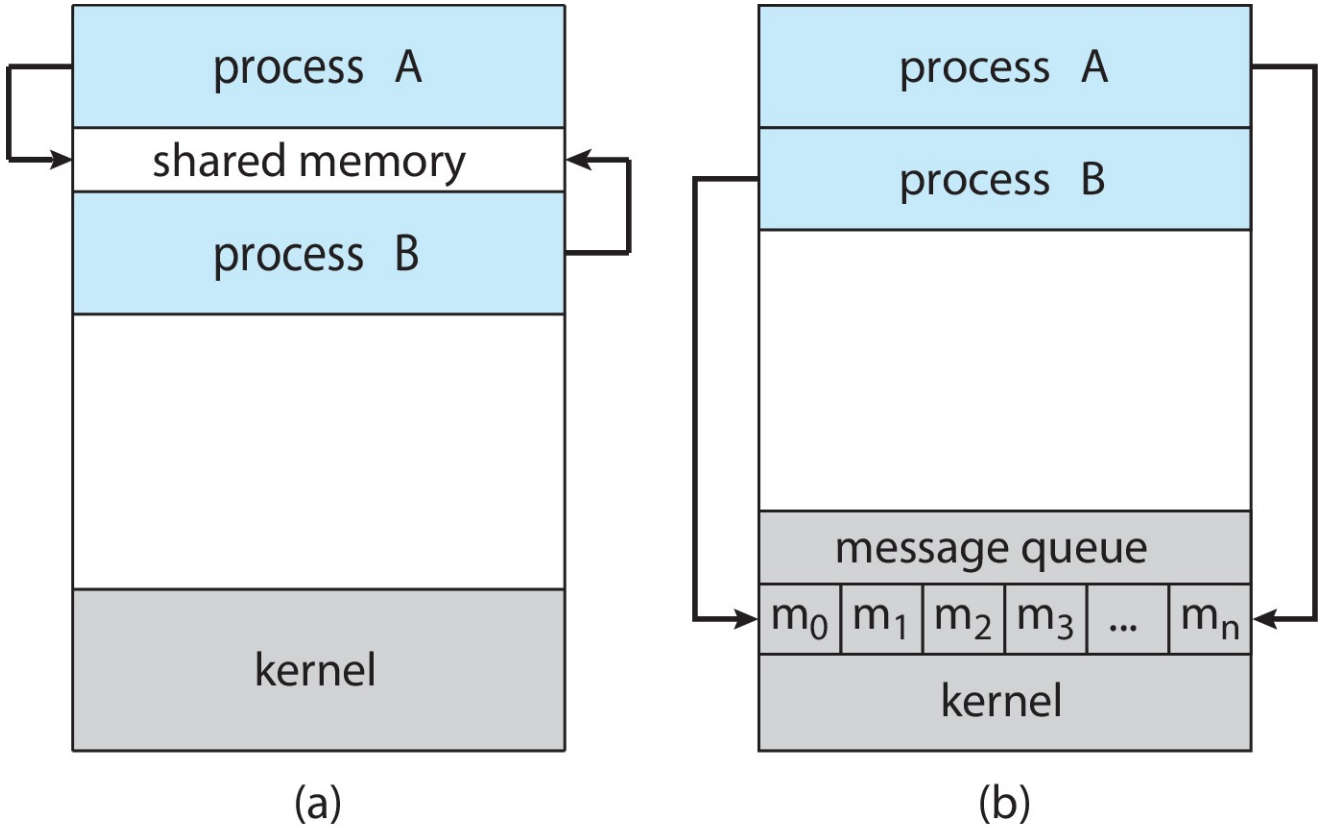
- **Competing processes**: Processes themselves do not share anything. But OS has to share the system resources among these processes "competing" for system resources such as disk, file or printer.

- **Cooperating processes** : Results of one or more processes may be needed for another process. Reasons for cooperation:
  - Information sharing
  - Computation Speedup
  - Modularity
  - Convenience

IPC – Big Picture



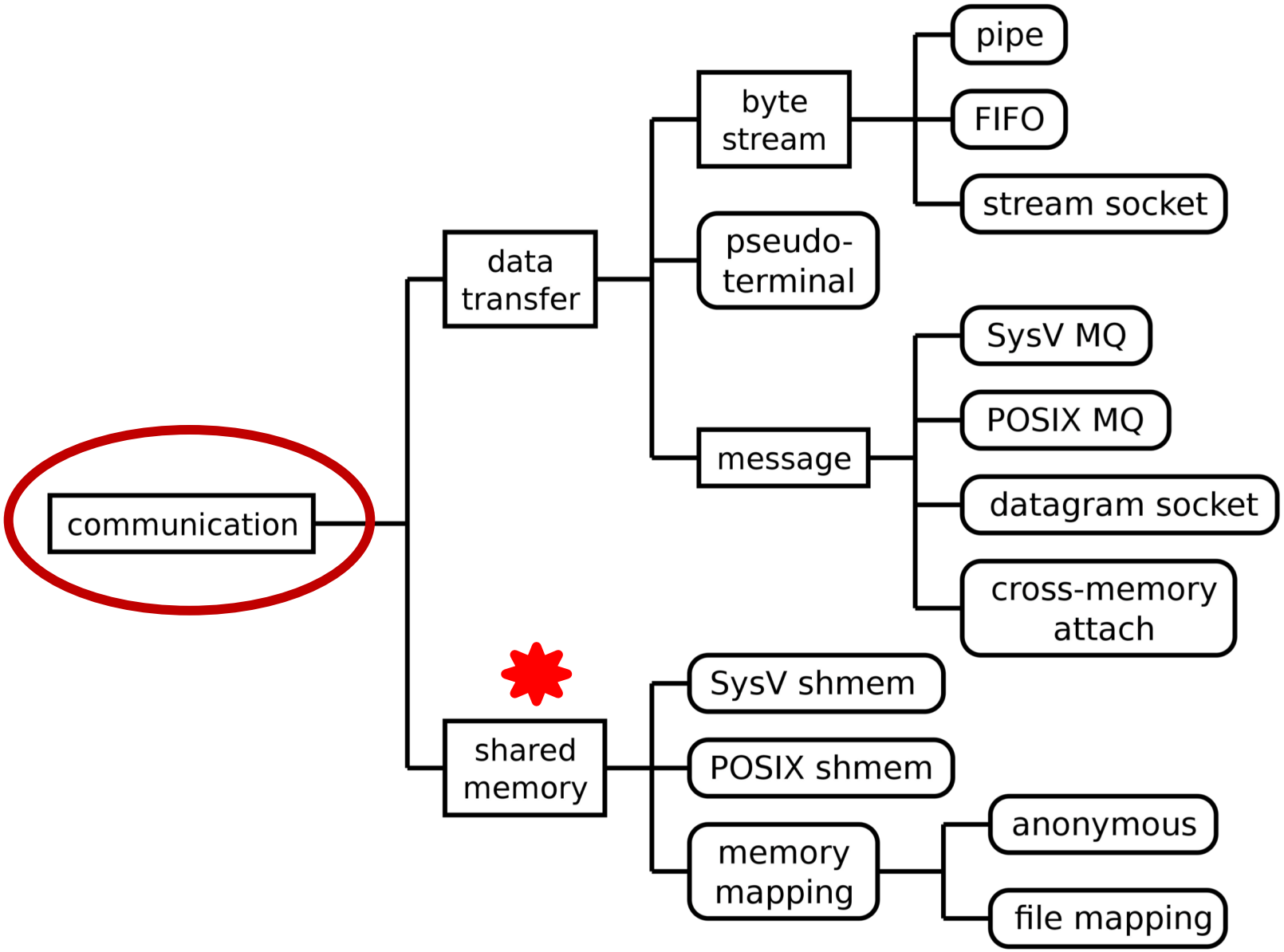
Models of IPC: Shared Memory, Message Passing



Shared memory

Message passing.

Communication



Models of IPC: Shared Memory, Message Passing

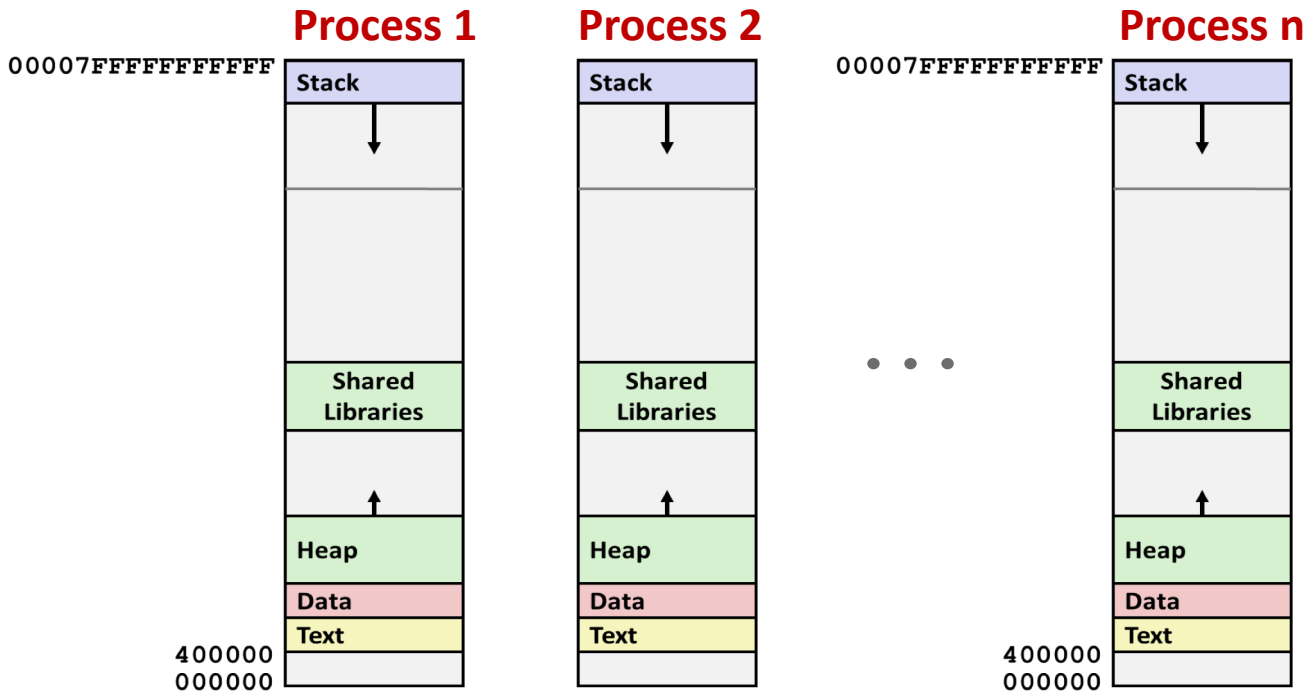
Both models are commonly used in operating systems

- Shared Memory
  - Faster than message passing as message passing is implemented using system calls (generally slow)
  - System Calls are needed only to establish shared memory regions
    - Once shared memory is created, access is the same as routine memory access – thus no help from OS is required
- Message passing
  - Useful for exchanging small amount of data
  - Easier to implement in distributed systems
  - Usually implemented using system calls

Shared Memory Concept

Shared Memory Concept

- Requires communicating processes to establish a region of shared memory
- How to create shared memory region – when each process has it's own address space?

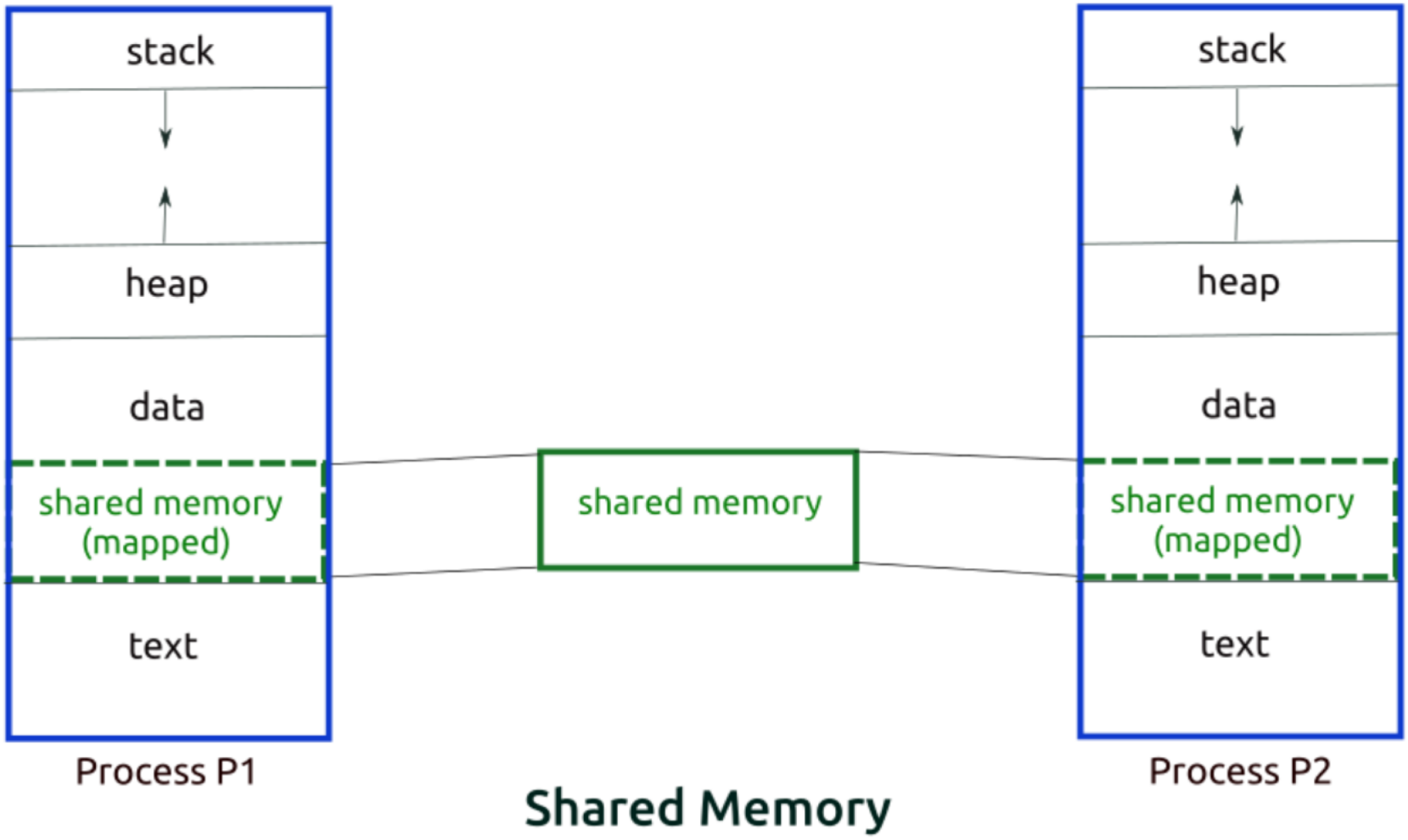


Shared Memory Concept

- A shared-memory region resides in the address space of the process creating the shared-memory segment
- Any process that wish to communicate using this shared memory segment must attach it to their address space
- Shared memory requires that two or more processes agree to remove the restriction of non-sharing in their address space
- They can exchange information by reading and writing data into the shared areas
  - Data and location are determined by processes
    - Not under control of OS
- Processes are responsible for ensuring that they are not writing the same location simultaneously
  - Producer Consumer Algorithm

Shared Memory Model - Steps

- Initiate shared memory mechanism with the help of kernel
- Kernel identifies “safe area” that is attached to both processes
- Attached shared area is used in consistent manner
- When finished, shared data area is detached from all processes which it was attached
- Information regarding the shared memory is deleted from the kernel
- Note that
  - shared memory segment is created by the kernel and mapped to the data segment of the address space of a requesting processes
  - A process can use the shared memory just like any other global variable in its address space


stack
heap
data
shared memory
(mapped)
text
Process P1
shared memory
stack
heap
data
shared memory
(mapped)
text
Process P2
Shared Memory

Shared Memory – Fast access

- Processes can read and write shared memory region (segment) directly as ordinary memory access (like they are accessing memory variables directly without kernel help)
  - During this time, kernel is not involved.
  - It is fast – there is no Kernel access
- Race condition can occur

Procedure for using Shared Memory

- A system wide key is used for identifying shared memory segments
  - Find this key (how?)
  - Use ftok() system call to generate key using a file path and bits of project id
    - This info is also be known to other process so they can also generate the key
- Use shmget() to allocate a shared memory
  - Get shared memory id (shmid) as return value
- Use shmat() to attach a shared memory to an address space
  - Use shmid as one of the parameter
  - Any process that has shmid can now attach
- Once communication is over
- Use shmdt() to detach a shared memory from an address space
- Use shmctl() to deallocate a shared memory

Shared Memory: key generation (1/3)

- To use shared memory, include the following:
  - #include <sys/types.h>
  - #include <sys/ipc.h>
  - #include <sys/shm.h>
- A key is a value of type key_t.
- There are three ways to generate a key:
  - Do it yourself
  - Use function ftok()
  - Ask the system to provide a private key

Shared Memory: key generation (2/3)

- Do it yourself: use

```
key_t    SomeKey;
SomeKey = 1234;
```

- Use ftok() to generate one for you:
  - key_t = ftok(char *path, int ID);
    - path is a path name (e.g., "./")
    - ID is an integer (e.g., 'a'), or Project Id bits
  - Function ftok() returns a key of type key_t:
  - SomeKey = ftok("./", 'x');
- Keys are global entities. If other processes know your key, they can access your shared memory.
- Ask the system to provide a private key using IPC_PRIVATE

Shared Memory: key generation (3/3)

- First step is to setup shared memory setup in kernel
- Key is generated using ftok() function

```
#include <sys/types.h>
#include <sys/ipc.h>

key_t ftok (const char *pathname, int proj_id);
```

- The *pathname* is an existing file in the filesystem
- The last eight bits of *proj_id* are used; these must not be zero
- A System V IPC key is returned

Asking for shared memory (1/4)

- Include the following:

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/shm.h>
```

- Use `shmget()` to request a shared memory:
  - `shm_id = shmget(`

```
key_t key,              /* identity key */
int size,           /* memory size */
int flag);          /* creation or use */
```

- `shmget()` returns a shared memory ID.
- The flag, for our purpose, is either `0666 (rw)` or `IPC_CREAT | 0666`. Yes, `IPC_CREAT`

Asking for shared memory (2/4)

- The following creates a shared memory of size `struct Data` with a private key `IPC_PRIVATE`. This is a creation `(IPC_CREAT)` and permits read and write `(0666)`.

```
struct Data { int a; double b; char x; };
int         ShmID;

ShmID = shmget(
          IPC_PRIVATE,  /* private key */
          sizeof(struct Data), /* size */
          IPC_CREAT | 0666);/* cr & rw */
```

Asking for shared memory (3/4)

- The following creates a shared memory with a key based on the current directory

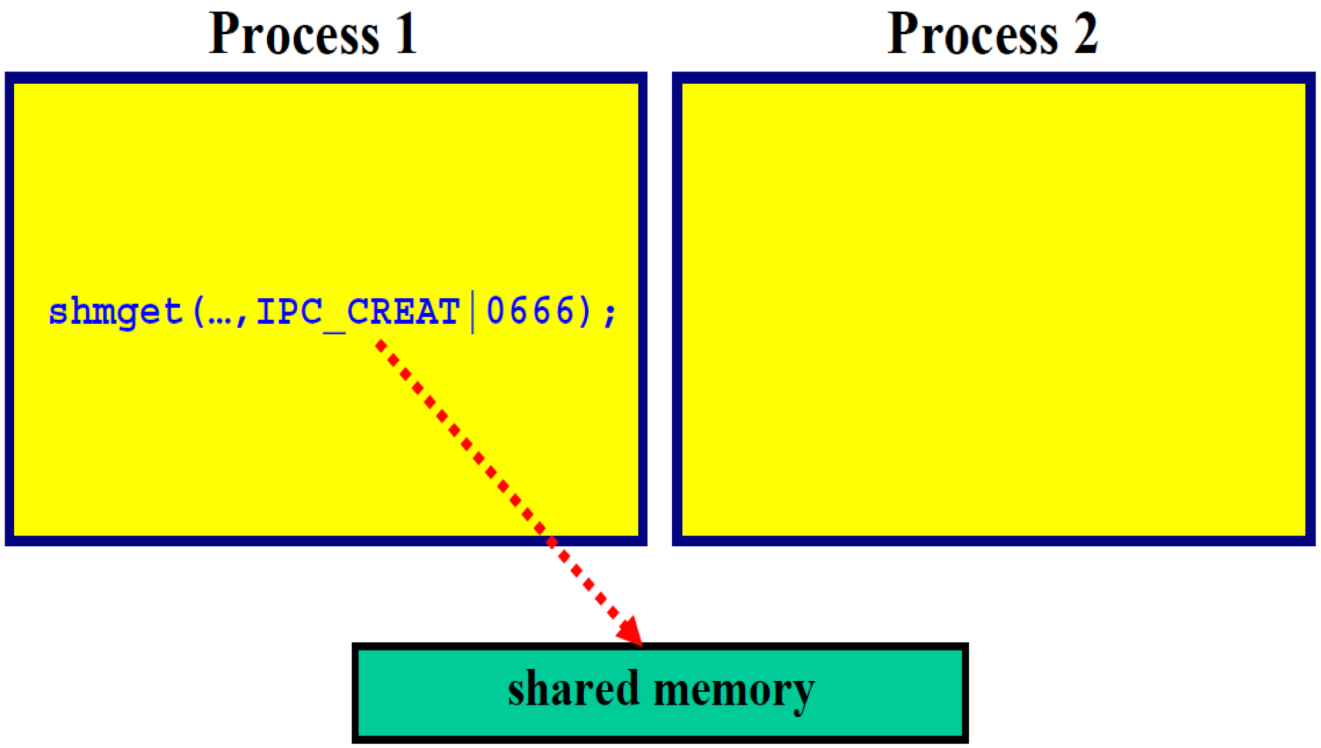
```
struct Data { int a; double b; char x;};
int    ShmID;
key_t  Key;

Key = ftok("./", 'h');
ShmID = shmget(
          Key,        /* a key */
          sizeof(struct Data),
          IPC_CREAT | 0666);
```

Asking for shared memory (4/4)

- The process that creates shared memory
  - It uses flag IPC_CREAT | 0666
- Other processes that accesses a created one shared segment using 0666
- If the return value is negative (Unix convention), the request was unsuccessful, and no shared memory is allocated

After the Execution of `shmget()`



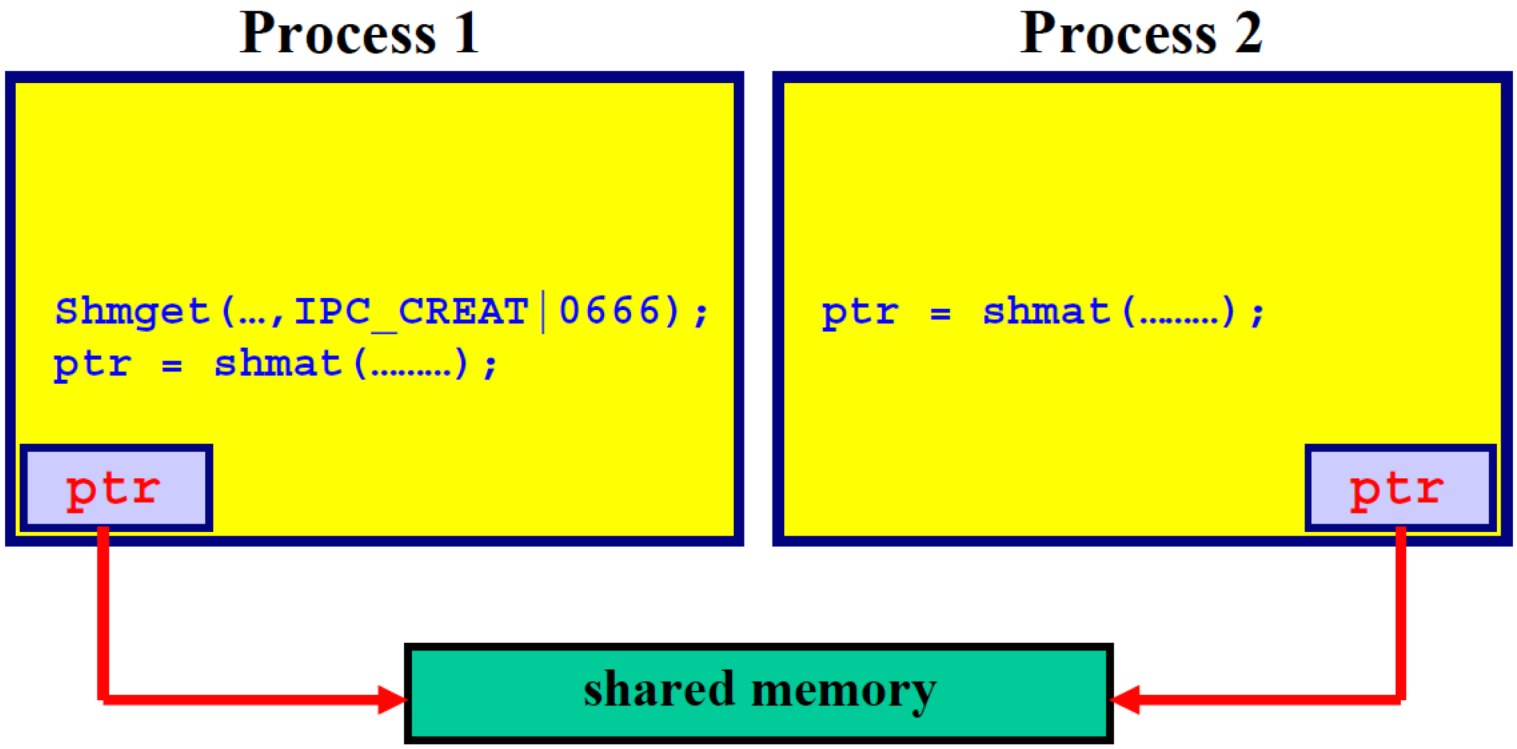
Shared memory is allocated; but, is not part of the address space

Attaching Shared Memory (1/2)

- Use shmat() to attach an existing shared memory to an address space:

```
shm_ptr = shmat(
int shm_id,          /* ID from shmget() */
char *ptr,          /* use NULL here */
int flag);          /* use 0 here */
```

- `shm_id` is the shared memory ID returned by `shmget()`
- Use NULL and 0 for the second and third arguments, respectively
- `shmat()` returns a void pointer to the memory.
- If unsuccessful, it returns a negative integer



Now processes can access the shared memory

Detaching or removing the shared memory

- To detach a shared memory, use

```
shmdt(shm_ptr);
```

`shm_ptr` is the pointer returned by `shmat()`.

- After a shared memory is detached, it is still there. You can re-attach and use it again
- To remove a shared memory, use

```
shmctl(shm_ID, IPC_RMID, NULL);
```

where `shm_ID` is the shared memory ID returned by `shmget()`.

- After a shared memory is removed, it no longer exist

Garbage Collection Concept

Where does it happen in OS?

Do we need to do it for ourselves ?

Lecture Summary

- Shared memory provides a fast IPC mechanism