CS 3305A

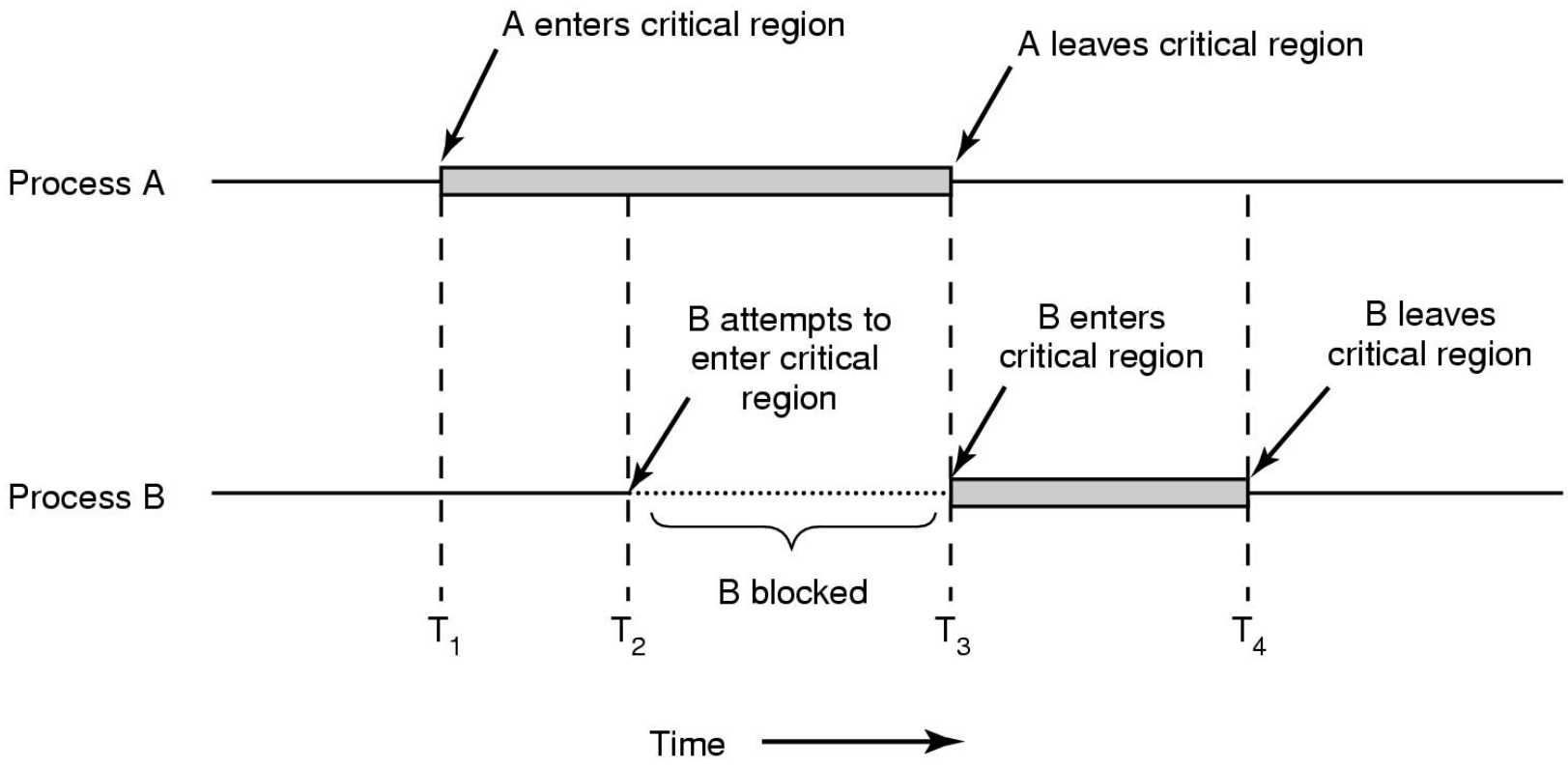
Process Synchronization

Lecture 13

Process Synchronization

- Race Condition
- Critical Section
- Mutual Exclusion
- Peterson's Solution
- Disabling Interrupts
- Test and Lock Instruction (TSL)
- Semaphores
- Deadlock

Mutual Exclusion in Critical Sections



Semaphores

- Semaphore is a process synchronization technique supported by the OS
- Semaphores are used by programmers to ensure mutual exclusion among the processes for entering the critical section
- Today there are libraries that provide application programmers with semaphores

What is a semaphore?

- A semaphore allows multiple processes to cooperate by using signal. Semaphore is an integer variable with the following three operations:

  - **Initialize:** Semaphore (S) is initialized to a positive value
  - **Decrement:** *(down operation)* decrements the semaphore
  - **Increment:** *(up operation)* increments the semaphore value

  - If S is positive then only a process enters into critical section
  - Two types of semaphore: Binary and Counting

What is a Semaphore?

- Use down before entering a critical section
- Use up after finishing with a critical section
- Example: Assume S is initialized to 1.
- **S = 1;**

```
{       down (S);
        critical section
        up(S);
        remainder section;
        }
```

Semaphores Example

Process P_0

```
S = 1
down(S);
   critical section
up(S);
```

Process P_1

```
S = 1
down(S);
   critical section
up(S);
```

- Initialize the semaphore variable, S, to 1
- Now what would happen if P_0 executes the down operation?
  - The semaphore S is currently 1.
  - **S becomes 0** and P_0 enters the critical section

Semaphores Example

Process P_0

```
S = 0
down(S);
   critical section
up(S);
```

Process P_1

```
S = 0
down(S);
   critical section
up(S);
```

- Now what would happen if P_1 executes the down operation?
  - The semaphore S is currently 0, P_1 **is blocked**

Semaphores Example

S = 0 → 1

Process P_0	Process P_1
down(S);	down(S);
critical section	critical section
up(S);	up(S);

- Now what would happen if P_0 is done with critical section?
  - P_0 calls the up function
    - **S becomes 1**
    - P_1 is unblocked and P_1 enters into Critical Section

Semaphore Types

- Binary Semaphore:
  - Allows only ONE process to be in critical section at a time
  - Initialized to 1
  - Often referred to as a mutex
    - In C system function pthread_mutex_lock()
- Counting Semaphore:
  - Allows multiple processes to be in critical section at a time
  - Initialized to N where N is the max processes that can be in critical section simultaneously

Deadlock

- Deadlock – Two or more processes are waiting indefinitely for an event that can only be caused by one of the waiting processes

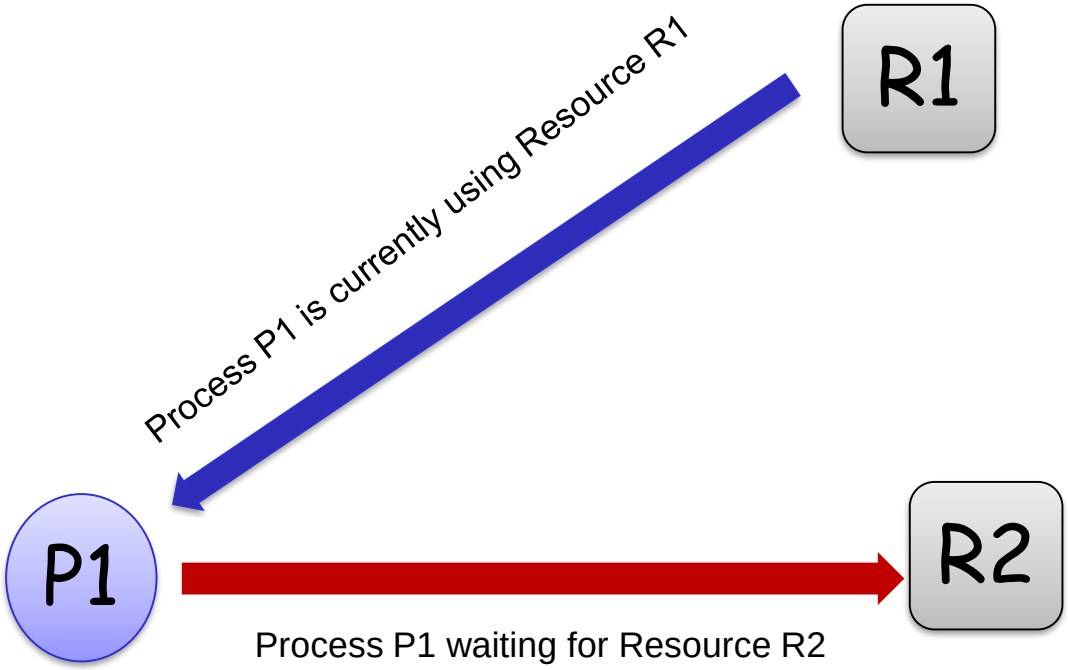
- Deadlock conditions:
  - Mutual exclusion: A resource is assigned to at most one process
  - Hold and Wait: A process currently holding a resource waiting for additional resources
  - Non-preemptive resource: A resource can not be taken away from a process until released by that process

Deadlock

- Deadlock conditions:
  - Resource allocation cycle (circular wait): There exists a cycle between two or more processes (and its resources) where each process is waiting for a resource that is used by another process in the cycle.

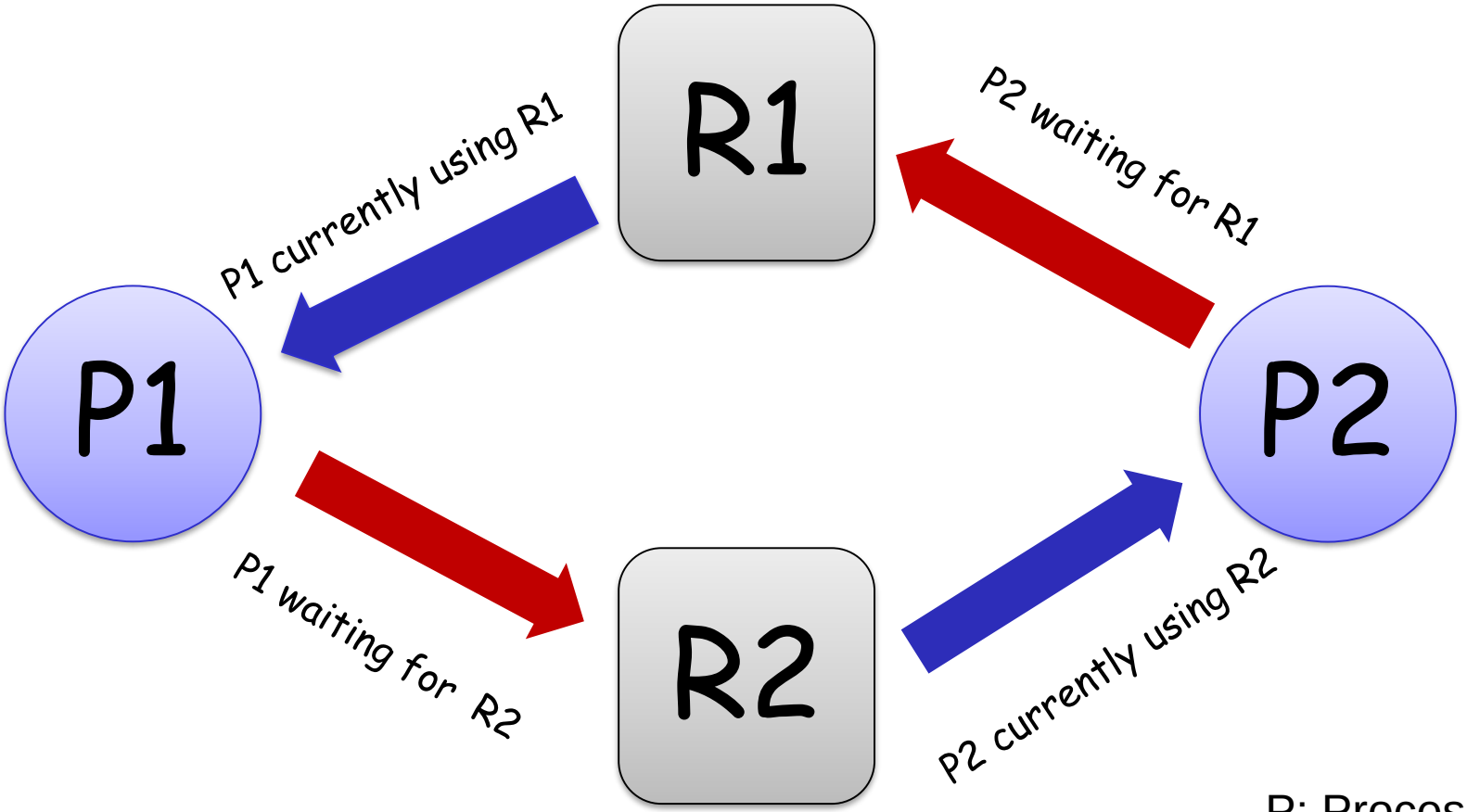
Deadlock

- Resource Allocation Graph



Deadlock

- Resource Allocation Cycle



Deadlock

- Avoidance Approaches
  - Avoid cycle in the resource allocation graph
  - Avoid Mutual Exclusion: Resources should be shared among processes
  - Avoid Hold & Wait
    - Release resources that may not be needed immediately
    - Do not request resource ahead of time
  - Block a process that requesting large number of resources

Deadlock

- Deadlock Recovery
  - Abort all deadlock processes
  - Back up all deadlock processes to the previous safe state and then restart
  - selectively abort processes until deadlock broken