

# Process Synchronization



# Race Condition

- **counter++** could be implemented as

```
register1 = counter
register1 = register1 + 1
counter = register1
```

- **counter--** could be implemented as

```
register2 = counter
register2 = register2 - 1
counter = register2
```

- Consider this execution interleaving with “count = 5” initially:

S0: producer execute	<code>register1 = counter</code>	{register1 = 5}
S1: producer execute	<code>register1 = register1 + 1</code>	{register1 = 6}
S2: consumer execute	<code>register2 = counter</code>	{register2 = 5}
S3: consumer execute	<code>register2 = register2 - 1</code>	{register2 = 4}
S4: producer execute	<code>counter = register1</code>	{counter = 6}
S5: consumer execute	<code>counter = register2</code>	{counter = 4}

# Critical Section

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## ■ General structure of process $P_i$

do {

*entry section*

critical section

*exit section*

remainder section

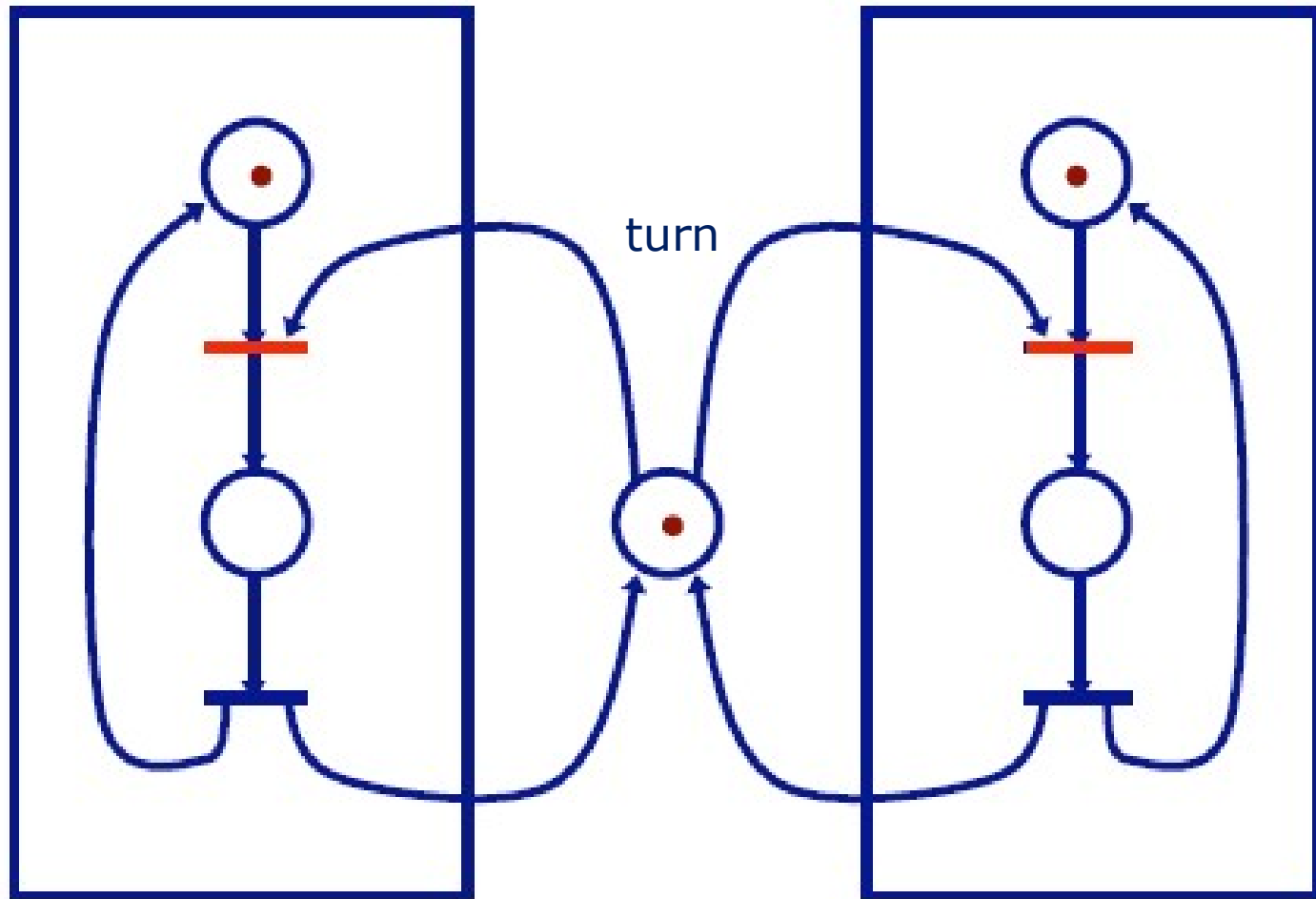
} while (true);

# Algorithm for Process $P_i$

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```
do {  
    flag[i] = true;  
    turn = j;  
    while (flag[j] && turn == j);  
        critical section  
    flag[i] = false;  
        remainder section  
} while (true);
```

# Petri net diagram for mutual exclusion



# Conditions for the Solution

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1. **Mutual Exclusion** - If process  $P_i$  is executing in its critical section, then no other processes can be executing in their critical sections
2. **Progress** - If no process is executing in its critical section and there exist some processes that wish to enter their critical section, then the selection of the processes that will enter the critical section next cannot be postponed indefinitely
3. **Bounded Waiting** - A bound must exist on the number of times that other processes are allowed to enter their critical sections after a process has made a request to enter its critical section and before that request is granted
  - Assume that each process executes at a nonzero speed
  - No assumption concerning **relative speed** of the  $n$  processes

# Conditions for Peterson's Solution

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- Provable that the three CS requirement are met:

1. Mutual exclusion is preserved

$P_i$  enters CS only if:

either `flag[j] = false` or `turn = i`

2. Progress requirement is satisfied
3. Bounded-waiting requirement is met

# Solution to Critical-section Problem Using Locks

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```
do {  
    acquire lock  
        critical section  
    release lock  
        remainder section  
} while (TRUE);
```



# Mutex Locks

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- Protect a critical section by first `acquire()` a lock then `release()` the lock
  - Boolean variable indicating if lock is available or not
- Calls to `acquire()` and `release()` must be atomic
  - Usually implemented via hardware atomic instructions

# acquire() and release()

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```
■ acquire() {  
    while (!available)  
        ; /* busy wait */  
    available = false;;  
}  
■ release() {  
    available = true;  
}  
■ do {  
    acquire lock  
    critical section  
    release lock  
    remainder section  
} while (true);
```

# Semaphore

- Synchronization tool that provides more sophisticated ways (than Mutex locks) for process to synchronize their activities.
- Semaphore **S** – integer variable
- Can only be accessed via two indivisible (atomic) operations

- **wait()** and **signal()**

- ▶ Originally called **P()** and **V()**

- Definition of the **wait()** operation

```
wait(S) {  
    while (S <= 0)  
        ; // busy wait  
    S--;  
}
```

- Definition of the **signal()** operation

```
signal(S) {  
    S++;  
}
```