CSc 360
Operating Systems
Deadlocks

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Review

- Ways to process synchronization
  - hardware-assisted solutions
  - mutex, semaphores
  - monitors
- Required properties
  - mutual exclusion
  - making progress (i.e., no deadlock)
  - bounded waiting (i.e., no live-lock)

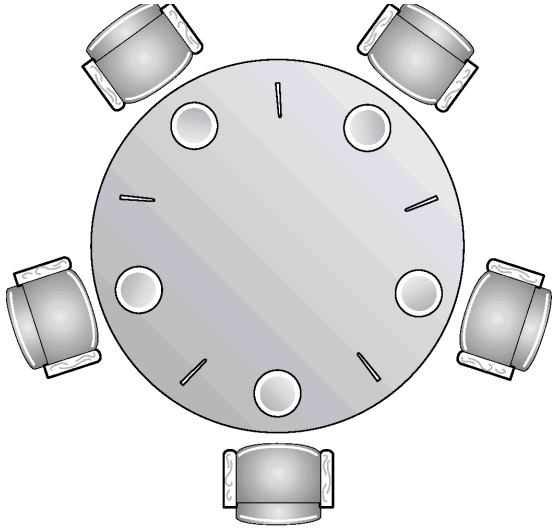
Dining philosophers: semaphores

- Shared data
  - Initially all values are 1

```
semaphore chopstick[5];
```

- Using semaphores, for Philosopher *i*:

```
do {
    wait(chopstick[i])
    wait(chopstick[(i+1) % 5])
        …
    eat
        …
    signal(chopstick[i]);
    signal(chopstick[(i+1) % 5]);
        …
    think
        …
} while (1);
```



Dining philosophers: monitors

```
monitor DP {
    …
    void test (int i) {
        if ( (state[(i + 4) % 5] != EATING) &&
        (state[i] == HUNGRY) &&
        (state[(i + 1) % 5] != EATING) ) {
            state[i] = EATING ;
       self[i].signal () ; // no effect if not blocked
        }
    }

     initialization_code() {
        for (int i = 0; i < 5; i++)
          state[i] = THINKING;
    }
}
```

- Using monitors

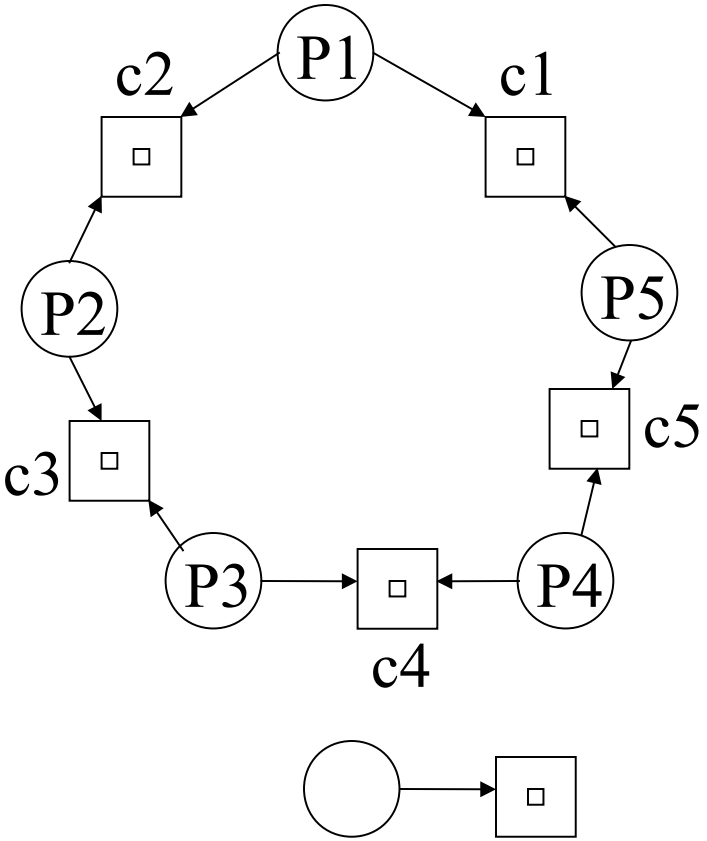
```
dp.pickup (i)
  ...
    EAT
  ...
dp.putdown (i)
```

Deadlocks

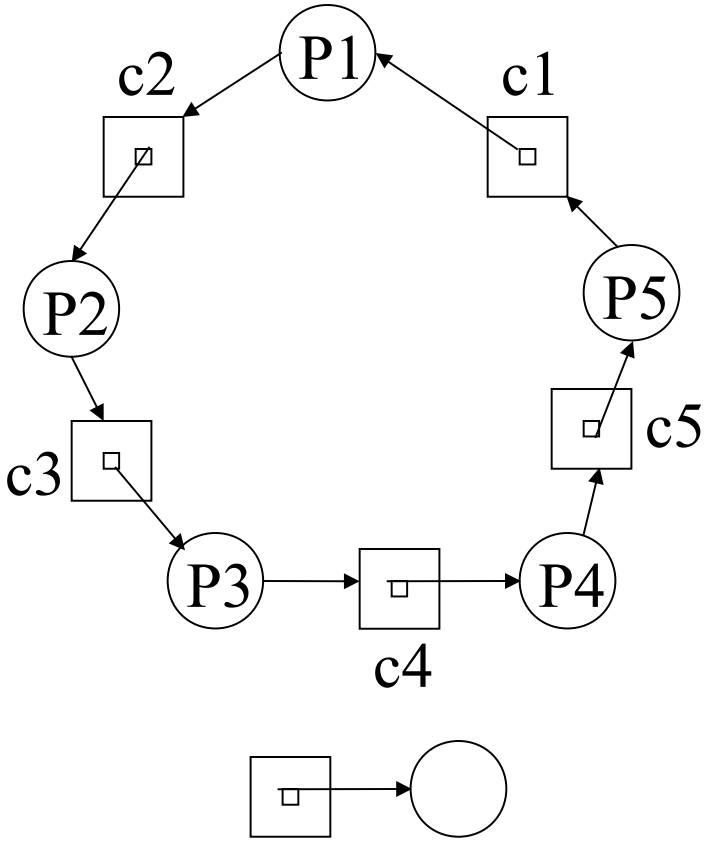
- Deadlock *can* occur if all are true
  - mutual exclusion
    - wait(chopstick[i]);
  - hold-and-wait
    - **wait(chopstick[i]);** wait(chopstick[(i+1)%5]);
  - no-preemption
    - wait();
  - circular-wait
    - chopstick[(i+1)%5]

Q: necessary conditions

Resource-allocation graph

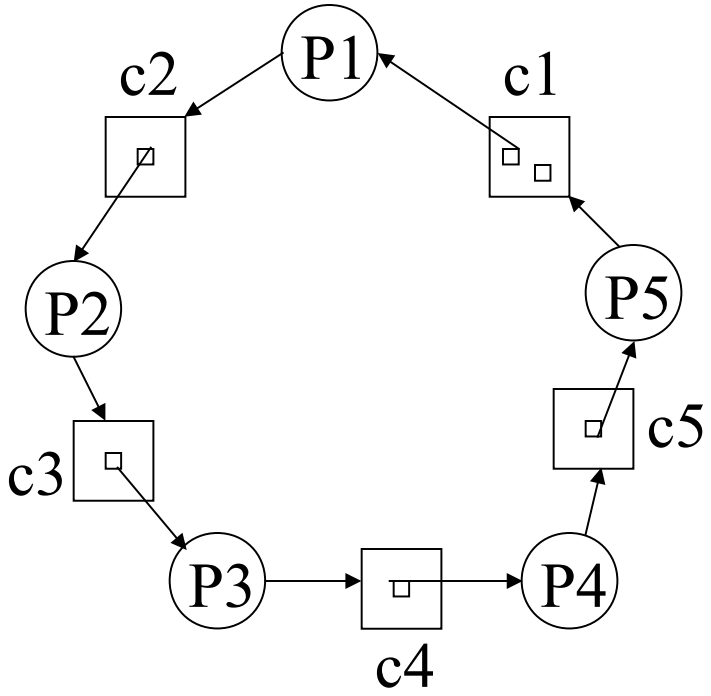


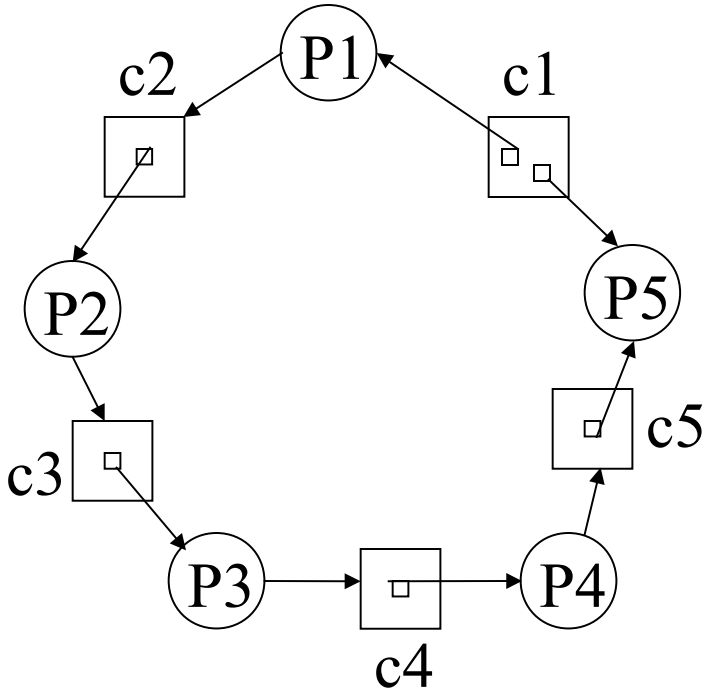
request edge



assignment edge

How about this?





- No directed cycle
  - no deadlock
- Directed cycle
  - one instance per resource type
    - deadlock
  - otherwise: *maybe*!

Preventing deadlocks

- Prevention
  - mutual exclusion
    - only when mutual exclusion is really necessary
  - hold-and-wait
    - all-or-none
  - non-preemption
    - give up on request
  - circular-wait
    - strictly ordered

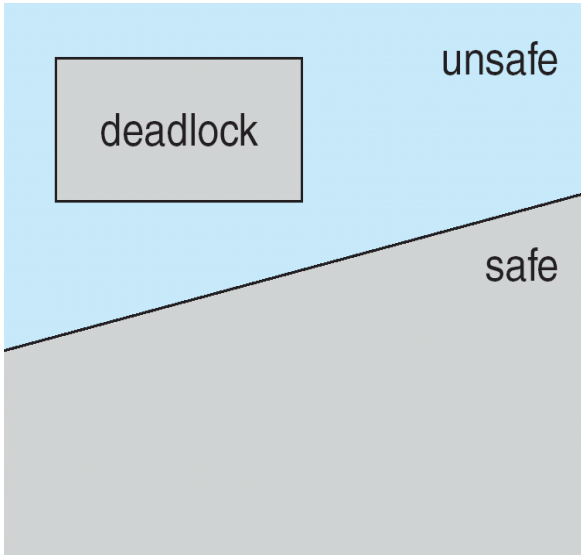
```
void test (int i) {
        if ( (state[(i + 4) % 5] != EATING) &&
        (state[i] == HUNGRY) &&
        (state[(i + 1) % 5] != EATING) ) {
                state[i] = EATING ;
                self[i].signal () ;
        }
}

  void pickup (int i) {
          state[i] = HUNGRY;
          test(i);
          if (state[i] != EATING)
                  self [i].wait;
  }
```

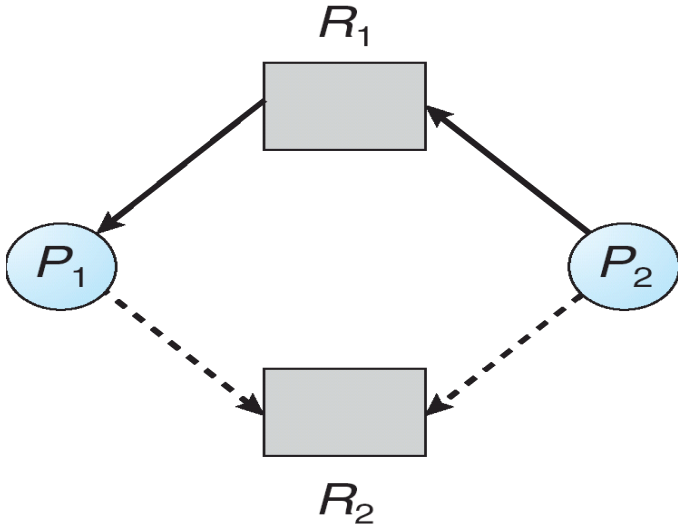
Avoiding deadlocks

- Avoidance
  - declare maximal resource usage in advance
    - claim edge
  - check against currently admitted processes
  - admit if safe (e.g., no circular-wait)
    - a sequence of P_i, such as P_i is satisfied with all $P_{j<i}$
    - single instance resource: resource-allocation graph
    - multi-instance resource: banker's algorithm

Deadlock avoidance

- Basic fact
  - in safe state: no deadlocks
  - in unsafe state:
    - possible deadlocks
  - avoidance: not in unsafe state
- Single instance of resource
  - resource-allocation graph
  - claim vs request edge
  - assignment edge





Banker's algorithm

Let n = number of processes, and m = number of resources types.

- ***Available***: Vector of length m. If available [j] = k, there are k instances of resource type R_j available.
- ***Max***: n x m matrix. If Max [i,j] = k, then process P_i may request at most k instances of resource type R_j.
- ***Allocation***: n x m matrix. If Allocation[i,j] = k then P_i is currently allocated k instances of R_j.
- ***Need***: n x m matrix. If $Need$[i,j] = k, then P_i may need k more instances of R_j to complete its task.

$$Need\ [i,j] = Max[i,j] - Allocation\ [i,j].$$

Safety algorithm

1. Let ***Work*** and ***Finish*** be vectors of length *m* and *n*, respectively. Initialize:

   Work = *Available*

   Finish [*i*] = *false* for *i* = 0, 1, …, *n*- 1.

2. Find and *i* such that both:

   (a) *Finish* [*i*] = *false*

   (b) $Need_i \overset{c}{\lambda} Work$

   If no such *i* exists, go to step 4.

3. *Work* = *Work* + $Allocation_i$

   Finish[*i*] = *true*
   go to step 2.

4. If *Finish* [*i*] == true for all *i*, then the system is in a safe state.

Resource-request algorithm

Request = request vector for process P_i. If $Request_i[j] = k$ then process P_i wants k instances of resource type R_j.

1. If $Request_i <= Need_i$ go to step 2. Otherwise, raise error condition, since process has exceeded its maximum claim.
2. If $Request_i <= Available$, go to step 3. Otherwise P_i must wait, since resources are not available.
3. Pretend to allocate requested resources to P_i by modifying the state as follows:

$$Available = Available - Request;$$

$$Allocation_i = Allocation_i + Request_i;$$

$$Need_i = Need_i - Request_i;$$

- *If safe: the resources are allocated to Pi.*
- *If unsafe: Pi must wait, and the old resource-allocation state is restored*

example on blackboard

This lecture

- Deadlocks
  - deadlock characteristics
  - how to prevent deadlocks
  - how to avoid deadlocks
  - how to detect and resolve deadlocks
    - after-class reading
- Explore further
  - CSC 464: Concurrency

Next lecture

- Memory management
  - read OSC7 Chapter 8 (or OSC6 Chapter 9)