Safety and Liveness

Safety

Something bad never happens

Liveness

Something good eventually happens

Safety vs Liveness

Using synchronization

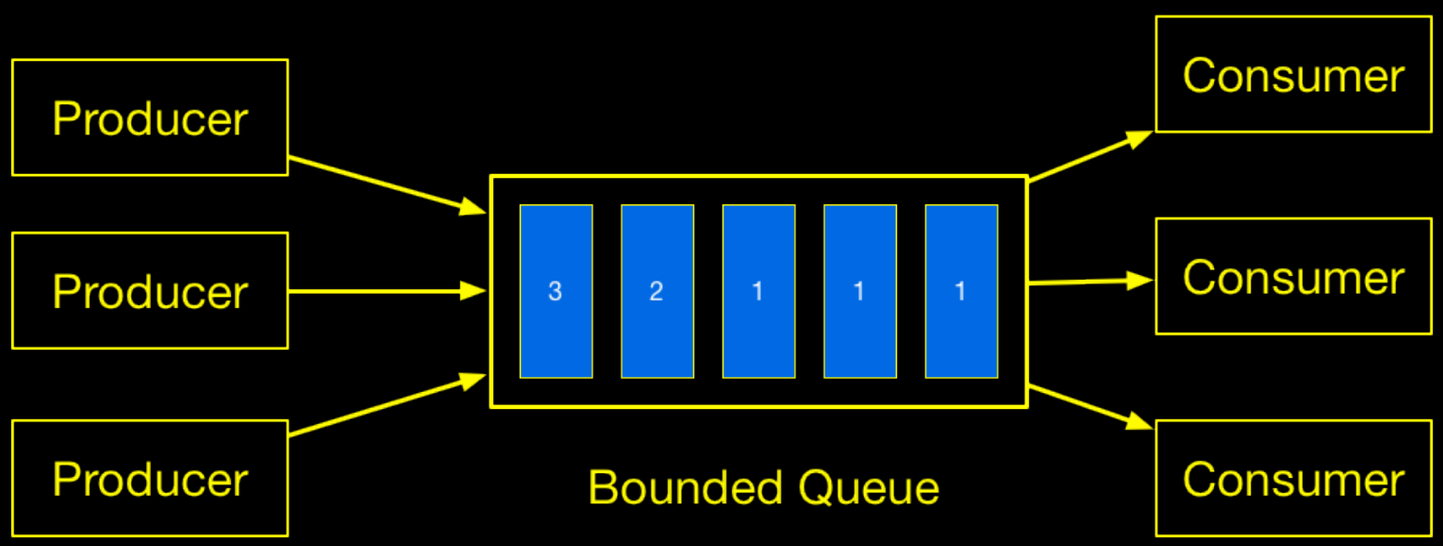
- To achieve **safety**
- But can prevent **liveness**
- And can reduce **throughput** (performance)

Liveness Issues

1. Starvation
2. Livelock
3. **Deadlock**
4. Poor responsiveness

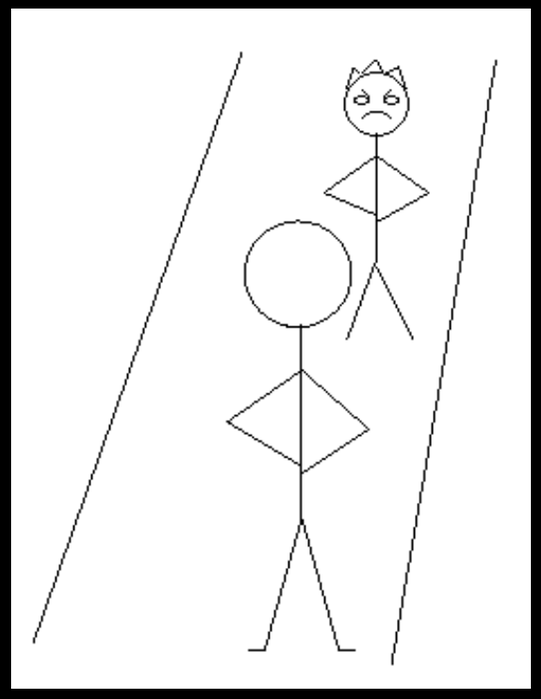
Starvation

Starvation describes a situation where a thread is unable to gain regular access to shared resources and is unable to make progress.



Livelock

Participants continuously change their state in response to the action of another thread.
1. A move to his left to let B pass
2. B move to his right to let A pass



Poor Responsiveness

- Common in GUI applications
- Occurs when user interface freeze

Solution:

Long running tasks should be executed by background threads

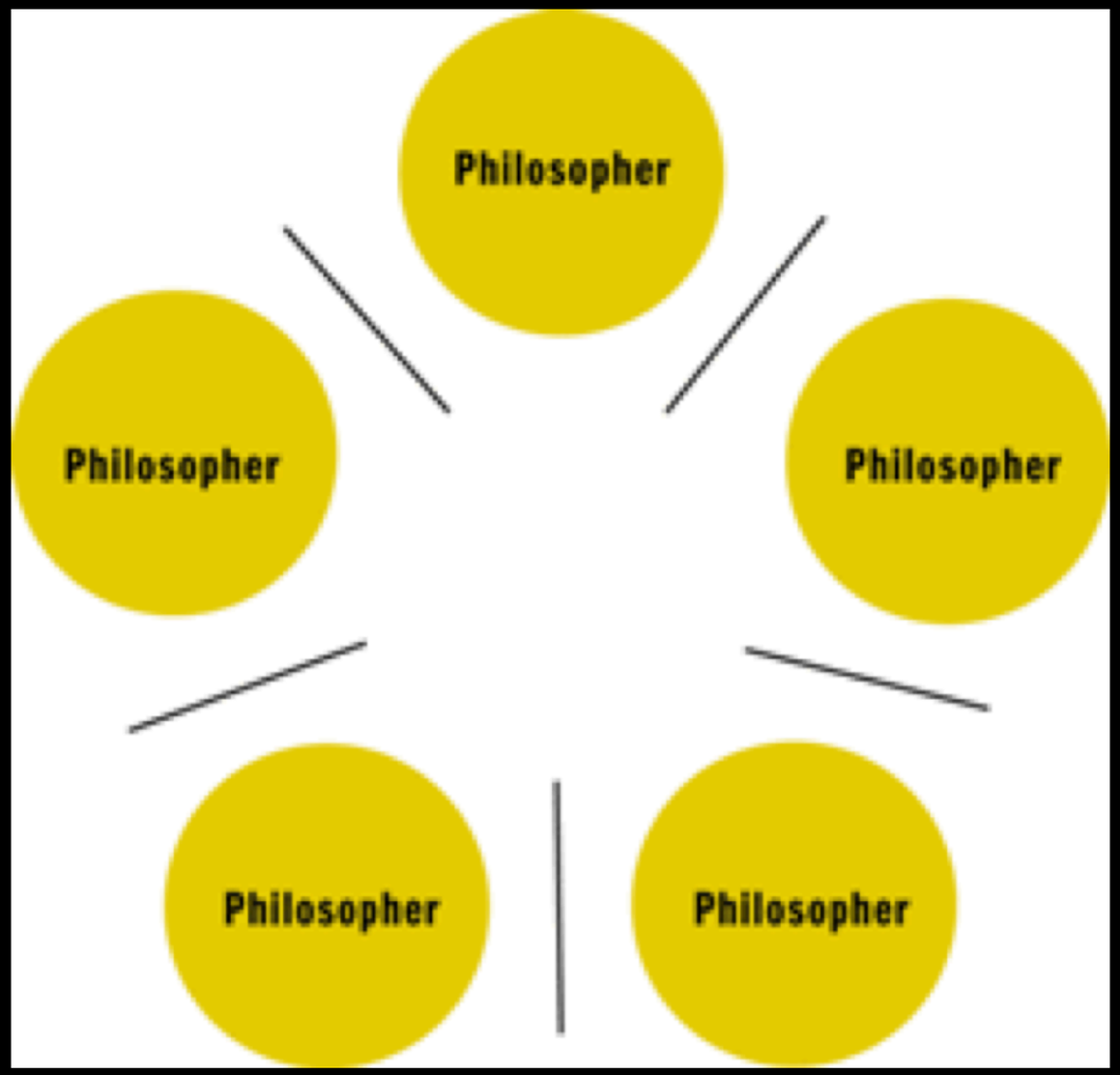
Deadlock

Deadlock arises when several participants are waiting on each other to reach a specific state to be able to progress.

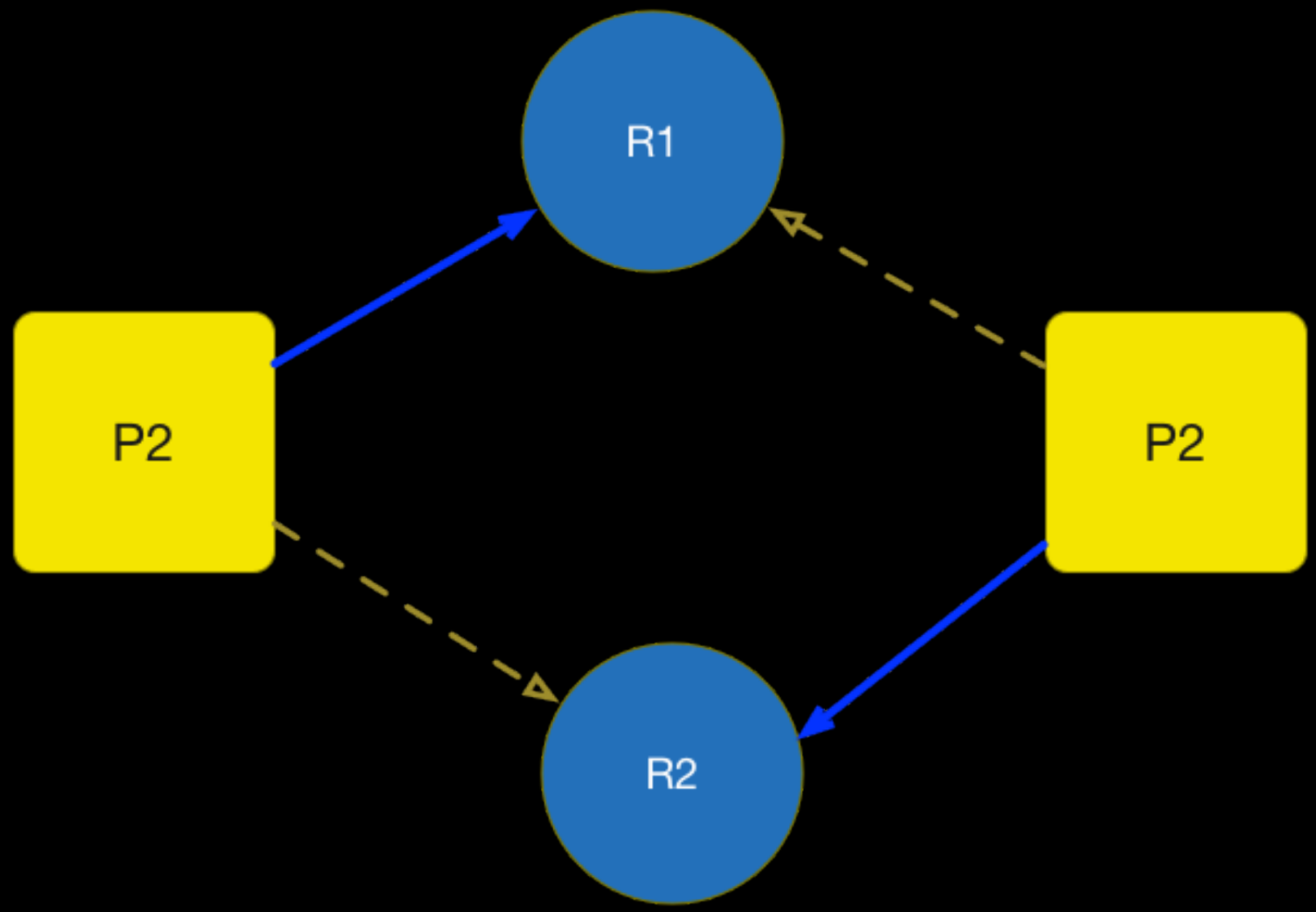
As none of them can progress without some other participant to reach a certain state.

Dining Philosophers

Eating requires 2 chopsticks



Lock-ordering

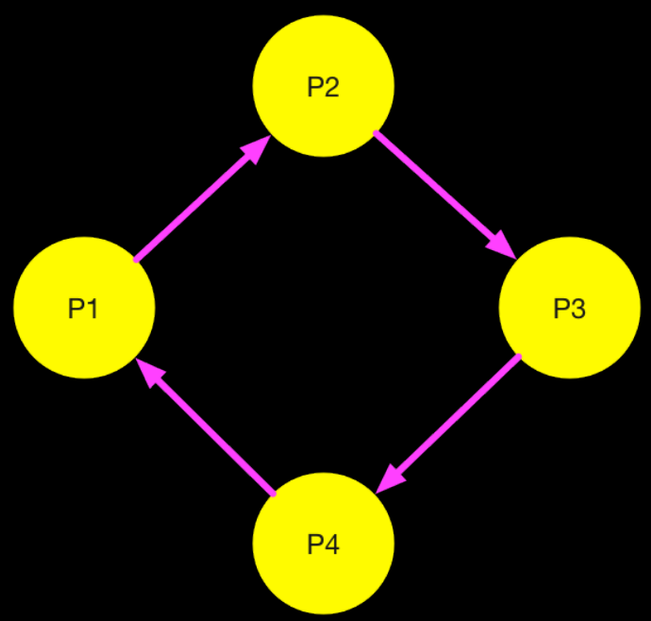


Deadlock occurs if all hold

1. **Mutual Exclusion:** at least one process exclusively uses a resource
2. **Hold and wait:** a process holds at least one resources and needs more, which are held by others
3. **No preemption:** resources are released only in voluntary manner
4. **Circular wait:** P1 → P2 → … → PN → P1

Deadlock Analysis

- Processes are nodes
- Edges are resource relations
- Cyclic => Deadlock



Dynamic Lock-ordering

```
public void transferMoney(Account fromAcc, Account toAcc, amount) {
  synchronized (fromAcc) {
    synchronized (toAcc) {
      fromAccount.debit(amount);
      toAccount.credit(amount);
    }
  }
}
```

Can deadlock occur ?

Deadlock happens if

A transfer to B and B transfer to A at the same time.

- transferMoney(A, B, _);
- transferMoney(B, A, _);

Solution 1

```
public void transferMoney(Account fromAcc, Account toAcc, amount) {
  synchronized(this) {
    synchronized (fromAcc) {
      synchronized (toAcc) {
        fromAccount.debit(amount);
        toAccount.credit(amount);
      }
    }
  }
}
```

Condition 2 & 4 are not held.

But new problem ???

Solution 2

- Ordering lock operations
- Account number is comparable
- No two accounts are equal

Solution 2 (cont)

```
if(fromAcc < toAcc) {
  synchronized(fromAcc){
    synchronized(toAcc) {

    }
  }
}else {
  synchronized(toAcc) {
    synchronized(fromAcc) {

    }
  }
}
```

Deadlock is not obvious

```
class Vehicle {
  Date beginTim, endTime;
  synchronized getBeginTime(){
    return beginTime;
  }
  synchronized enter(){
    beginTime = Date();
    station.notifyParking(this);
  }

  synchronized leave(){
    endTime = Date();
    station.notifyLeaving(this)
  }
}
```

```
class Station {
  List[Vehicle] vehicles;

  synchronized notifyParking(Vehicle v){
    vehicles.add(v);
  }

  synchronized notifyLeaving(Vehicle v){
    vehicles.remove(v);
  }

  synchronized scans() {
    for(v in vehicles) {
      if(Date()  - v.time > 1 day) {
        //Issue fine tickets
      }
    }
  }
}
```

Deadlock can occur if

Call leave and scans at the same time
- `leave()`: first lock the vehicle, then lock station
- `scans()`: first lock station, then lock vehicles

Deadlock is even harder to detect with multiple coopering objects

Open Call

Calling a method with no locks held is called an open call

```
class Vehicle {
  Date beginTime, endTime;
  synchronized getBeginTime(){
    return beginTime;
  }
  enter(){
    synchronized(this){
       beginTime = Date();
    }
    station.notifyParking(this);
  }

  leave(){
    synchronized(this){
      endTime = Date();
    }
    station.notifyLeaving(this)
  }
}
```

```
class Station {
  List[Vehicle] vehicles;

  synchronized notifyParking(Vehicle v){
    vehicles.add(v);
  }

  synchronized notifyLeaving(Vehicle v){
    vehicles.remove(v);
  }

  scans() {
      now = Date();
      synchronized(this){
          current = vehicles.copy();
      }
      for(v in current) {
        if(now  - v.time > 1 day) {
          //Issue fine tickets
        }
      }
   }
}
```

Dealing with deadlock

- Ignore
- Prevent
- Detect & Recover

Ignore deadlock

Allow deadlock happens and ignore if

- Deadlock is rare
- If happens, consequence is not too severe

Prevent deadlock

Prevent deadlock by assuring at least 1 of 4 condition does not hold

Detect and recover

- Database Management System (DBMS)
- Allows deadlock happen then
- Detects deadlock
- Terminate one or all
- Remained processes can execute

Deadlock practices

1. Uses single lock if possible
2. When has to use multiple locks
    - Minimize the set of lock
    - Ordering the set of lock
3. Open call methods

Summary

1. Deadlock is one of the biggest issues of concurrency
2. Deadlock is not obvious
3. Four conditions of deadlock