Lecture 12 – Deadlock

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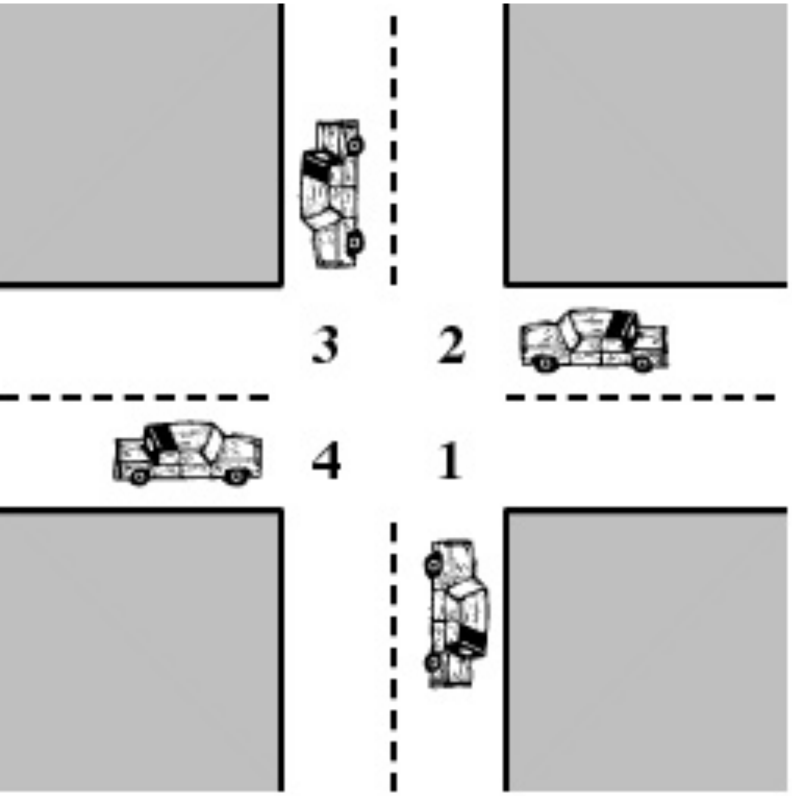
Objectives

- In this class we will discuss:
  - What is deadlock
  - Deadlock avoidance
  - Deadlock Detection

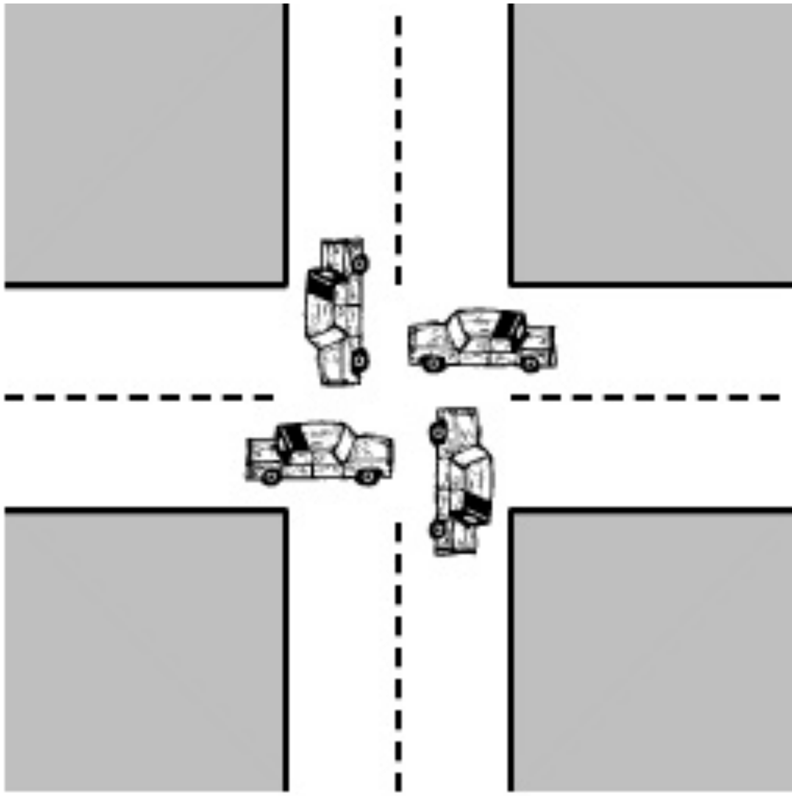
Deadlock

- Permanent blocking of a set of processes that either compete for system resources or communicate with each other
- No efficient solution
- Involve conflicting needs for resources by two or more processes

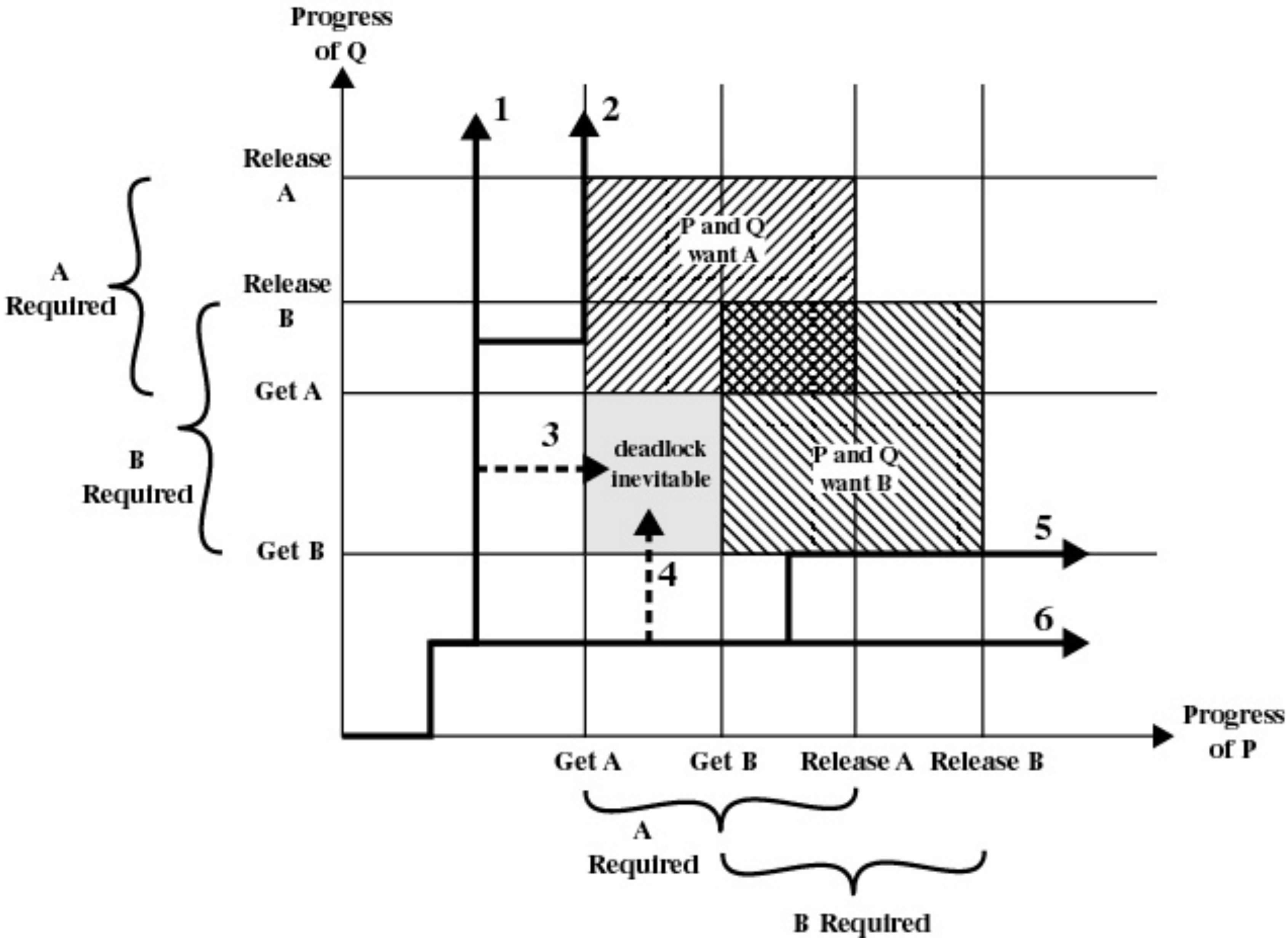
Deadlock



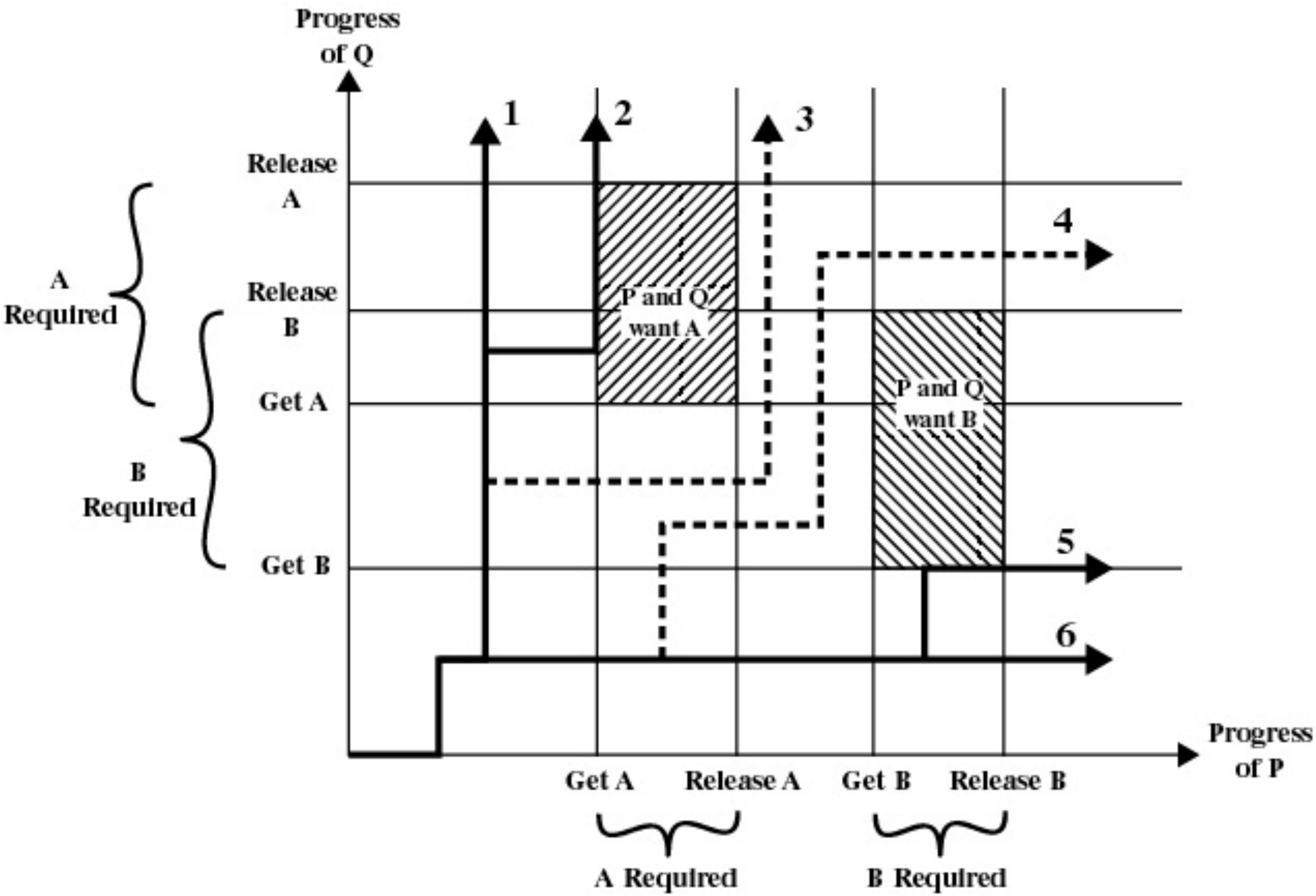
(a) Deadlock possible



(b) Deadlock



Progress of Q
1
2
Release A
Release B
Get A
Get B
A Required
B Required
P and Q want A
deadlock inevitable
3
4
P and Q want B
5
6
Progress of P
Get A
Get B
Release A
Release B
A Required
B Required


Progress of Q
Release A
Release B
Get A
Get B
A Required
B Required
1
2
3
4
5
6
P and Q want A
P and Q want B
Progress of P
Get A
Release A
Get B
Release B
A Required
B Required

Reusable Resources

- Used by one process at a time and not depleted by that use
- Processes obtain resources that they later release for reuse by other processes
- Processors, I/O channels, main and secondary memory, files, databases, and semaphores
- Deadlock occurs if each process holds one resource and requests the other

Example of Deadlock

Process P

Step	Action
p_0	Request (D)
p_1	Lock (D)
p_2	Request (T)
p_3	Lock (T)
p_4	Perform function
p_5	Unlock (D)
p_6	Unlock (T)

Process Q

Step	Action
q_0	Request (T)
q_1	Lock (T)
q_2	Request (D)
q_3	Lock (D)
q_4	Perform function
q_5	Unlock (T)
q_6	Unlock (D)

Figure 6.4 Example of Two Processes Competing for Reusable Resources

Another Example of Deadlock

- Space is available for allocation of 200K bytes, and the following sequence of events occur

P1	P2
. . .	. . .
Request 80K bytes;	Request 70K bytes;
. . .	. . .
Request 60K bytes;	Request 80K bytes;

- Deadlock occurs if both processes progress to their second request

Consumable Resources

- Created (produced) and destroyed (consumed) by a process
- Interrupts, signals, messages, and information in I/O buffers
- Deadlock may occur if a Receive message is blocking
- May take a rare combination of events to cause deadlock

Conditions for Deadlock

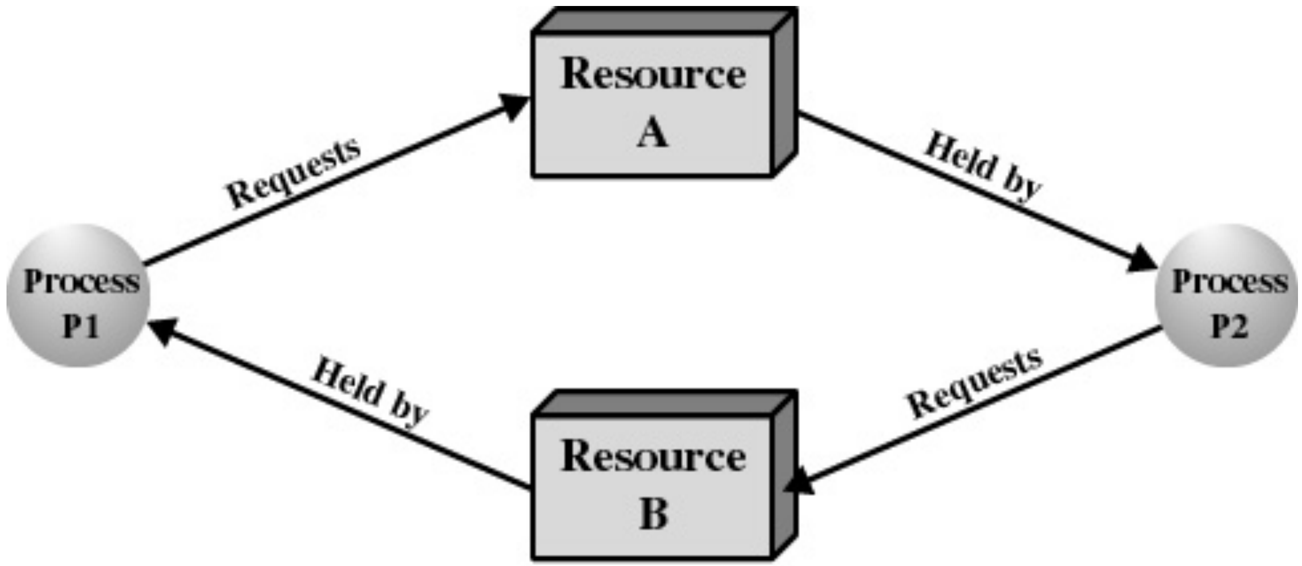
- **Mutual exclusion**
  - **only one process may use a resource at a time**
- **Hold-and-wait**
  - **A process request all of its required resources at one time**

Conditions for Deadlock

- **No preemption**
  - **If a process holding certain resources is denied a further request, that process must release its original resources**
  - **If a process requests a resource that is currently held by another process, the operating system may preempt the second process and require it to release its resources**

Conditions for Deadlock

- **Circular wait**
  - **Prevented by defining a linear ordering of resource types**



Deadlock Avoidance

- A decision is made dynamically whether the current resource allocation request will, if granted, potentially lead to a deadlock
- Requires knowledge of future process request

Two Approaches to Deadlock Avoidance

- **Do not start a process if its demands might lead to deadlock**
- **Do not grant an incremental resource request to a process if this allocation might lead to deadlock**

Resource Allocation Denial

- Referred to as the banker’s algorithm
- State of the system is the current allocation of resources to process
- Safe state is where there is at least one sequence that does not result in deadlock
- Unsafe state is a state that is not safe

Determination of a Safe State Initial State

	R1	R2	R3
P1	3	2	2
P2	6	1	3
P3	3	1	4
P4	4	2	2

Claim Matrix

	R1	R2	R3
P1	1	0	0
P2	6	1	2
P3	2	1	1
P4	0	0	2

Allocation Matrix

R1	R2	R3
9	3	6

Resource Vector

R1	R2	R3
0	1	1

Available Vector

(a) Initial state

Determination of a Safe State
P2 Runs to Completion

Claim Matrix

	R1	R2	R3
P1	3	2	2
P2	0	0	0
P3	3	1	4
P4	4	2	2

Allocation Matrix

	R1	R2	R3
P1	1	0	0
P2	0	0	0
P3	2	1	1
P4	0	0	2

Available Vector

R1	R2	R3
6	2	3

(b) P2 runs to completion

Determination of a Safe State P1 Runs to Completion

	R1	R2	R3
P1	0	0	0
P2	0	0	0
P3	3	1	4
P4	4	2	2

Claim Matrix

	R1	R2	R3
P1	0	0	0
P2	0	0	0
P3	2	1	1
P4	0	0	2

Allocation Matrix

R1	R2	R3
7	2	3

Available Vector

(c) P1 runs to completion

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Determination of a Safe State
P3 Runs to Completion

	R1	R2	R3
P1	0	0	0
P2	0	0	0
P3	0	0	0
P4	4	2	2

Claim Matrix

	R1	R2	R3
P1	0	0	0
P2	0	0	0
P3	0	0	0
P4	0	0	2

Allocation Matrix

R1	R2	R3
9	3	4

Available Vector

(d) P3 runs to completion

Determination of an Unsafe State

	R1	R2	R3
P1	3	2	2
P2	6	1	3
P3	3	1	4
P4	4	2	2

Claim Matrix

	R1	R2	R3
P1	1	0	0
P2	5	1	1
P3	2	1	1
P4	0	0	2

Allocation Matrix

R1	R2	R3
9	3	6

Resource Vector

R1	R2	R3
1	1	2

Available Vector

(a) Initial state

Determination of an Unsafe State

	R1	R2	R3
P1	3	2	2
P2	6	1	3
P3	3	1	4
P4	4	2	2

Claim Matrix

	R1	R2	R3
P1	2	0	1
P2	5	1	1
P3	2	1	1
P4	0	0	2

Allocation Matrix

R1	R2	R3
0	1	1

Available Vector

(b) P1 requests one unit each of R1 and R3

Deadlock Avoidance

- Maximum resource requirement must be stated in advance
- Processes under consideration must be independent; no synchronization requirements
- There must be a fixed number of resources to allocate
- No process may exit while holding resources

Deadlock Detection

	R1	R2	R3	R4	R5
P1	0	1	0	0	1
P2	0	0	1	0	1
P3	0	0	0	0	1
P4	1	0	1	0	1

Request Matrix Q

	R1	R2	R3	R4	R5
P1	1	0	1	1	0
P2	1	1	0	0	0
P3	0	0	0	1	0
P4	0	0	0	0	0

Allocation Matrix A

R1	R2	R3	R4	R5
2	1	1	2	1

Resource Vector

R1	R2	R3	R4	R5
0	0	0	0	1

Available Vector

Figure 6.9 Example for Deadlock Detection

Deadlock Detection

- **Use a Resource Allocation Graph to discover a deadlock.**
- **The Ostrich Algorithm**

Strategies once Deadlock Detected

- **Abort all deadlocked processes**
- **Back up each deadlocked process to some previously defined checkpoint, and restart all process**
  - **original deadlock may occur**
- **Successively abort deadlocked processes until deadlock no longer exists**
- **Successively preempt resources until deadlock no longer exists**

Selection Criteria Deadlocked Processes

- Least amount of processor time consumed so far
- Least number of lines of output produced so far
- Most estimated time remaining
- Least total resources allocated so far
- Lowest priority

Summary

- **We have covered**
  - **Definition of deadlock**
  - **Examples of deadlock**
  - **Strategies for avoidance**
  - **Strategies for resolving**

Next Lecture

- (To be decided)
- Lecture Notes: http://www.cs.rhul.ac.uk/~karl