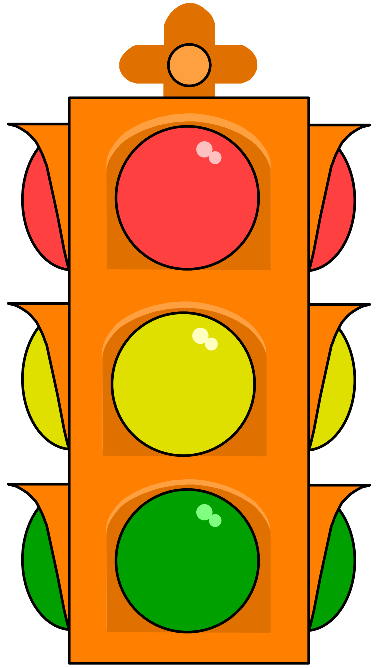
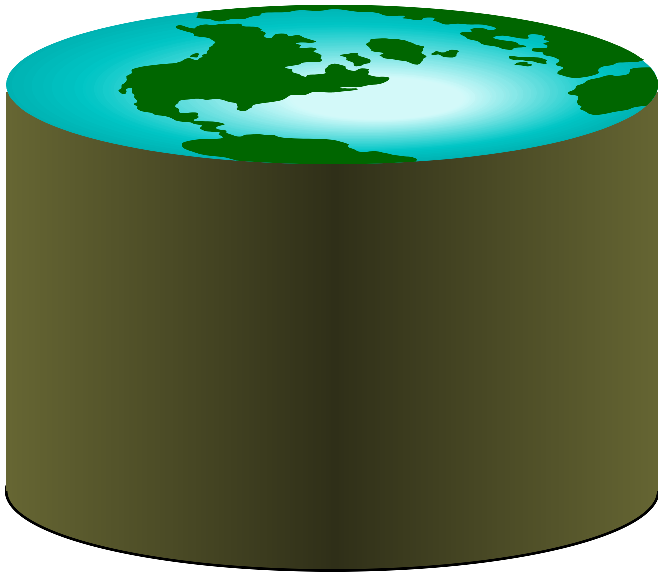
Concurrency Control



R&G - Chapter 17

Smile, it is the key that fits the lock of everybody's heart.

Anthony J. D'Angelo,
The College Blue Book



Review

- ACID transaction semantics.
- Today: focus on Isolation property
  - Serial schedules safe but slow
  - Try to find schedules *equivalent* to serial …

Conflicting Operations

- Need a tool to decide if 2 schedules are equivalent
- Use notion of "conflicting" operations

- Definition: Two operations **conflict** if:
  - They are by different transactions,
  - they are on the same object,
  - and at least one of them is a write.

Conflict Serializable Schedules

- <u>Definition</u>: Two schedules are conflict equivalent iff:
  - They involve the same actions of the same transactions, and
  - every pair of conflicting actions is ordered the same way
- <u>Definition</u>: Schedule S is conflict serializable if:
  - S is conflict equivalent to some serial schedule.
- Note, some “serializable” schedules are NOT conflict serializable
  - A price we pay to achieve efficient enforcement.

T1	T2	T3
R(A)		
	W(A)	
W(A)		
		W(A)

Conflict Serializability – Intuition

- **A schedule S is conflict serializable if:**
  - **You are able to transform S into a serial schedule by swapping consecutive non-conflicting operations of different transactions.**
- ***Example:***

R(A) W(A) R(B) W(B)

R(A) W(A) R(B) W(B)

$\equiv$

R(A) W(A) R(B) W(B)

R(A) W(A) R(B) W(B)

Conflict Serializability (Continued)

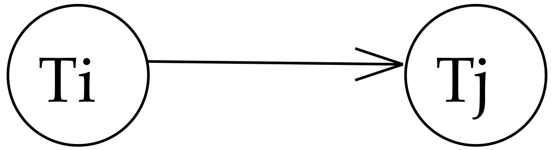
- Here's another example:

R(A)			W(A)
	R(A)	W(A)	

- Serializable or not????

NOT!

Dependency Graph



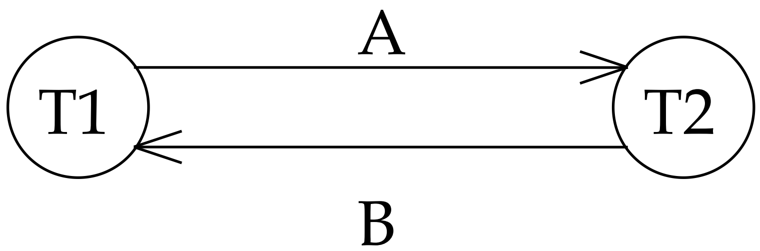
- ***Dependency graph***:
  - One node per Xact
  - Edge from Ti to Tj if:
    - An operation Oi of Ti conflicts with an operation Oj of Tj and
    - Oi appears earlier in the schedule than Oj.

- **Theorem**: Schedule is conflict serializable *if and only if* its dependency graph is acyclic.

Example

- **A schedule that is not conflict serializable:**

T1:	R(A), W(A),		R(B), W(B)
T2:		R(A), W(A), R(B), W(B)	



Dependency graph

- **The cycle in the graph reveals the problem. The output of T1 depends on T2, and vice-versa.**

Two-Phase Locking (2PL)

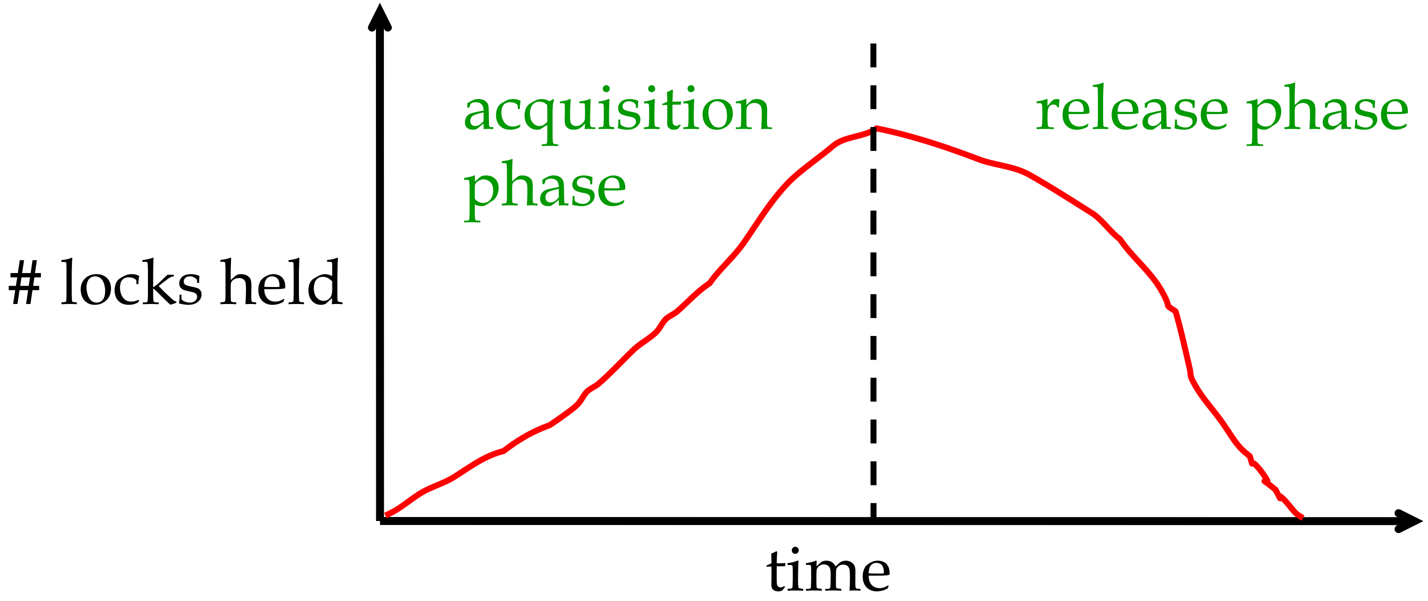
Lock Compatibility Matrix

	S	X
S	√	–
X	–	–

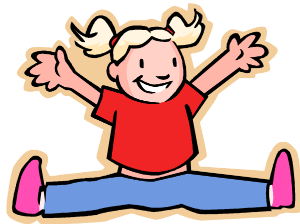
rules:

- **Xact must obtain a S (*shared*) lock before reading, and an X (*exclusive*) lock before writing.**
- **Xact cannot get new locks after releasing any locks.**

Two-Phase Locking (2PL), cont.



2PL guarantees conflict serializability



But, does *not* prevent Cascading Aborts.

Strict 2PL

- ***Problem:*** **Cascading Aborts**
- ***Example:*** **rollback of T1 requires rollback of T2!**

T1:	R(A), W(A),		R(B), W(B), Abort
T2:		R(A), W(A)	

- **Strict Two-phase Locking (Strict 2PL) protocol:**

  Same as 2PL, except:

  <u>Locks released only when transaction completes</u>

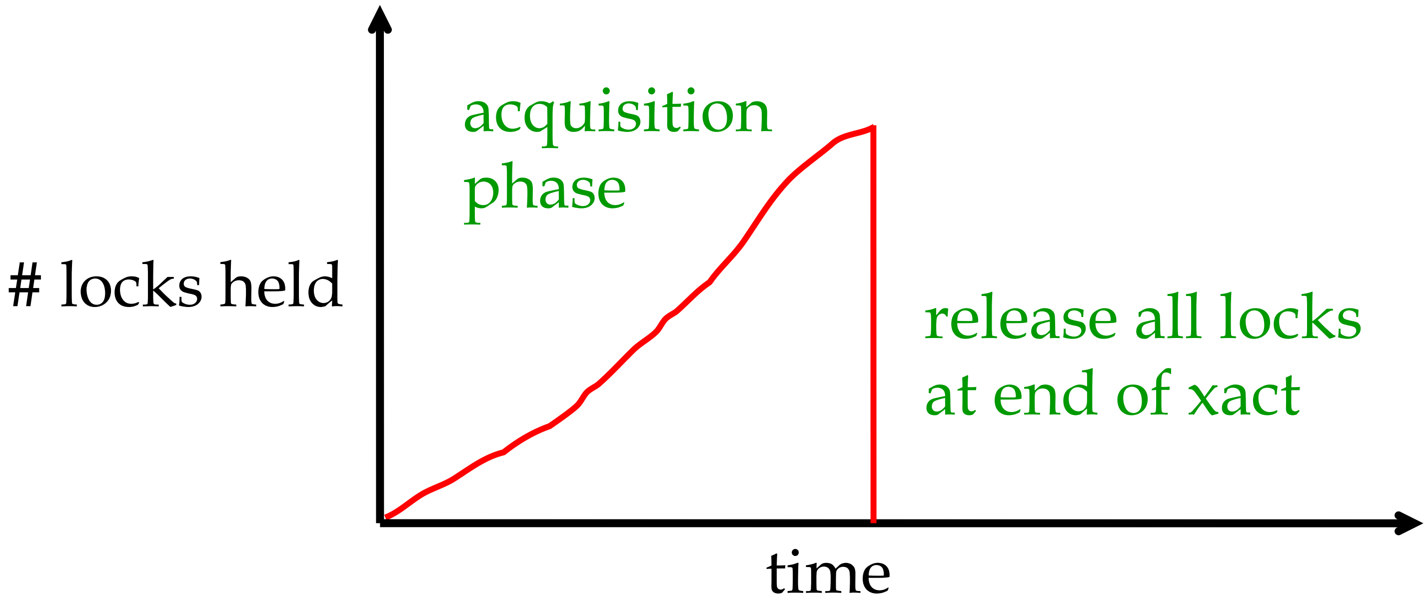
  i.e., either:

  (a) transaction has committed (commit record on disk),

  or

  (b) transaction has aborted and rollback is complete.

Strict 2PL (continued)



Next ...

- A few examples

Non-2PL, A= 1000, B=2000, Output =?

Lock_X(A)	
Read(A)	Lock_S(A)
A: = A-50	
Write(A)	
Unlock(A)	
	Read(A)
	Unlock(A)
	Lock_S(B)
Lock_X(B)	
	Read(B)
	Unlock(B)
	PRINT(A+B)
Read(B)	
B := B +50	
Write(B)	
Unlock(B)	

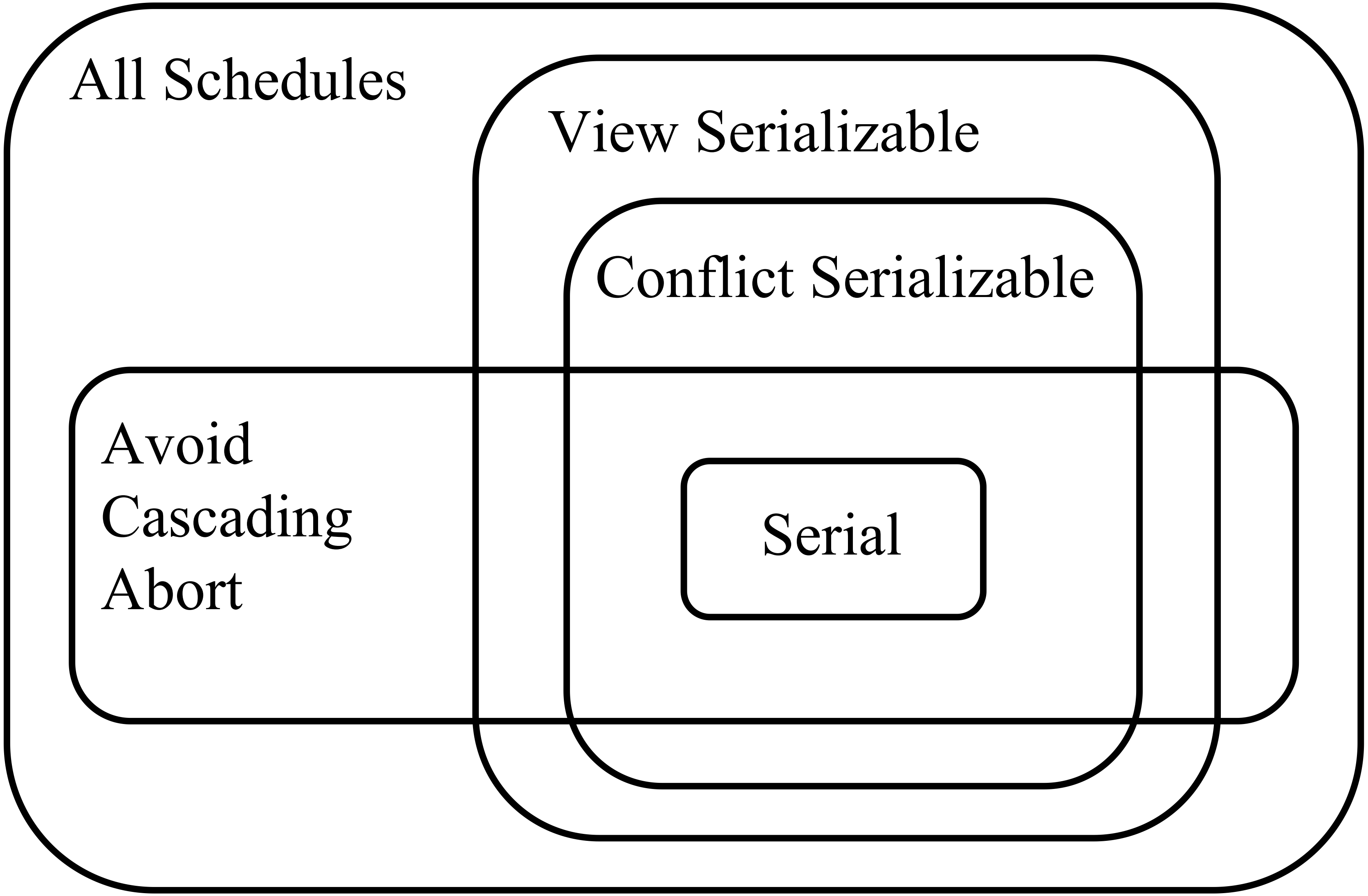
2PL, A= 1000, B=2000, Output =?

Lock_X(A)	
Read(A)	Lock_S(A)
A: = A-50	
Write(A)	
Lock_X(B)	
Unlock(A)	
	Read(A)
	Lock_S(B)
Read(B)	
B := B +50	
Write(B)	
Unlock(B)	Unlock(A)
	Read(B)
	Unlock(B)
	PRINT(A+B)

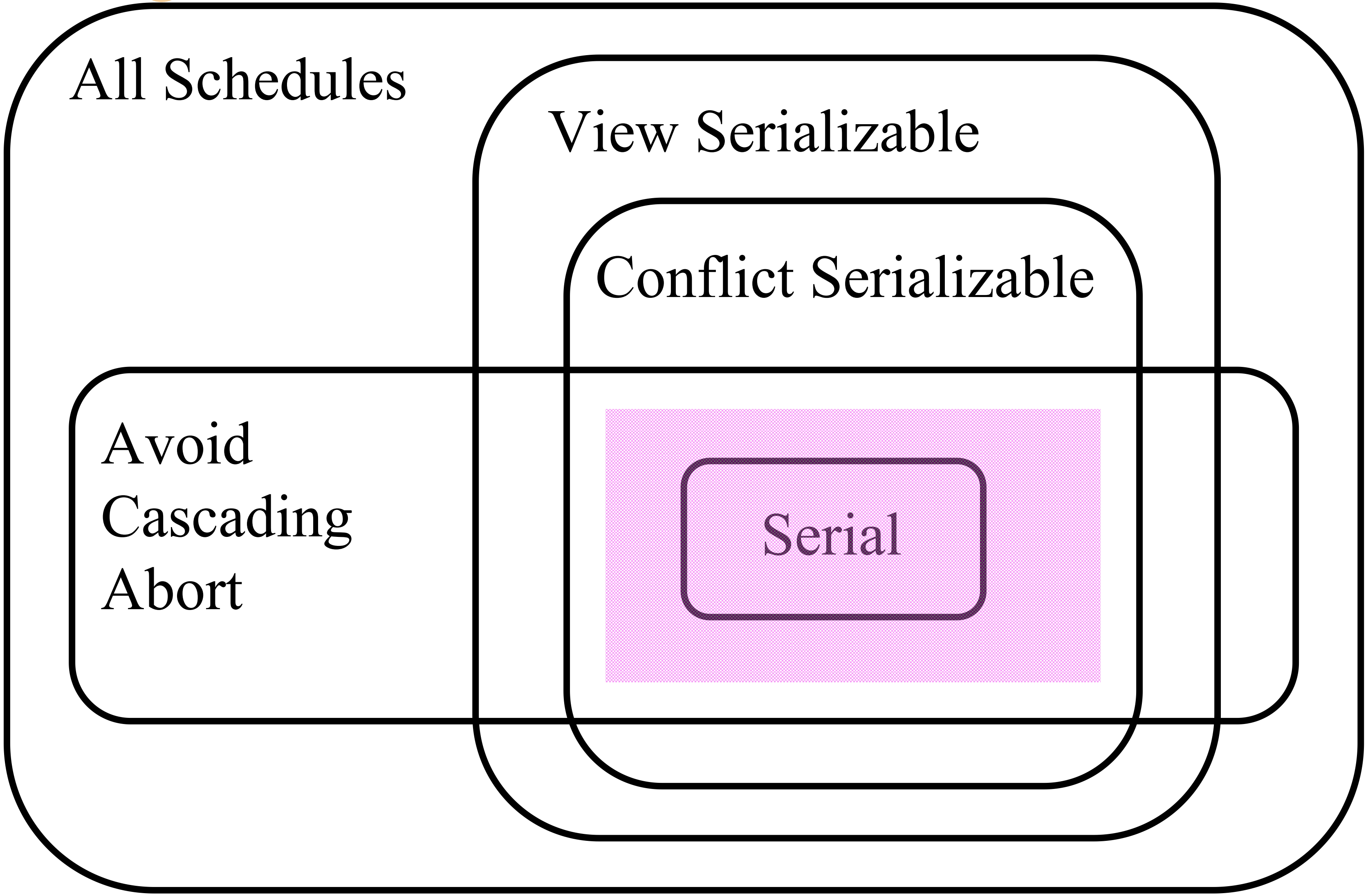
Strict 2PL, A= 1000, B=2000, Output =?

Lock_X(A)	
Read(A)	Lock_S(A)
A: = A-50	
Write(A)	
Lock_X(B)	
Read(B)	
B := B +50	
Write(B)	
Unlock(A)	
Unlock(B)	
	Read(A)
	Lock_S(B)
	Read(B)
	PRINT(A+B)
	Unlock(A)
	Unlock(B)

Venn Diagram for Schedules



Which schedules does Strict 2PL allow?



Lock Management

- Lock and unlock requests handled by **Lock Manager**

- LM keeps an entry for each currently held lock.
- Entry contains:
  - List of xacts currently holding lock
  - Type of lock held (shared or exclusive)
  - Queue of lock requests

Lock Management, cont.

- When lock request arrives:
  - Does any other xact hold a conflicting lock?
    - If no, grant the lock.
    - If yes, put requestor into wait queue.

- Lock upgrade:
  - xact with shared lock can request to upgrade to exclusive

Example

Lock_X(A)	
	Lock_S(B)
	Read(B)
	Lock_S(A)
Read(A)	
A: = A-50	
Write(A)	
Lock_X(B)	

Deadlocks

- **Deadlock:** Cycle of transactions waiting for locks to be released by each other.

- Two ways of dealing with deadlocks:
  - prevention
  - detection

- Many systems just punt and use Timeouts
  - What are the dangers with this approach?

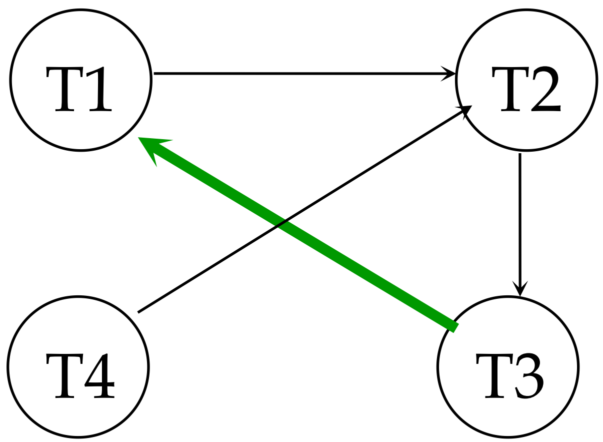
Deadlock Detection

- Create and maintain a "waits-for" graph
- Periodically check for cycles in graph

Deadlock Detection (Continued)

Example:

T1:	**S(A), S(D),**		**S(B)**				
T2:		**X(B)**			**X(C)**		
T3:				**S(D), S(C),**			**X(A)**
T4:						**X(B)**	



Deadlock Prevention

- **Assign priorities based on timestamps.**
- **Say Ti wants a lock that Tj holds**

  Two policies are possible:

  Wait-Die: If Ti has higher priority, Ti waits for Tj; otherwise Ti aborts

  Wound-wait: If Ti has higher priority, Tj aborts; otherwise Ti waits

- **Why do these schemes guarantee no deadlocks?**
- **Important detail: If a transaction re-starts, make sure it gets its original timestamp. -- Why?**

Summary

- Correctness criterion for isolation is “serializability”.
  - In practice, we use “conflict serializability,” which is somewhat more restrictive but easy to enforce.
- Two Phase Locking and Strict 2PL: Locks implement the notions of conflict directly.
  - The lock manager keeps track of the locks issued.
  - **Deadlocks** may arise; can either be prevented or detected.