Transactions &
Update Correctness

Correctness

- Data Correctness (Constraints)
- Query Correctness (Plan Rewrites)
- **Update Correctness (Transactions)**

What could go wrong?

- **Parallelism**: What happens if two updates modify the same data?
  - Maximize use of IO / Minimize Latencies.
- **Persistence**: What happens if something breaks during an update?
  - When is my data safe?

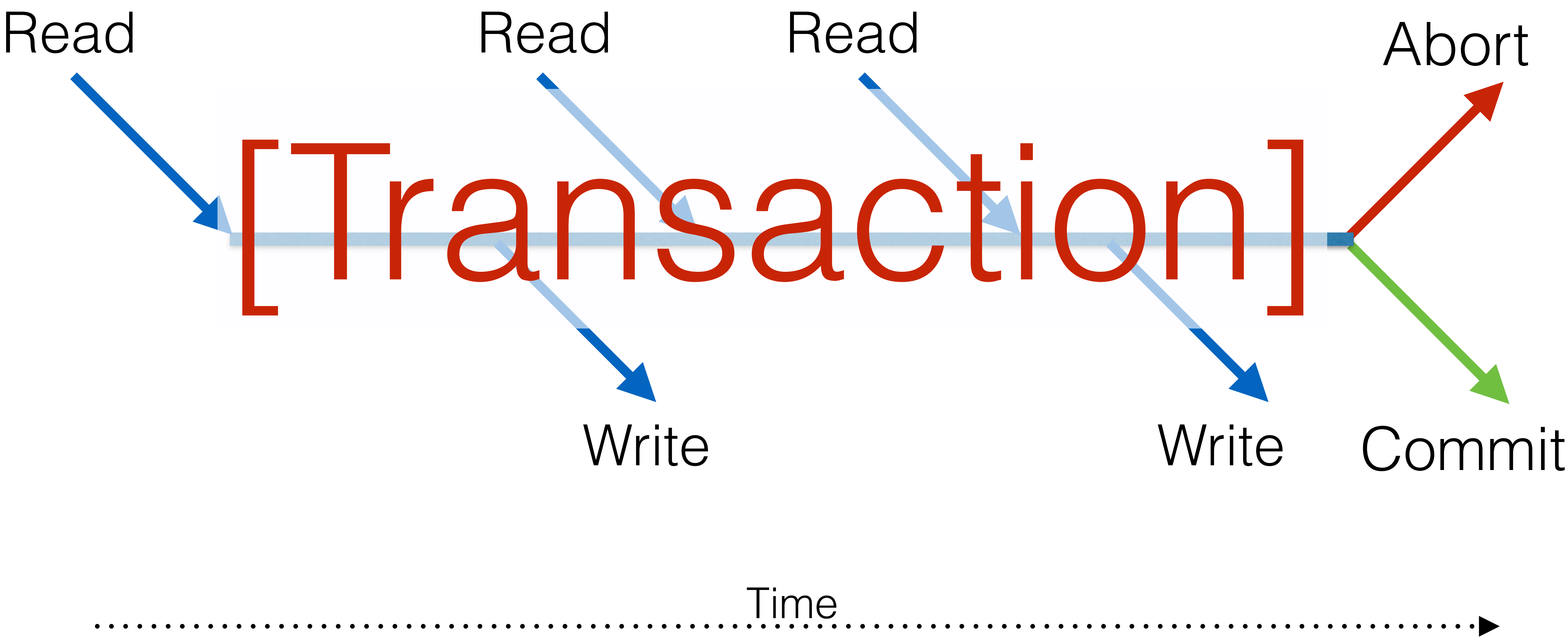
What does it mean for a database operation to be correct?

What is an Update?

- INSERT INTO …?
- UPDATE … SET … WHERE …?
- Non-SQL?

Can we abstract?

Abstract Update Operatons



Transaction

What does it mean for a ~~database operation~~ to be correct?

Transaction Correctness

- Reliability in database transactions guaranteed by ACID
- A - Atomicity (“Do or Do Not, there is nothing like try”) - usually ensured by logs
- C - Consistency (“Within the framework of law”) - usually ensured by integrity constraints, validations, etc.
- I - Isolation (“Execute in parallel or serially, the result should be same”) - usually ensured by locks
- D - Durability (“once committed, remain committed”) - usually ensured at hardware level

Atomicity

- A transaction completes by committing, or terminates by aborting.
    - Logging is used to undo aborted transactions.
- **Atomicity**: A transaction is (or appears as if it were) applied in one ‘step’, independent of other transactions.
    - All ops in a transaction commit or abort together.

Isolation

```
T1: BEGIN A=A+100,  B=B-100  END
T2: BEGIN A=1.06*A, B=1.06*B END
```

- Intuitively, T1 transfers $100 from A to B and T2 credits both accounts with interest.
- What are possible interleaving errors?

Example: Schedule

Time	T1	T2
↓	`A=A+100`	
		`A=1.06*A`
	`B=B-100`	
		`B=1.06*B`

OK!

Example: Schedule

Time	T1	T2
↓	`A=A+100`	
		`A=1.06*A`
		`B=1.06*B`
	`B=B-100`	

Not OK!

Example:The DBMS's View

Time	T1	T2
↓	`R(A)`	
	`W(A)`	
		`R(A)`
		`W(A)`
		`R(B)`
		`W(B)`
	`R(B)`	
	`W(B)`	

Not OK!

What went wrong?

What could go wrong?

Reading uncommitted data

(write-read/WR conflicts; aka “Dirty Reads”)

```
T1: R(A),W(A),                    R(B),W(B),ABRT
T2:           R(A),W(A),CMT,
```

Unrepeatable Reads

(read-write/RW conflicts)

```
T1: R(A),                   R(A),W(A),CMT
T2:       R(A),W(A),CMT,
```

What could go wrong?

Overwriting Uncommitted Data
(write-write/WW conflicts)

```
T1: W(A),                 W(B),CMT
T2:       W(A),W(B),CMT,
```

Schedule

An ordering of read and write operations.

Serial Schedule

No interleaving between transactions **at all**

Serializable Schedule

Guaranteed to produce equivalent output
to a serial schedule

Conflict Equivalence

Possible Solution: Look at read/write, etc… conflicts!

Allow operations to be reordered as long as conflicts are ordered the same way

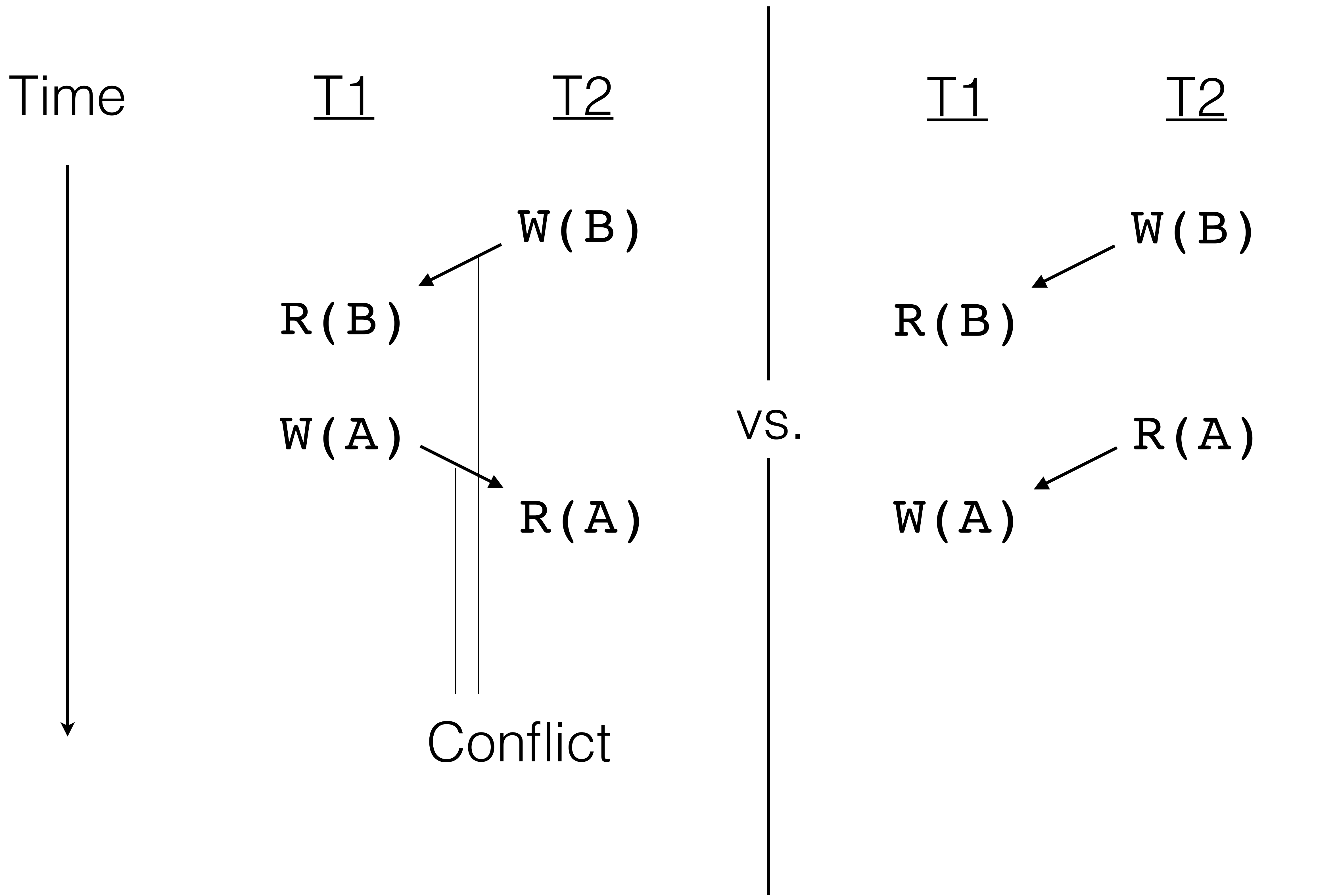
Conflict Equivalence: Can reorder one schedule into another without reordering conflicts.

Conflict Serializability: Conflict Equivalent to a serial schedule.

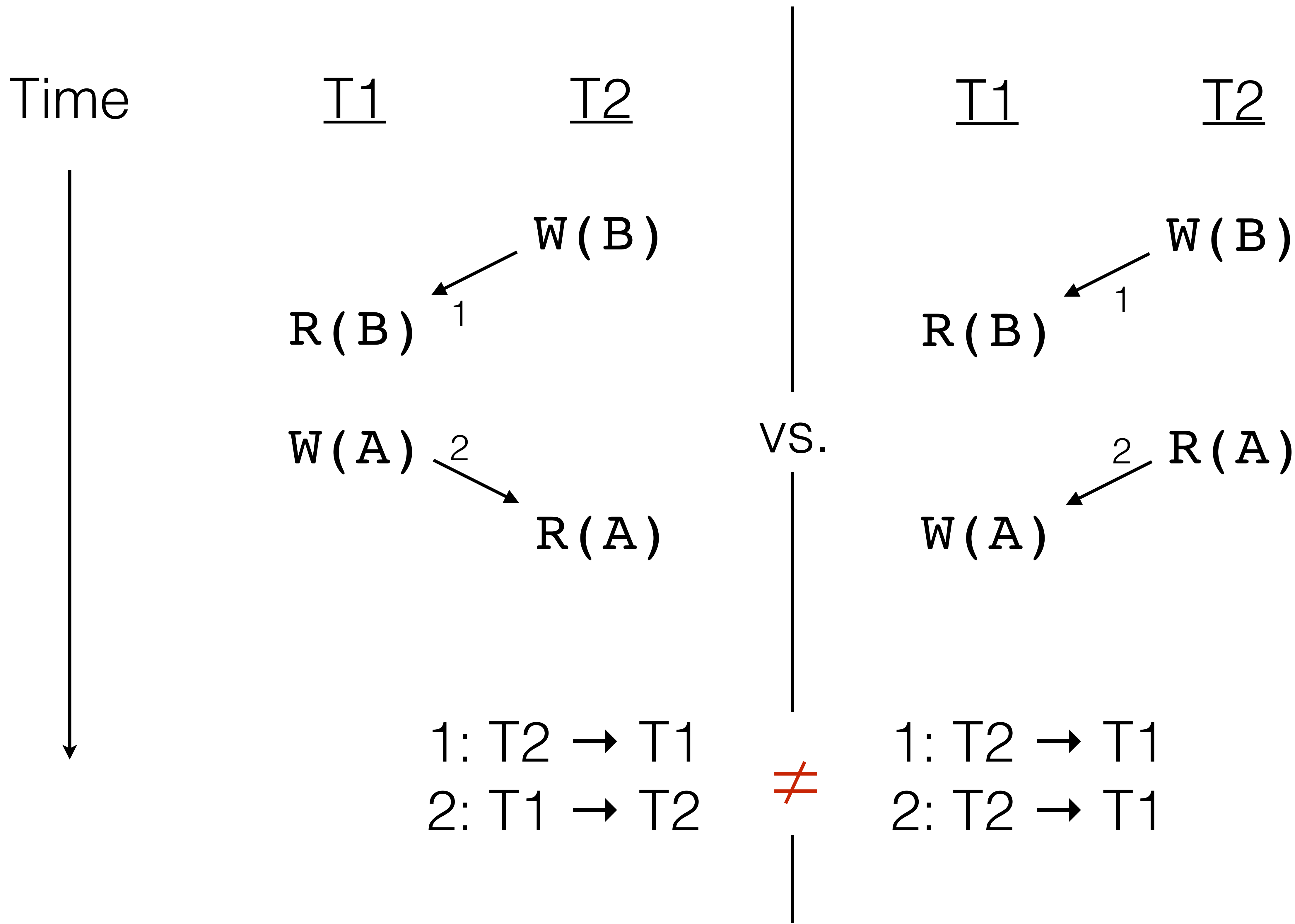
Conflict Serializability

- **Step 1:** Serial Schedules are Always Correct
- **Step 2:** Schedules with the same operations and the same conflict ordering are conflict-equivalent.
- **Step 3:** Schedules conflict-equivalent to an always correct schedule are also correct.
  - … or conflict serializable

Example



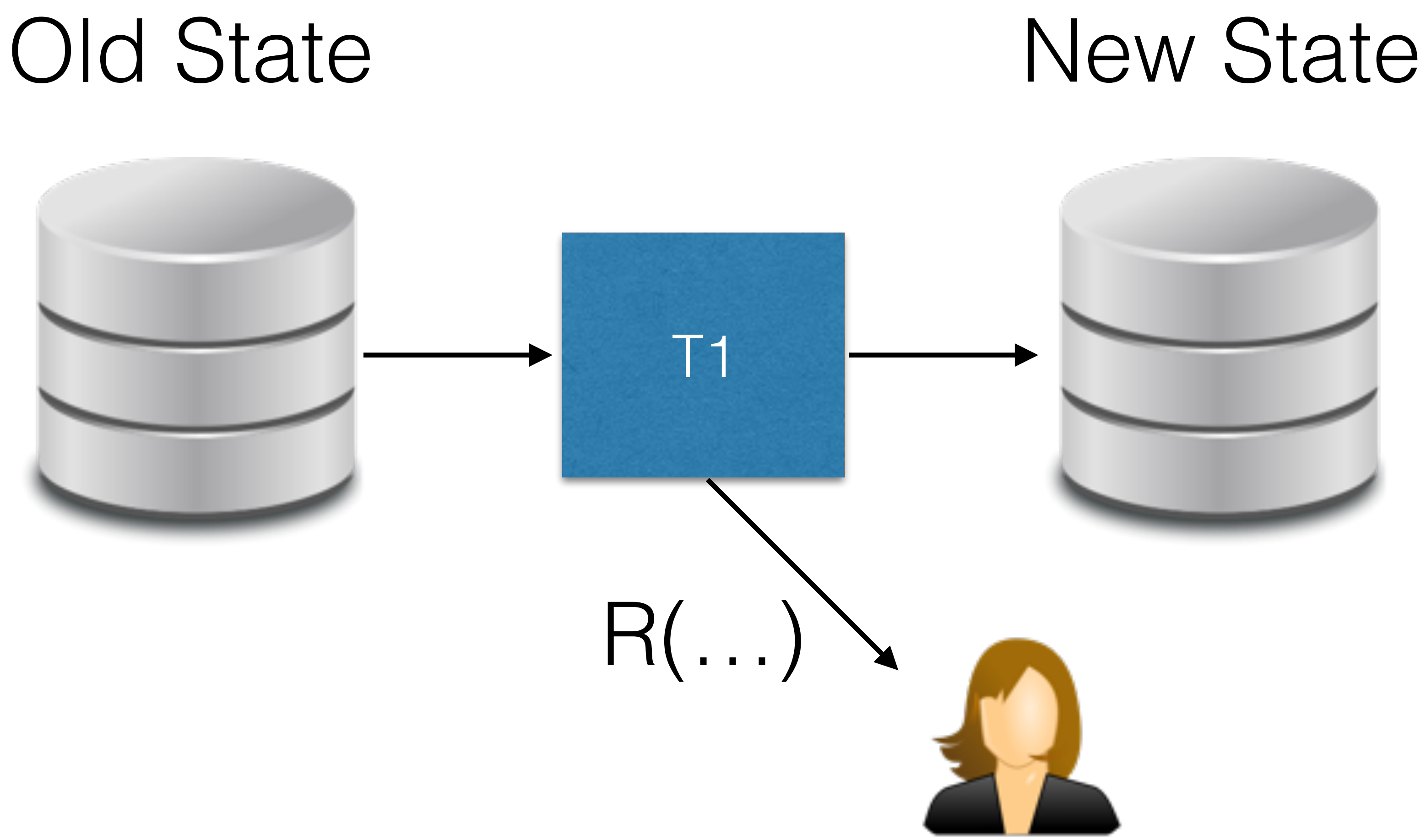
Example


Time
T1
T2
W(B)
R(B)
1
W(A)
2
R(A)
1: T2 → T1
2: T1 → T2
vs.
≠
T1
T2
W(B)
1
R(B)
R(A)
2
W(A)
1: T2 → T1
2: T2 → T1

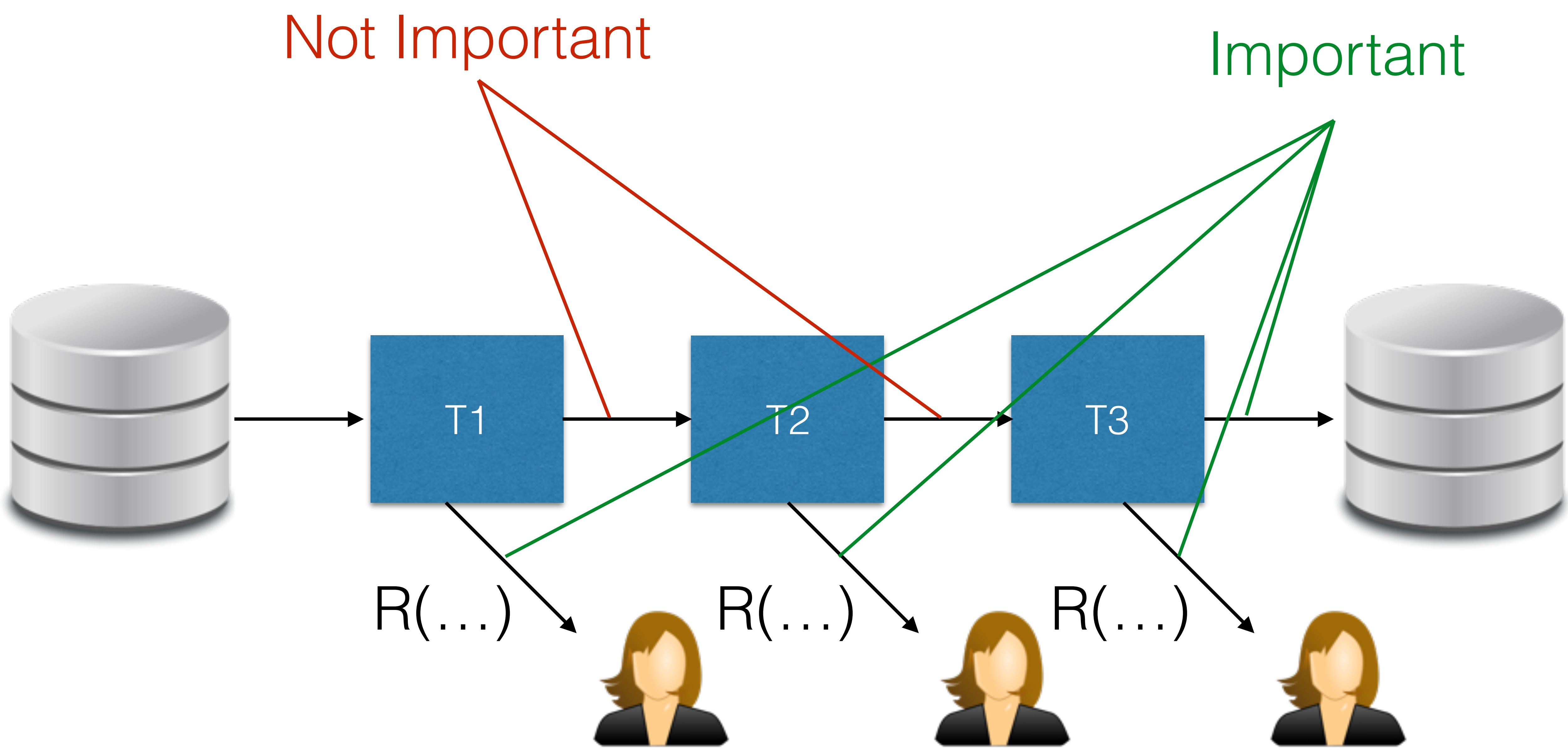
Equivalence

- Look at the actual effects
  - Can’t determine effects without running
- Look at the conflicts
  - Too strict
- Look at the possible <u>effects</u>

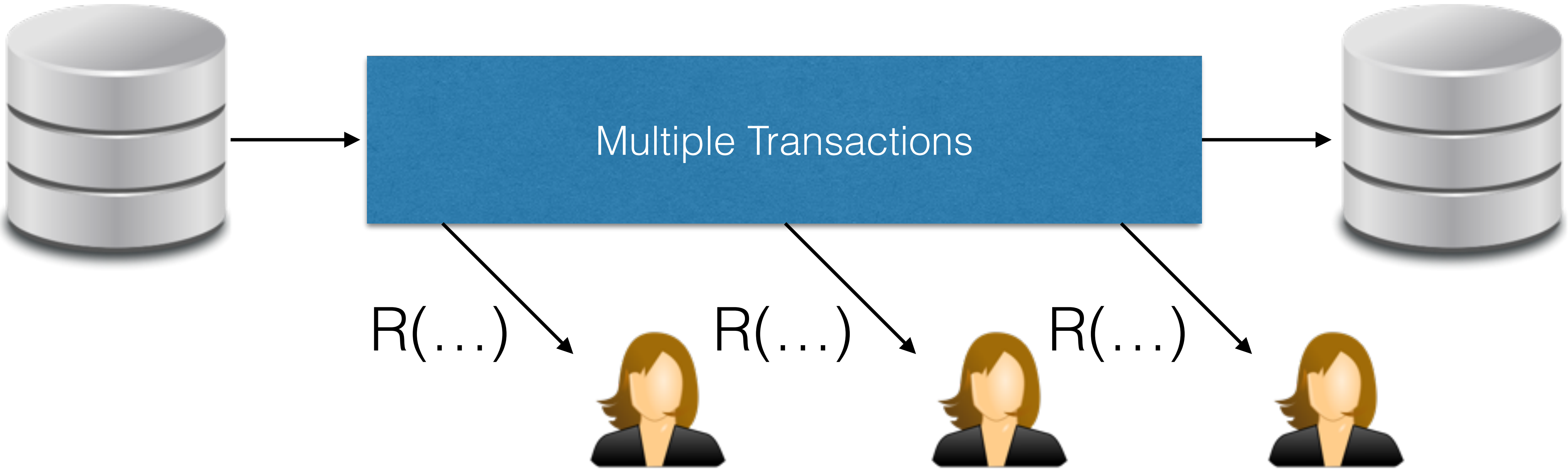
Information Flow



Information Flow



Information Flow



View Serializability

Possible Solution: Look at data flow!

View Equivalence: All reads read from the same writer
Final write in a batch comes from the same writer

View Serializability: Conflict Equivalent to a serial schedule.

View Equivalence

- For all Reads R
  - If R reads old state in S1, R reads old state in S2
  - If R reads Ti’s write in S1, R reads the the same write in S2
- For all values V being written.
  - If W is the last write to V in S1, W is the last write to V in S2
- If these conditions are satisfied, S1 and S2 are view-equivalent

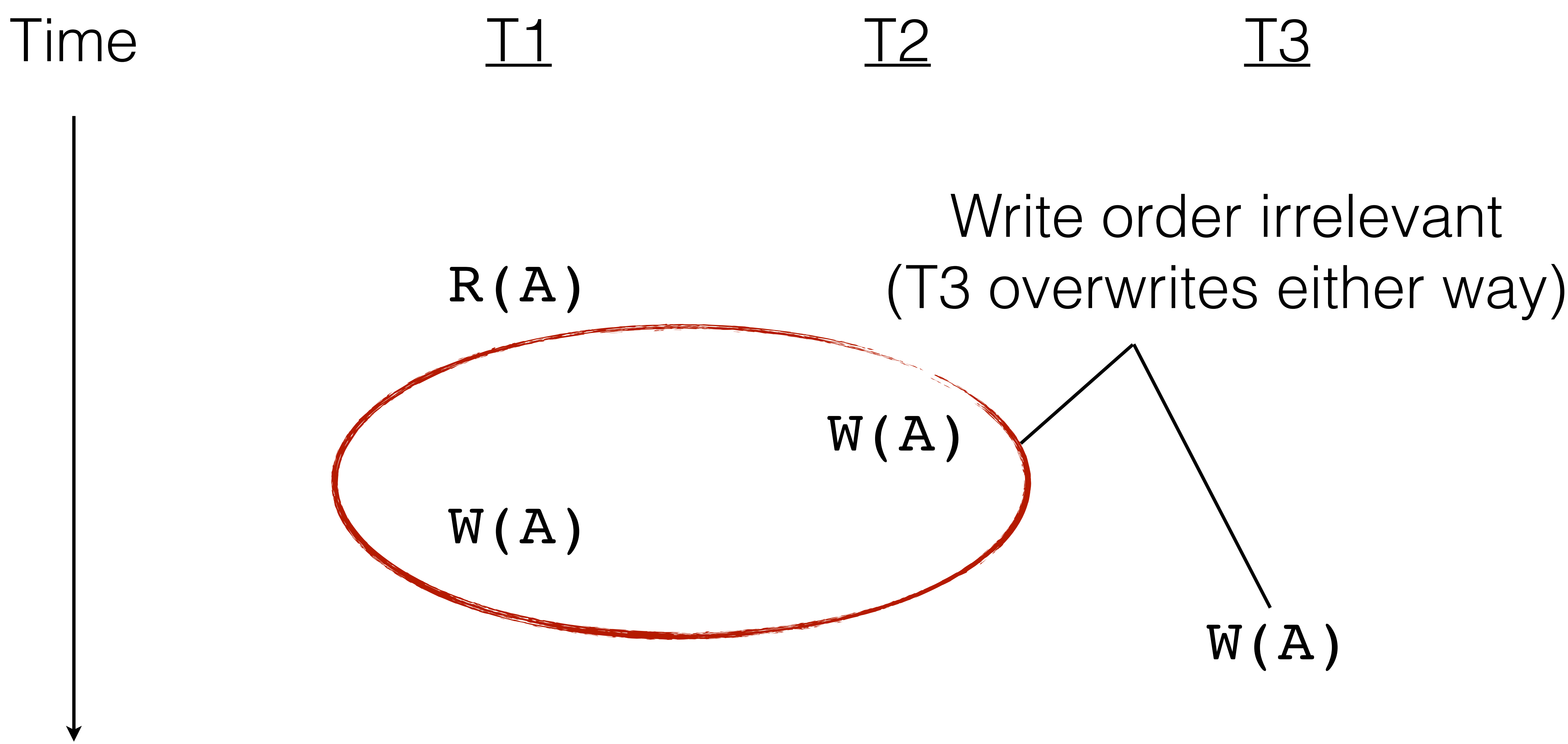
View Serializability

- **Step 1:** Serial Schedules are Always Correct
- **Step 2:** Schedules with the same information flow are view-equivalent.
- **Step 3:** Schedules view-equivalent to an always correct schedule are also correct.
  - … or view serializable

Example

Time	T1	T2	T3
↓	`R(A)`		
	`W(A)`		
		`W(A)`	
			`W(A)`

Example

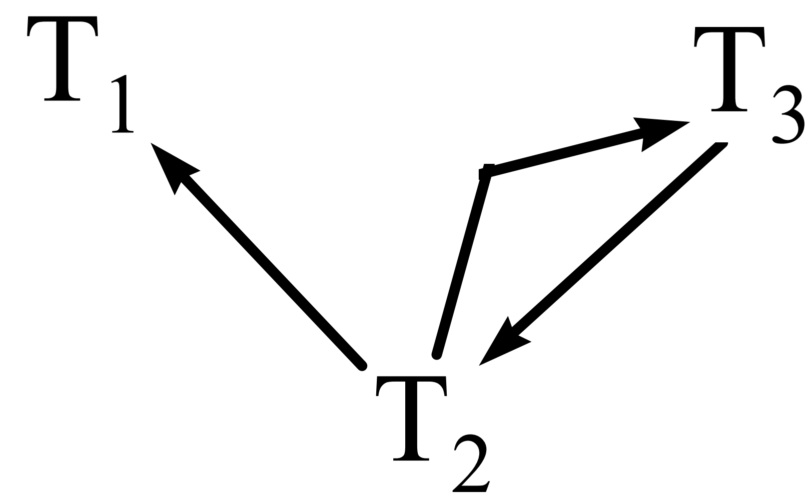

Time
T1
T2
T3
Write order irrelevant
(T3 overwrites either way)
R(A)
W(A)
W(A)
W(A)

Enforcing Serializability

- Conflict Serializability:
  - Does locking enforce conflict serializability?
- View Serializability
  - Is view serializability stronger, weaker, or incomparable to conflict serializability?
- What do we need to enforce either fully?

How to detect conflict serializable schedule?

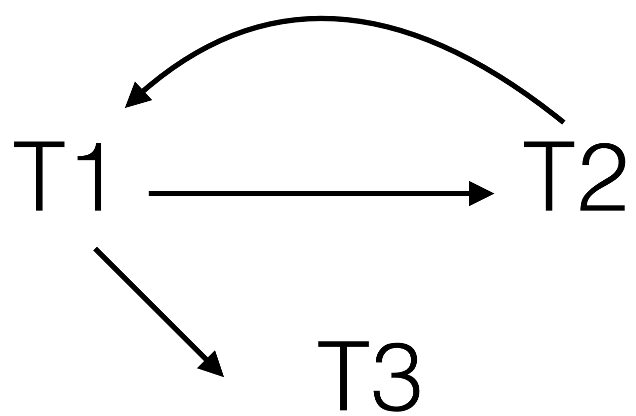
T1	T2	T3
W(a)		
	R(b)	
		W(d)
W(b)		
	R(d)	
		W(d)



Precedence Graph

Cycle!
Not Conflict serializable

Not conflict serializable but view serializable



Satisfies 3 conditions of view serializability

T1	T2	T3
W(y)		
	W(y)	
	W(x)	
W(x)		
		W(x)

Every view serializable schedule which is not conflict serializable has blind writes.

How can conflicts be avoided?

Optimistic Concurrency Control

Conservative Concurrency Control

Conservative Concurrency Control

- How can bad schedules be detected?
- What problems does each approach introduce?
- How do we resolve these problems?

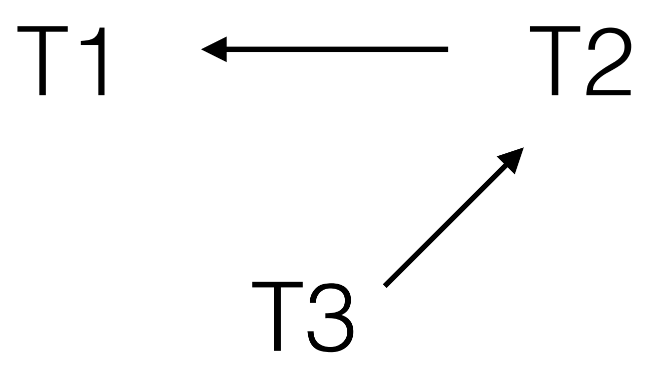
Two-Phase Locking

- Phase 1: Acquire (do not release) locks.
- Phase 2: Release (do not acquire) locks.

Why?

Can we do even better?

Example



Acyclic -
Conflict Serializable
2PL exists

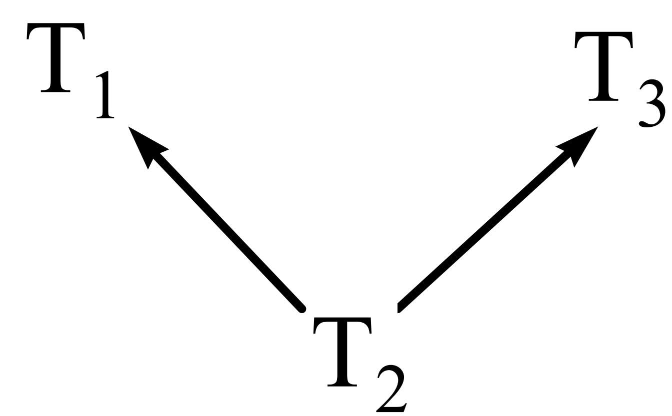
T1	T2	T3
		R(d)
W(a)		
	R(b)	
		W(d)
W(b)		
	R(d)	

Example

T1	T2	T3
		L(d) R(d)
L(a) W(a)		
	L(b) R(b)	
		W(d) R-L(d)
	L(d) R-L(b)	
L(b) R-L(a) W(b) R-L(b)		
	R(d) R-L(d)	

Need for shared and exclusive locks

T1	T2	T3
		L(d) R(d)
L(a) W(a)		
	L(b) R(b)	
L(b) W(b)		
	R(d)	
		W(d)



Precedence Graph

It is conflict Serializable but requires granular control of locks

Need for shared and exclusive locks

T1	T2	T3
		SL(d) R(d)
XL(a) W(a)		
	SL(b) SL(d) R(b) R-SL(b)	
XL(b) W(b) R-XL(b)		
	R(d) R-SL(d)	
		XL(d) W(d) R-XL(d)

		Lock requested	
		S	X
Lock held in mode	S	Yes	No
	X	No	No

Reader/Writer (S/X)

- When accessing a DB Entity…
    - Table, Row, Column, Cell, etc…
- Before reading: Acquire a Shared (S) lock.
    - Any number of transactions can hold S.
- Before writing: Acquire an Exclusive (X) lock.
    - If a transaction holds an X, no other transaction can hold an S or X.