Transactions & Update Correctness

April 11, 2018

Correctness

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- Data Correctness (Constraints)
- Query Correctness (Plan Rewrites)

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- 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?

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What is an Update?

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

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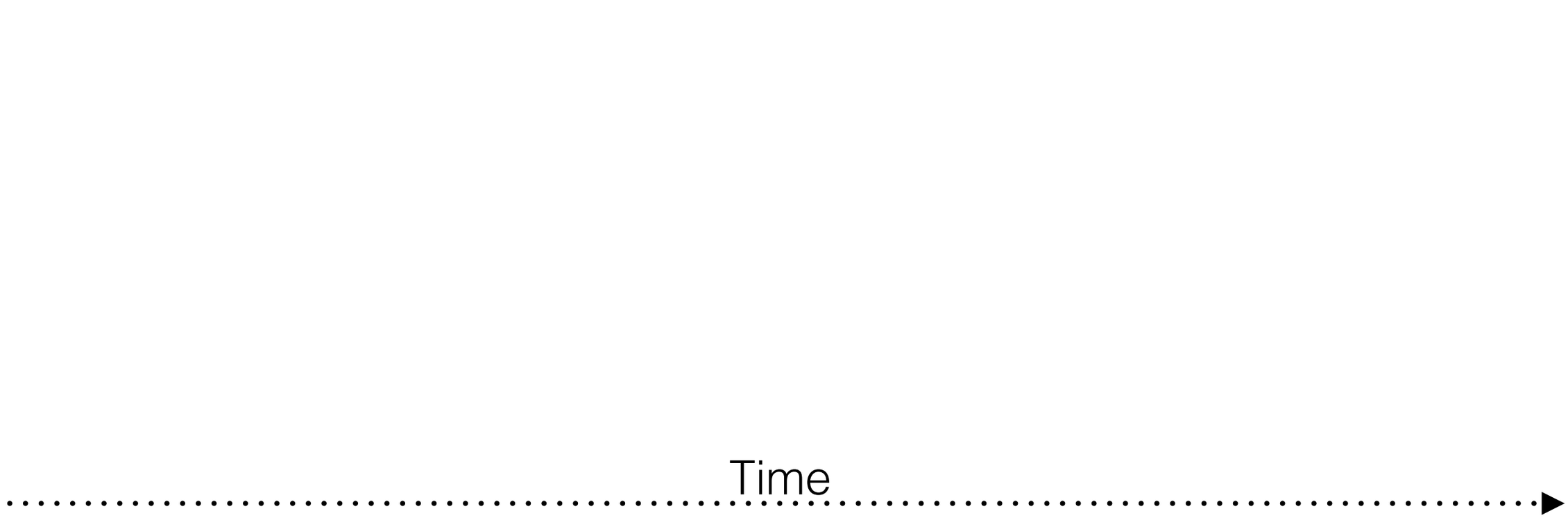
- INSERT INTO …?
- UPDATE … SET … WHERE …?
- Non-SQL?

Can we abstract?

Abstract Update Operatons



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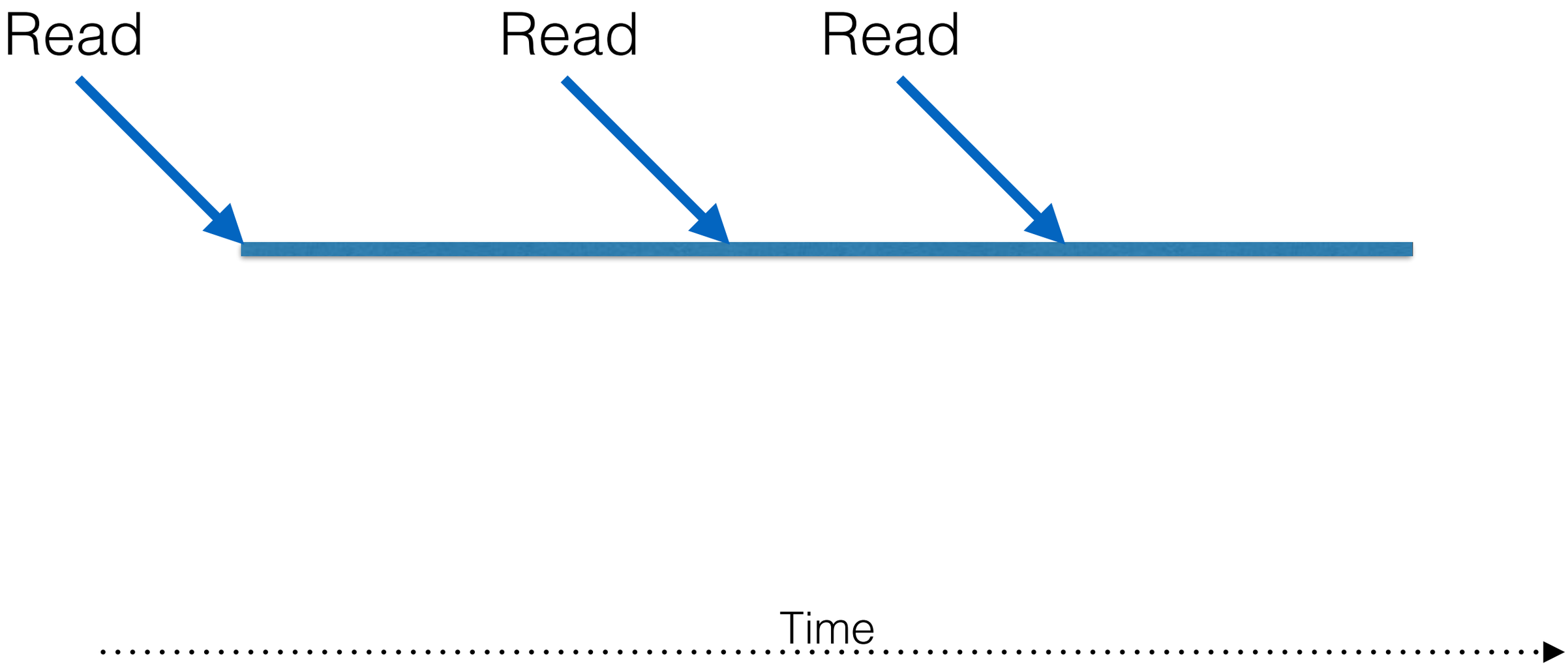

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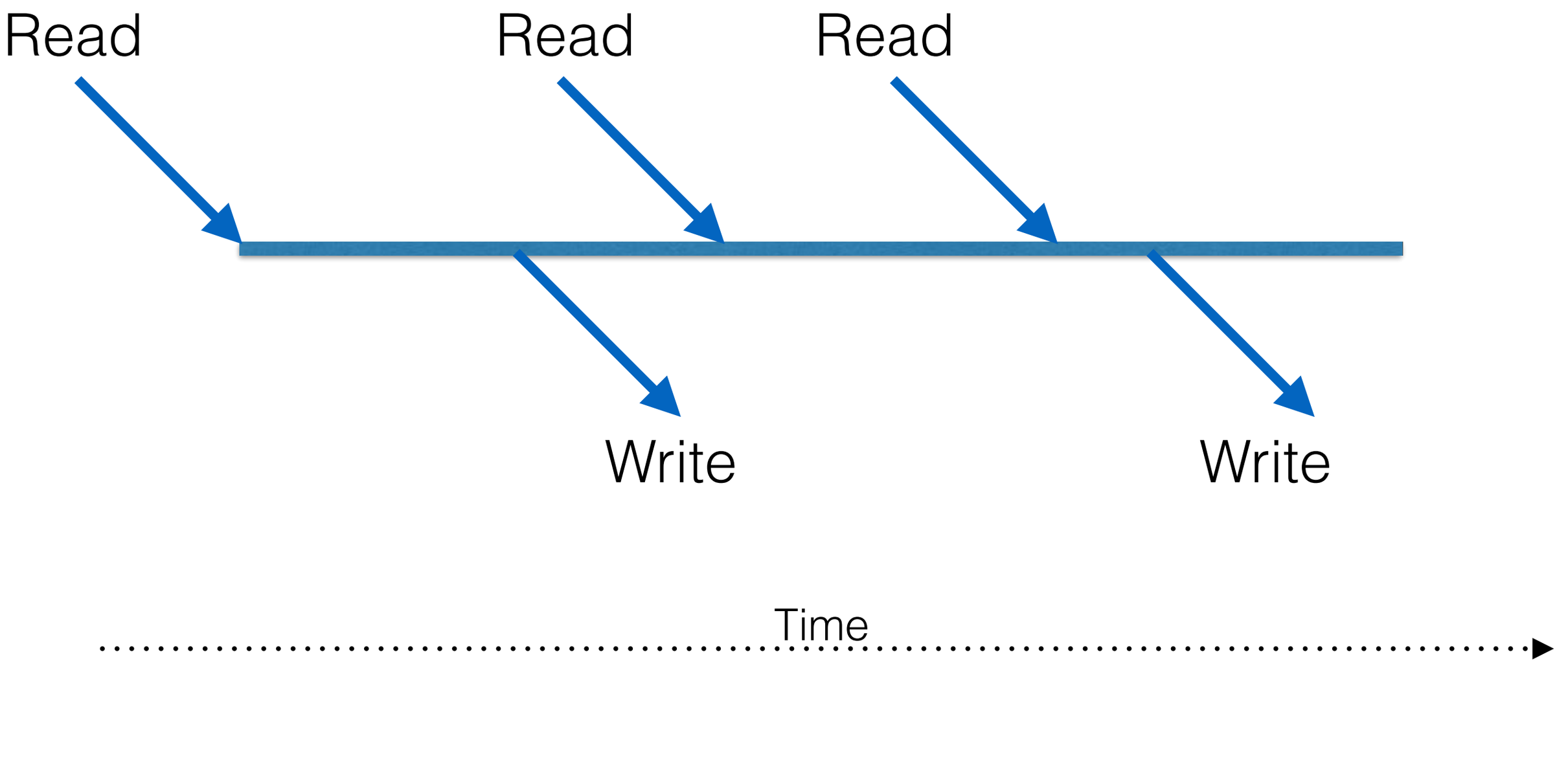

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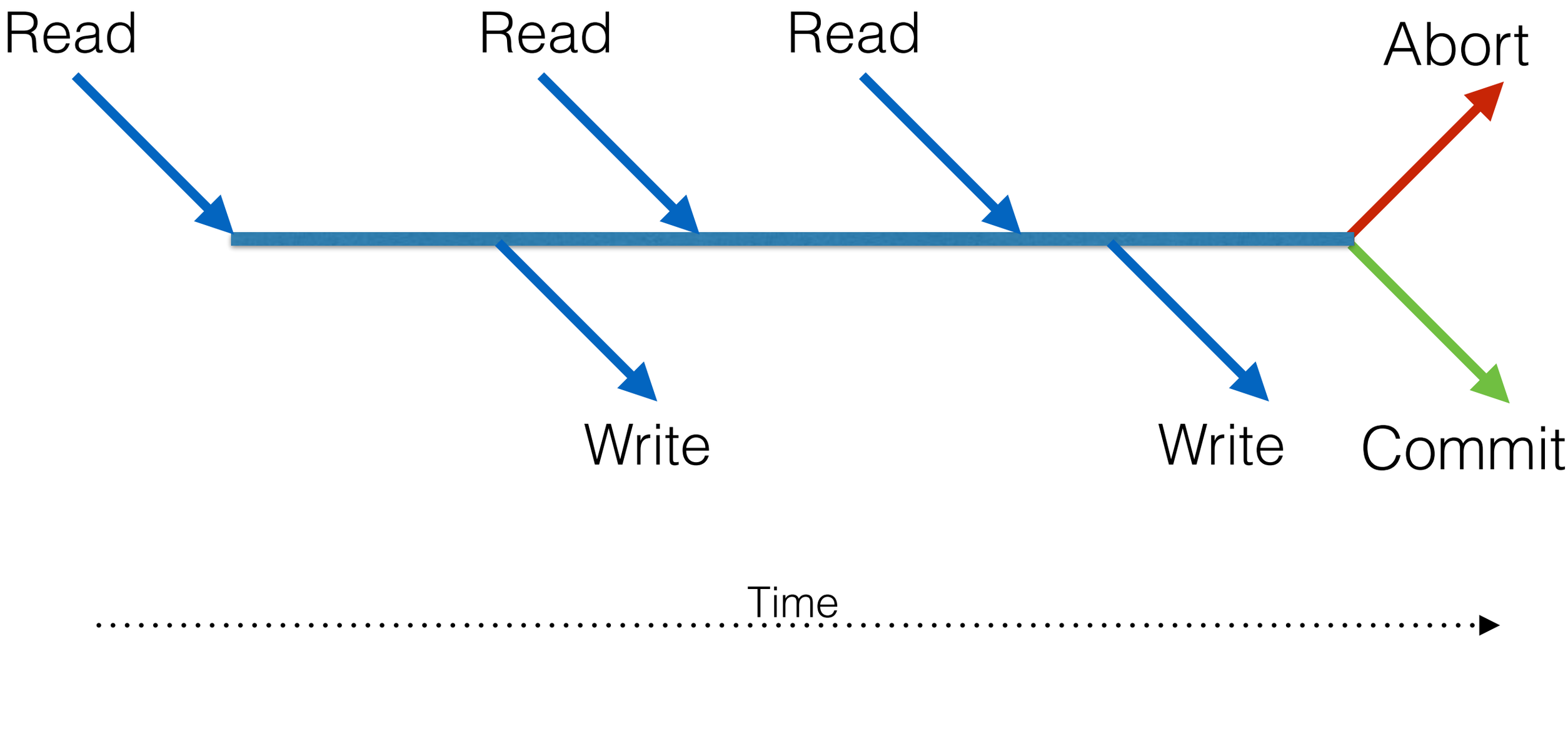

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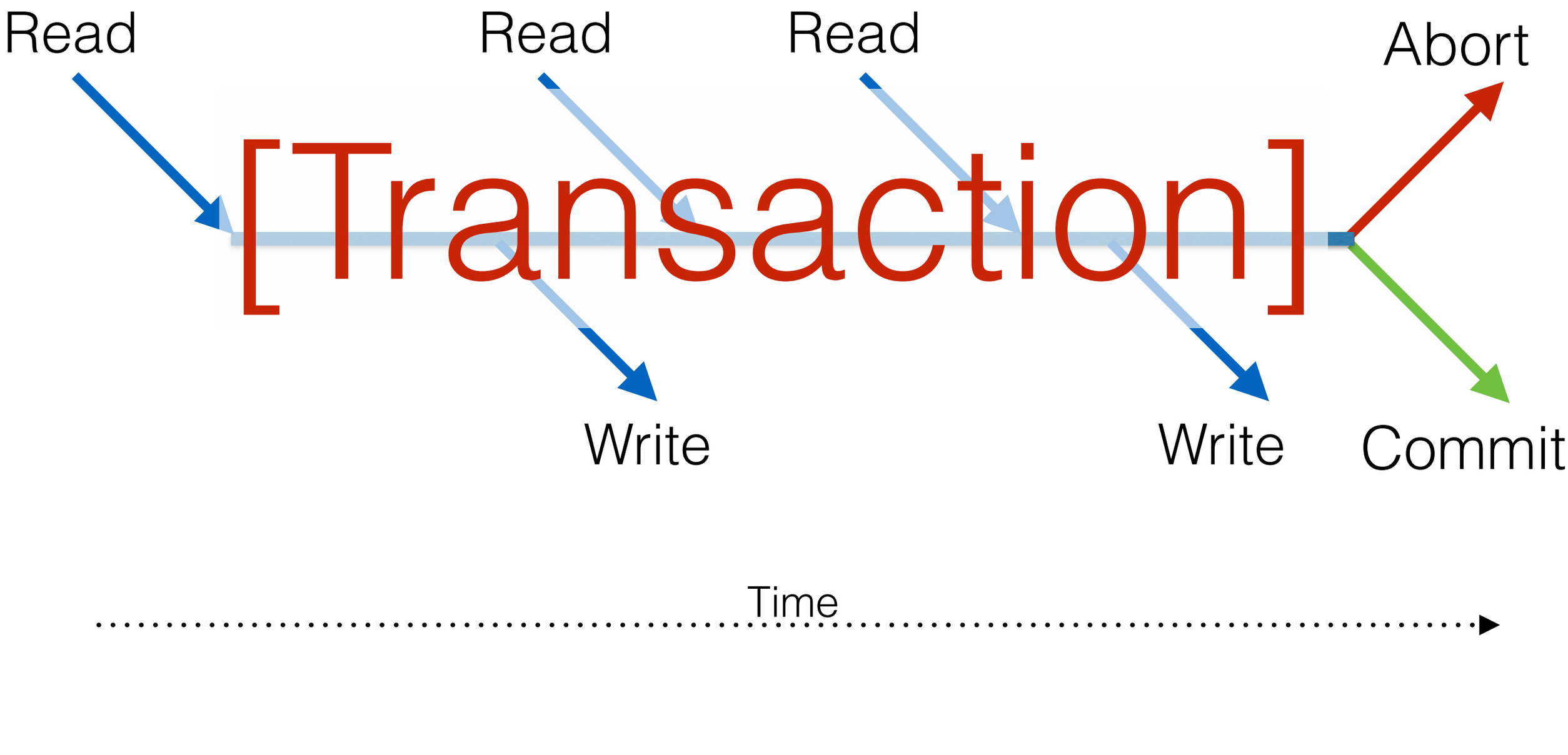


Transaction

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

Transaction Correctness

- From the user's perspective, transactions…
  - … execute fully or not at all. (atomicity)
  - … preserve integrity constraints (correctness)
  - … execute as if on their own (isolation)
  - … have their outputs persisted (durability)

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.

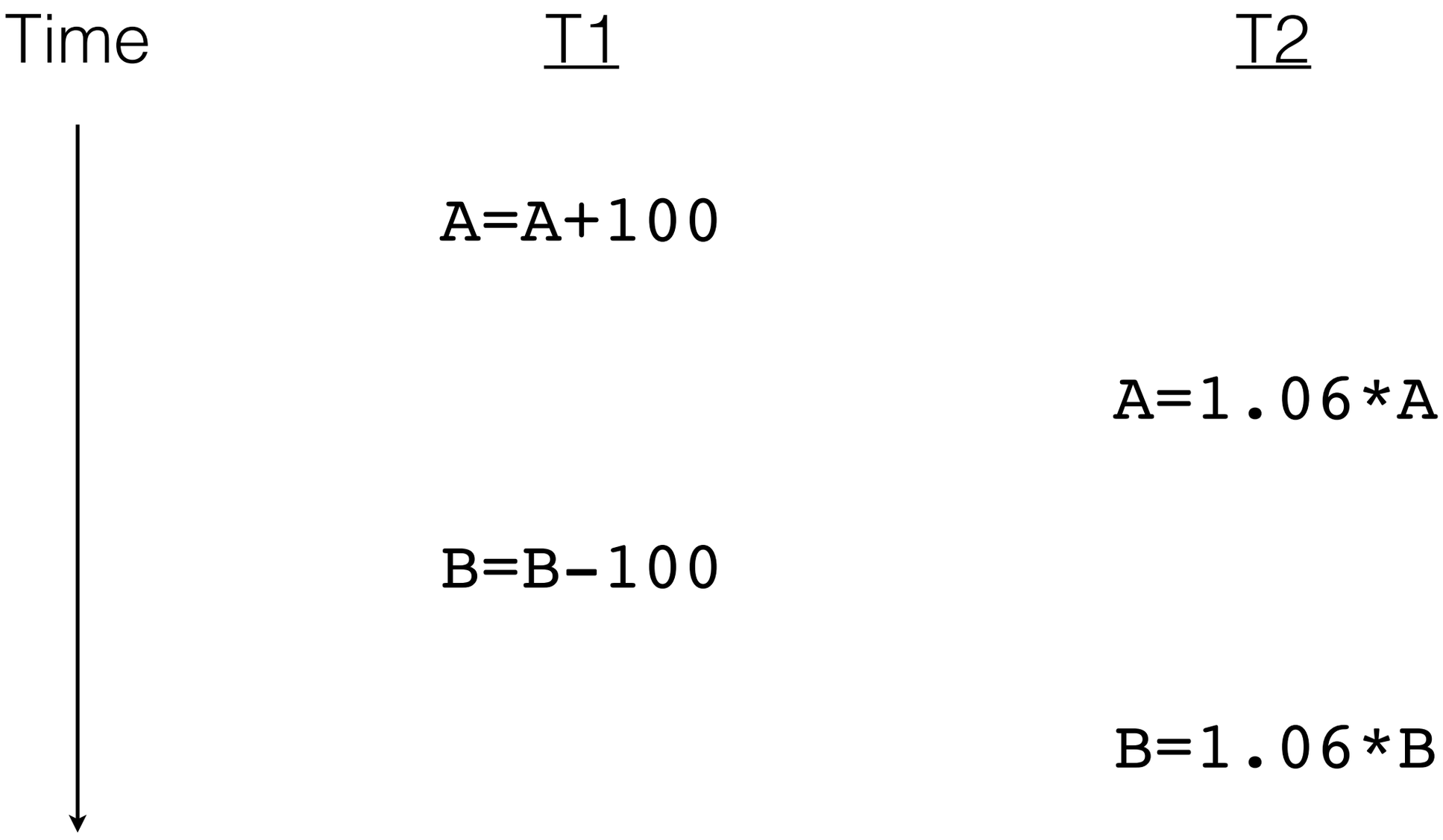
Isolation

```
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



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`	

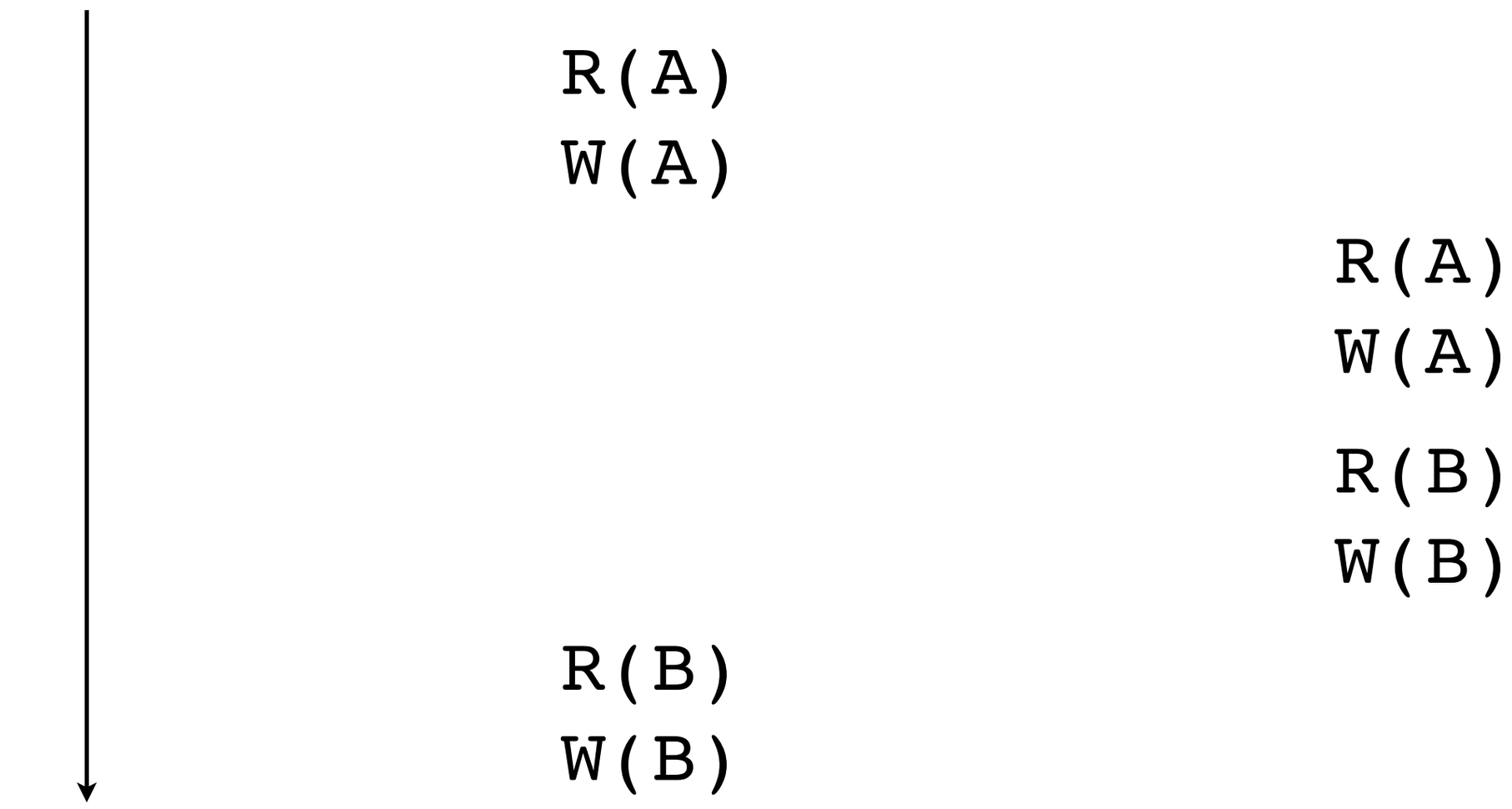
Example: Schedule

Time

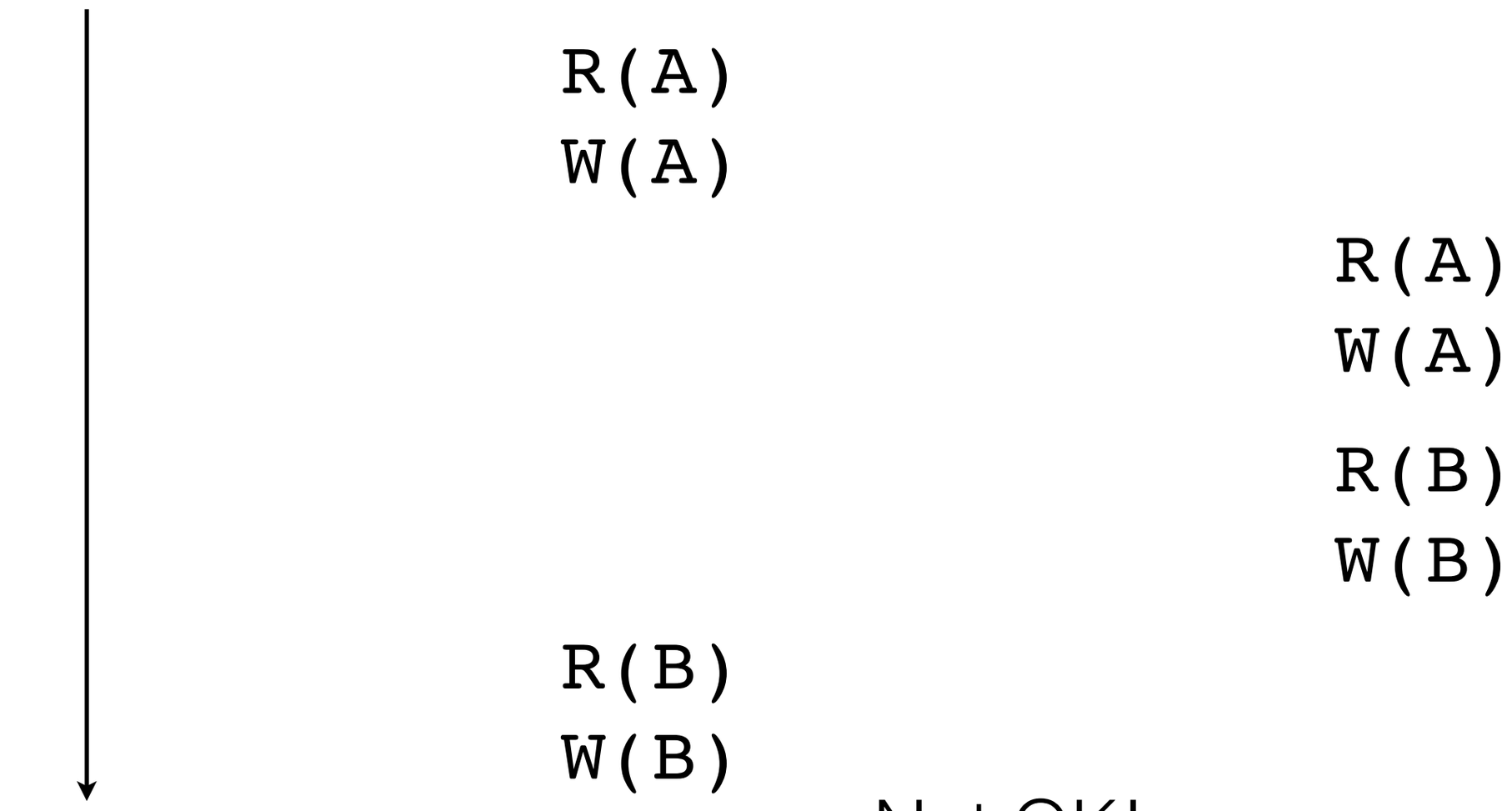
T1	T2
`A=A+100`	
	`A=1.06*A`
	`B=1.06*B`
`B=B-100`	

Not OK!

Example:The DBMS's View



Example:The DBMS's View



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

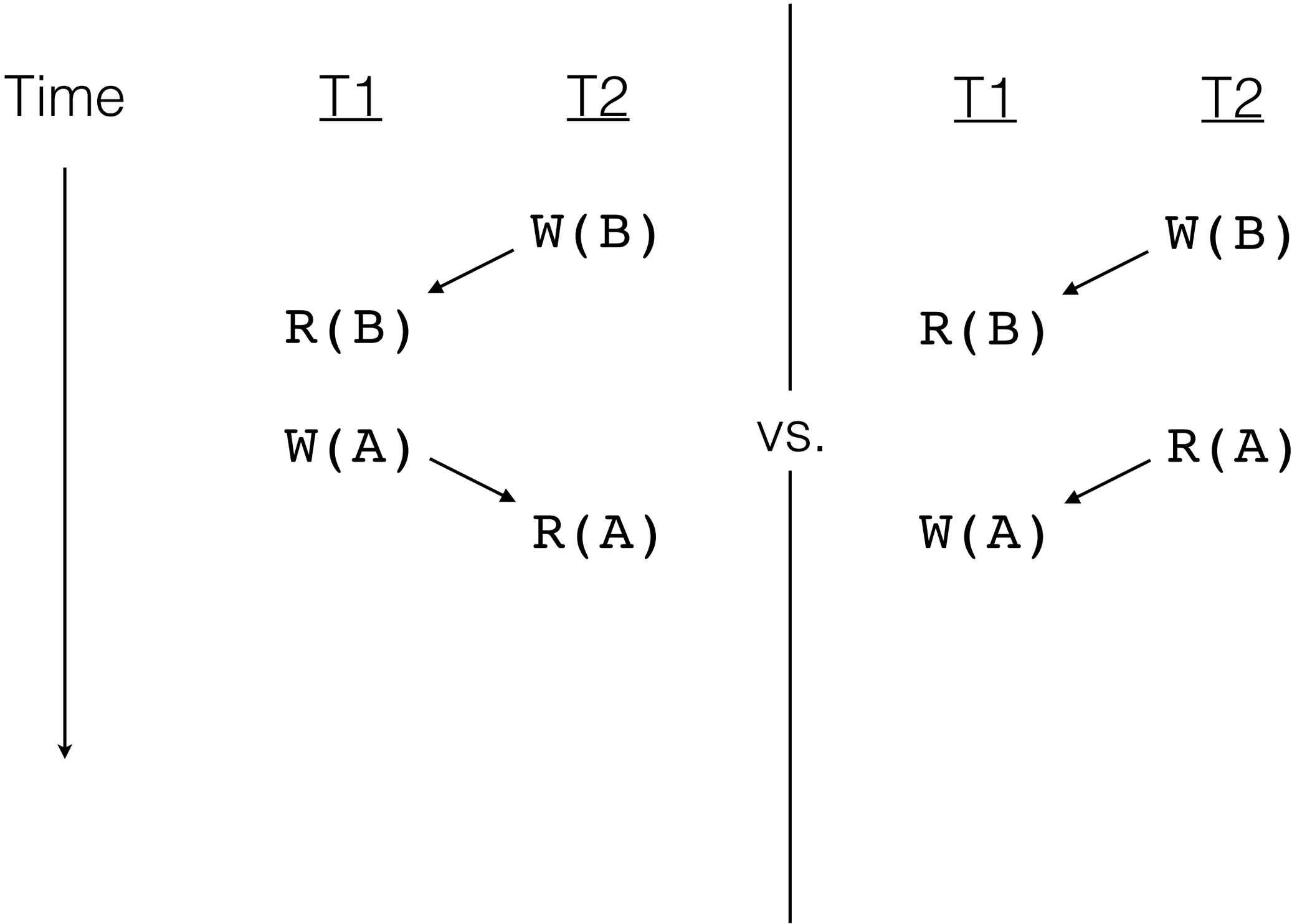
Conflict Equivalence: Can reorder one schedule into another without reordering conflicts.

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



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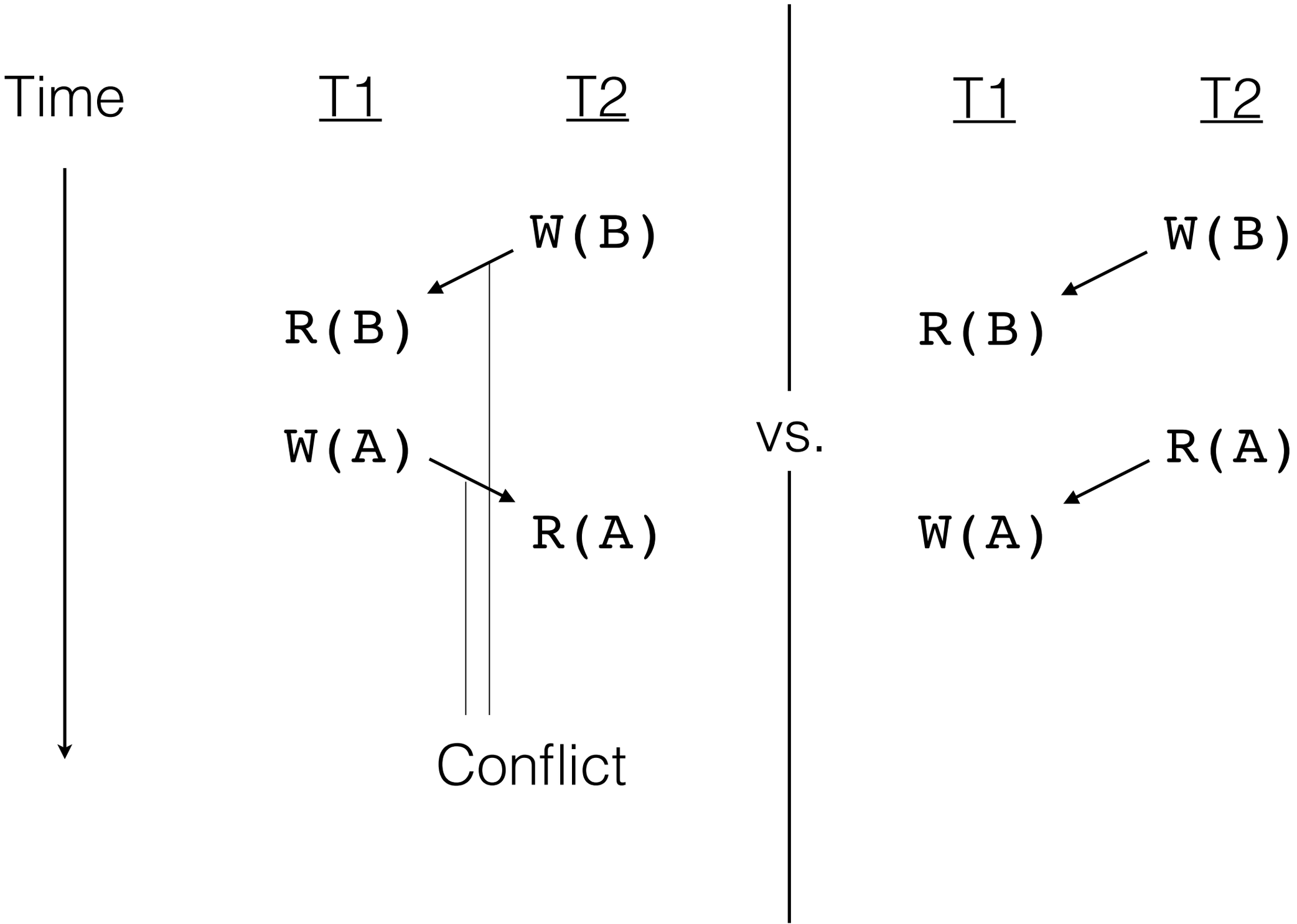

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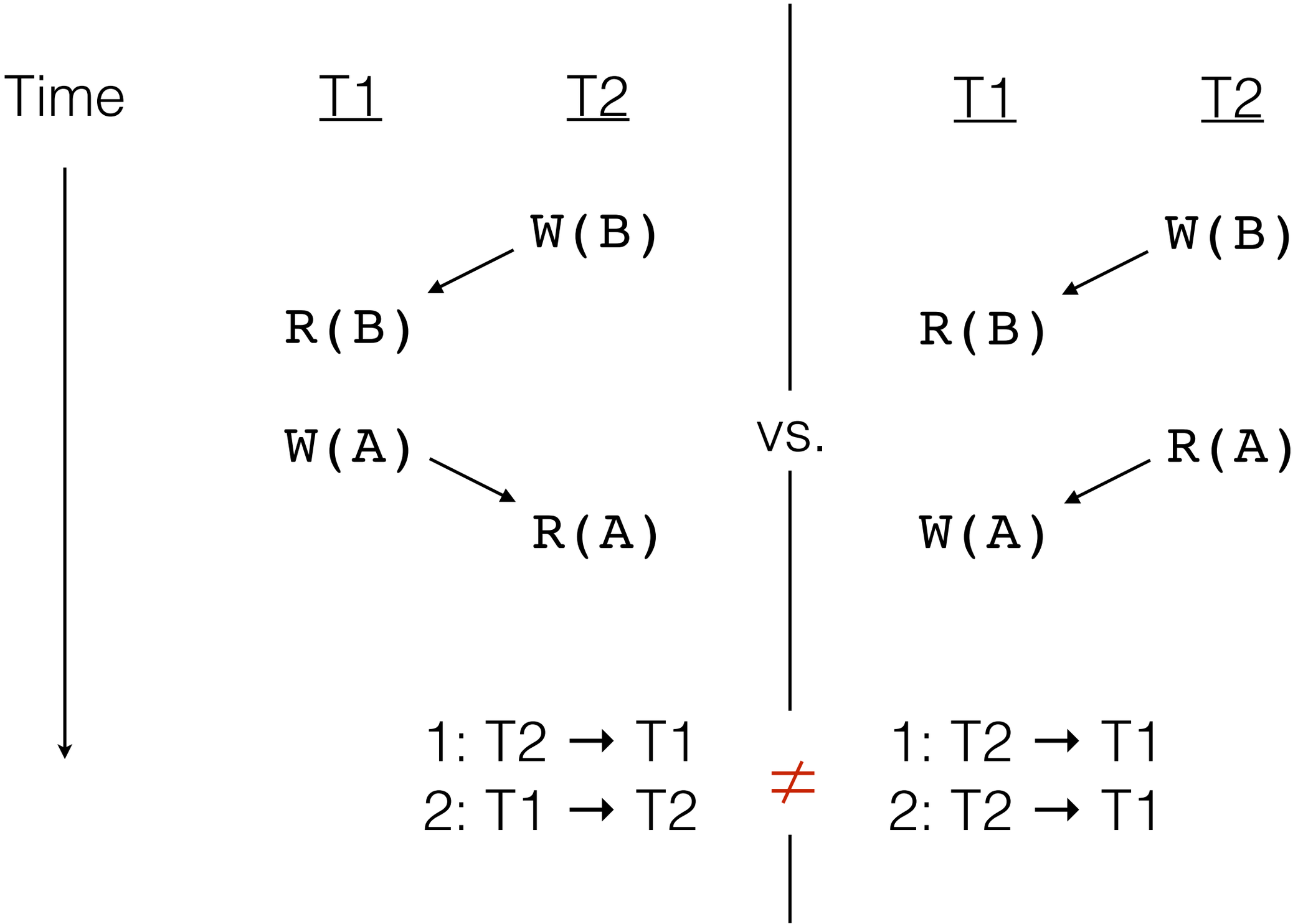
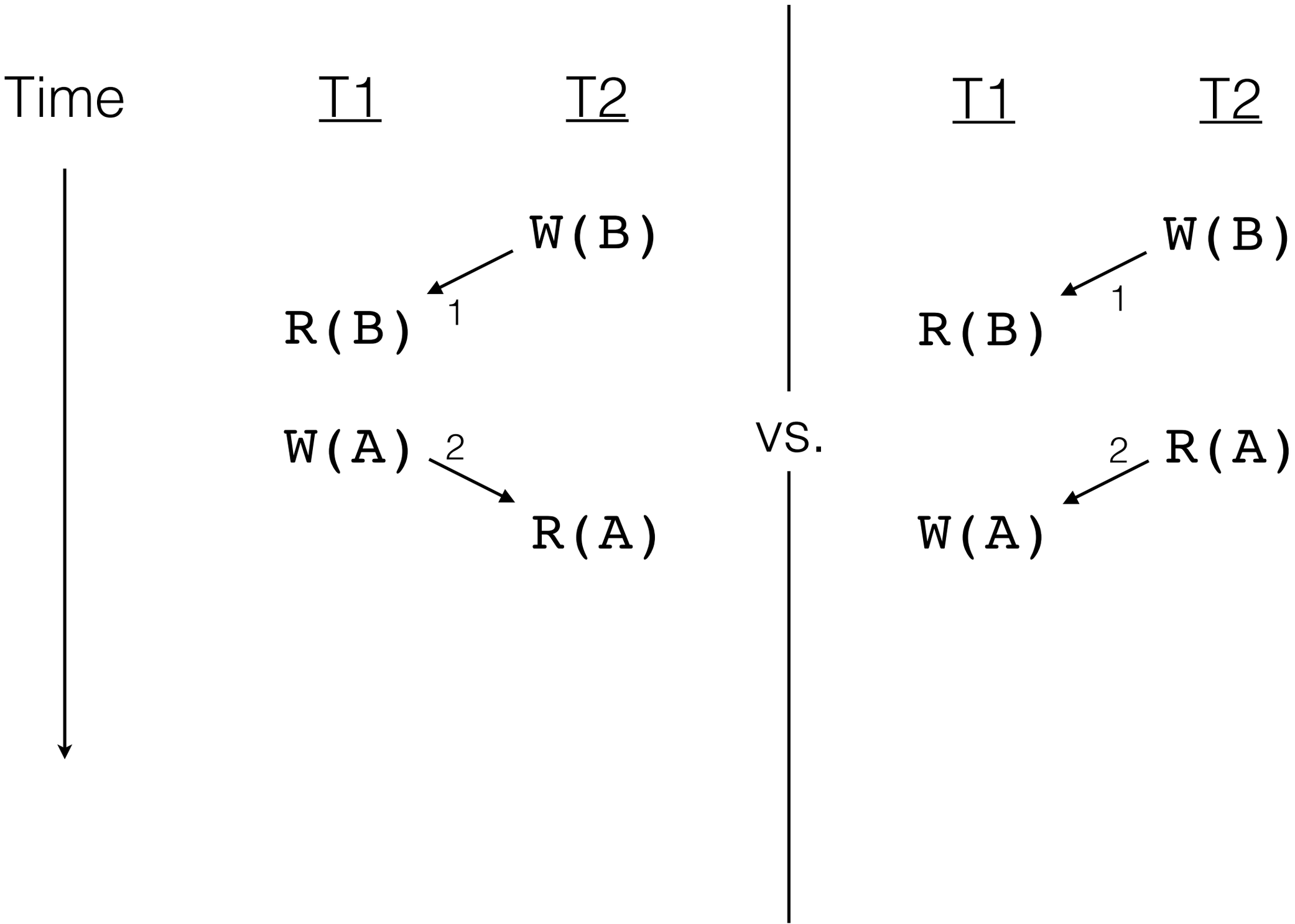

Time
T1
T2
W(B)
R(B)
W(A)
R(A)
VS.
T1
T2
W(B)
R(B)
R(A)
W(A)
1: T2 → T1
2: T1 → T2
≠
1: T2 → T1
2: T2 → T1

Example



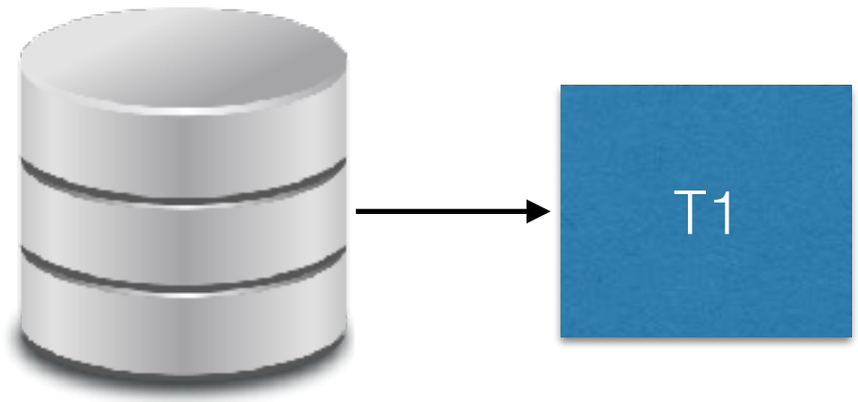
Equivalence

- Look at the actual effects
  - Can't determine effects without running
- Look at the conflicts
  - Too strict
- Look at the possible effects

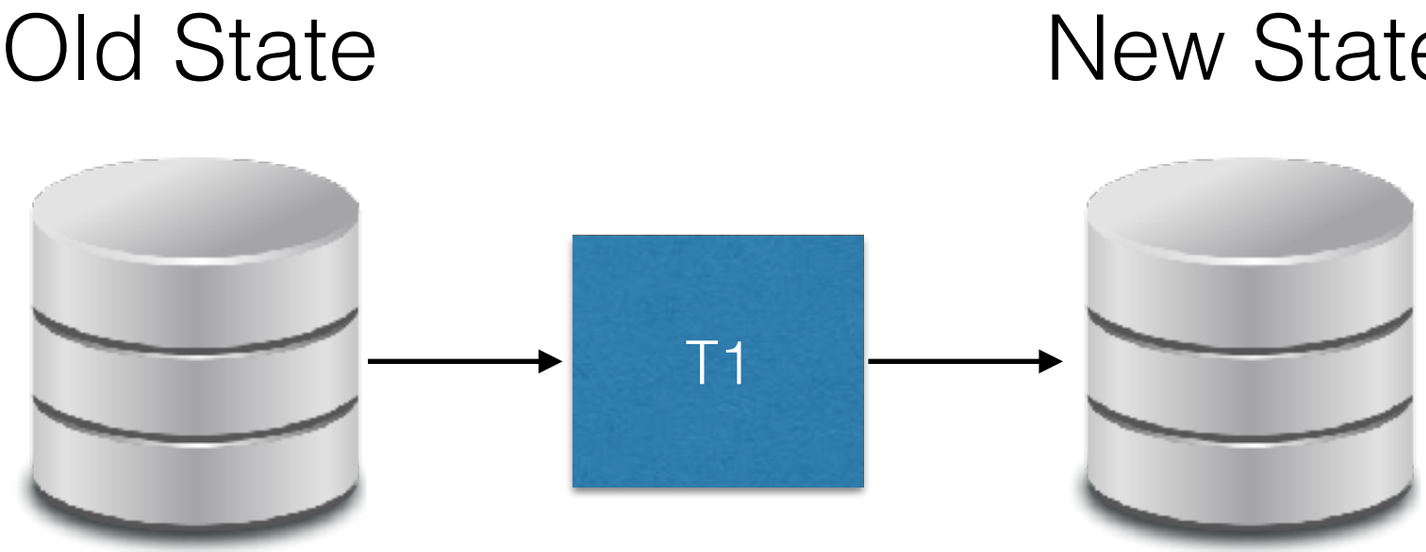
Information Flow

Information Flow

Old State



Information Flow



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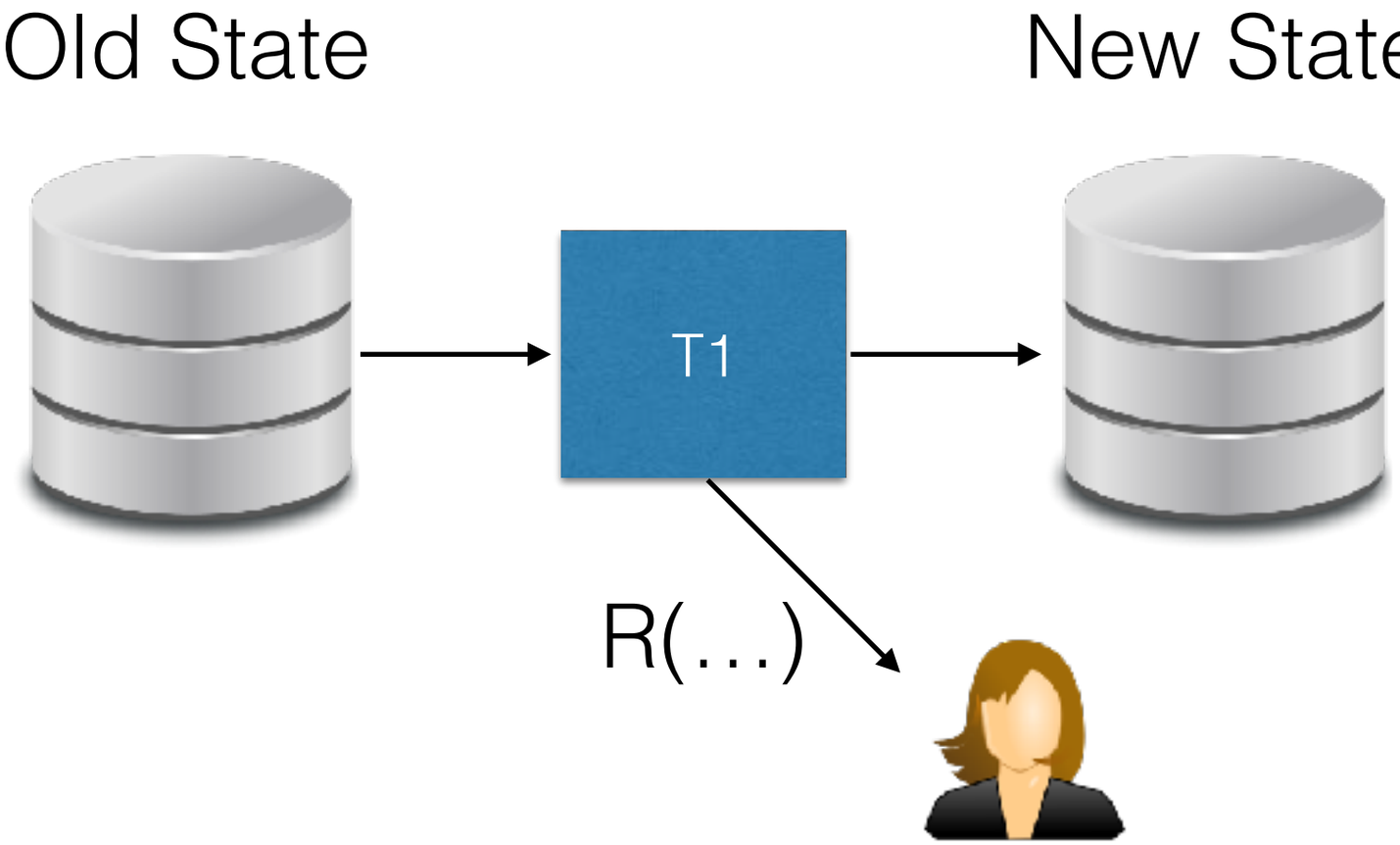

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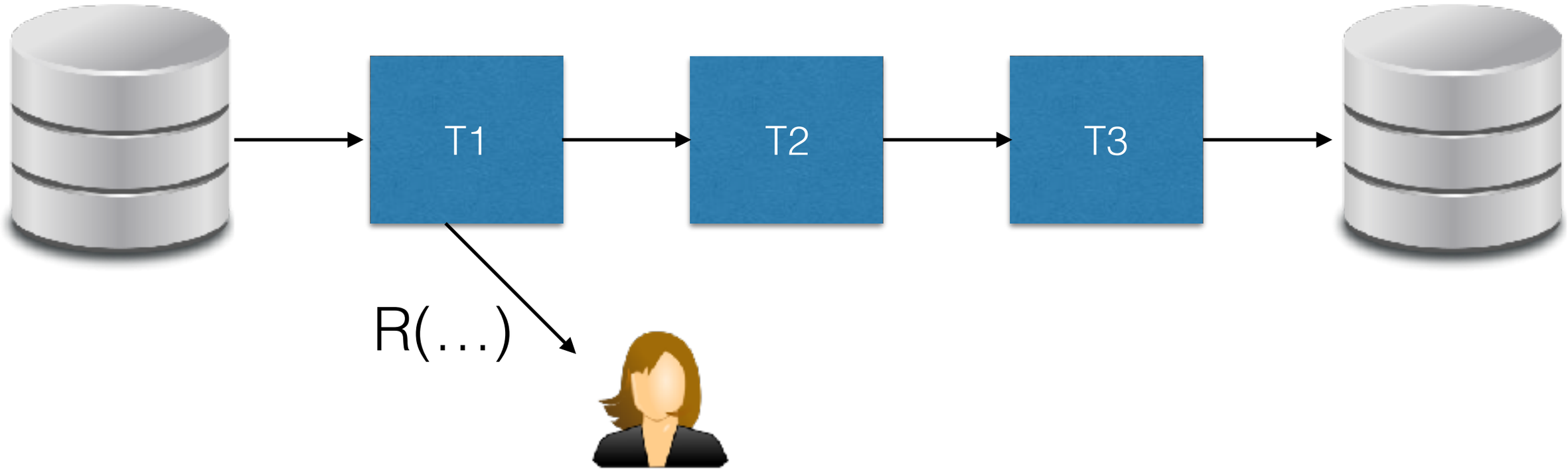

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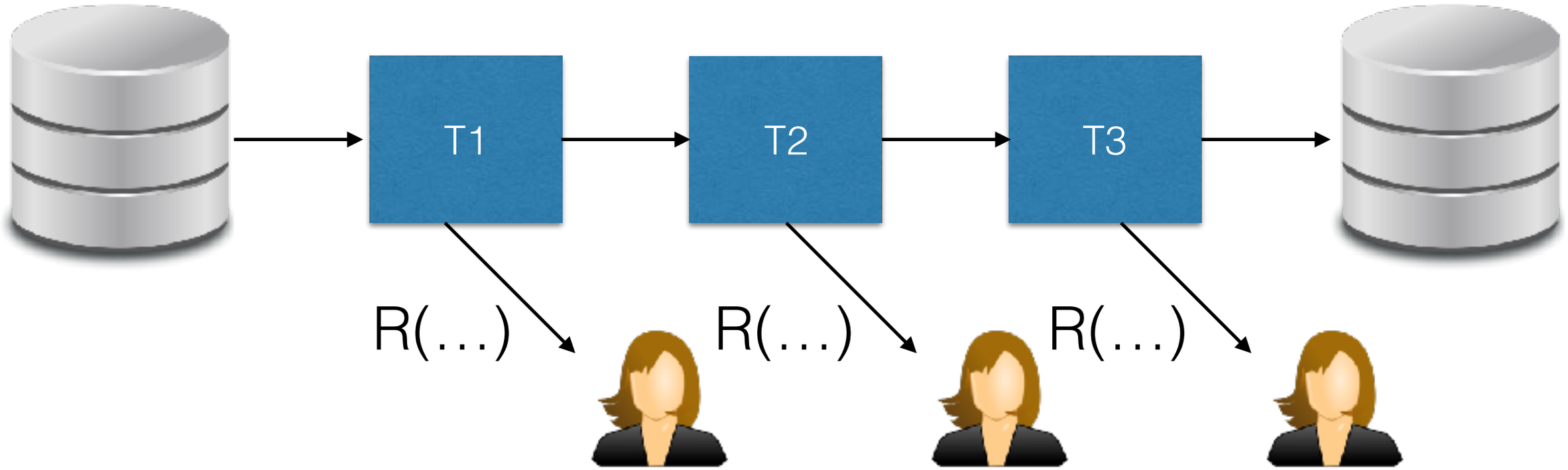

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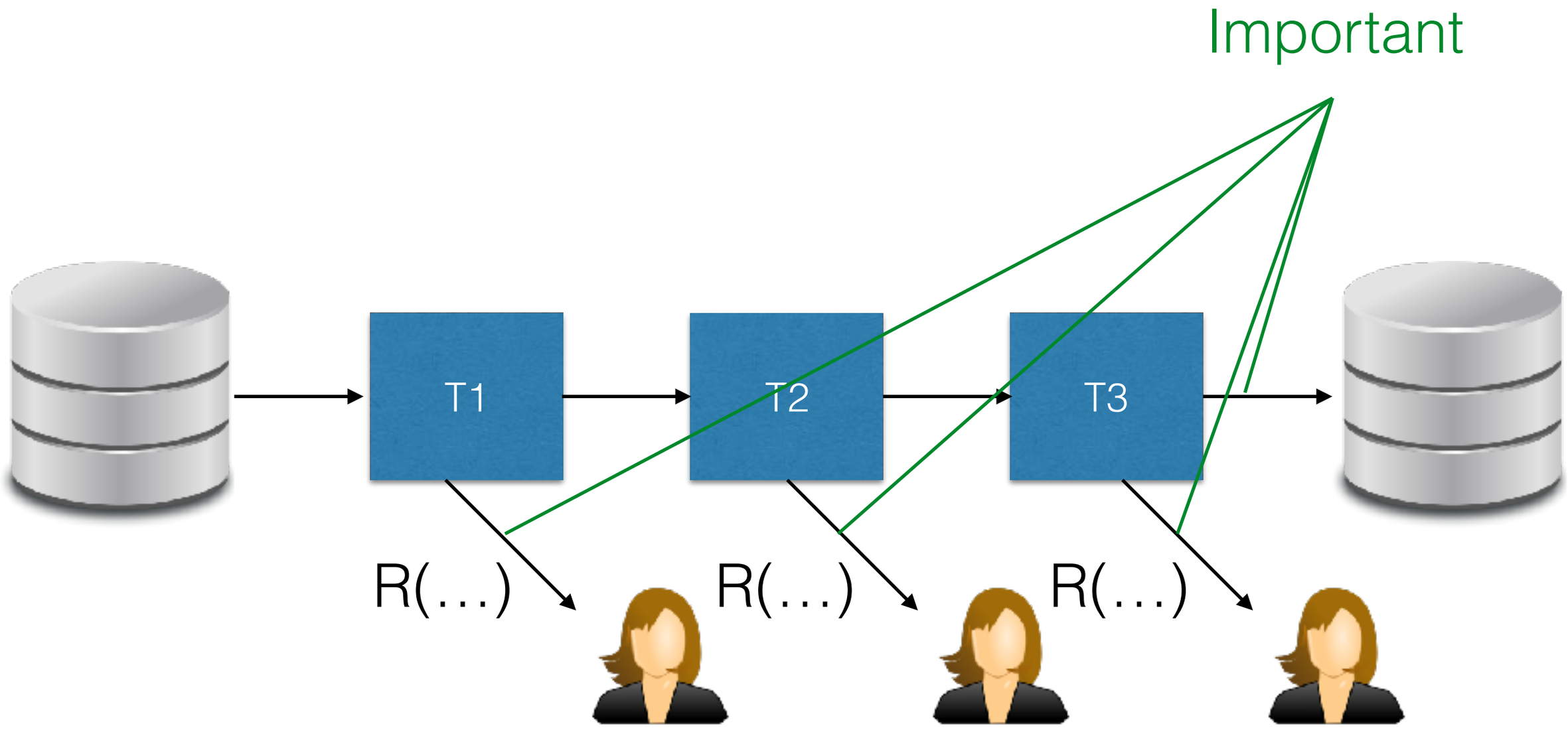

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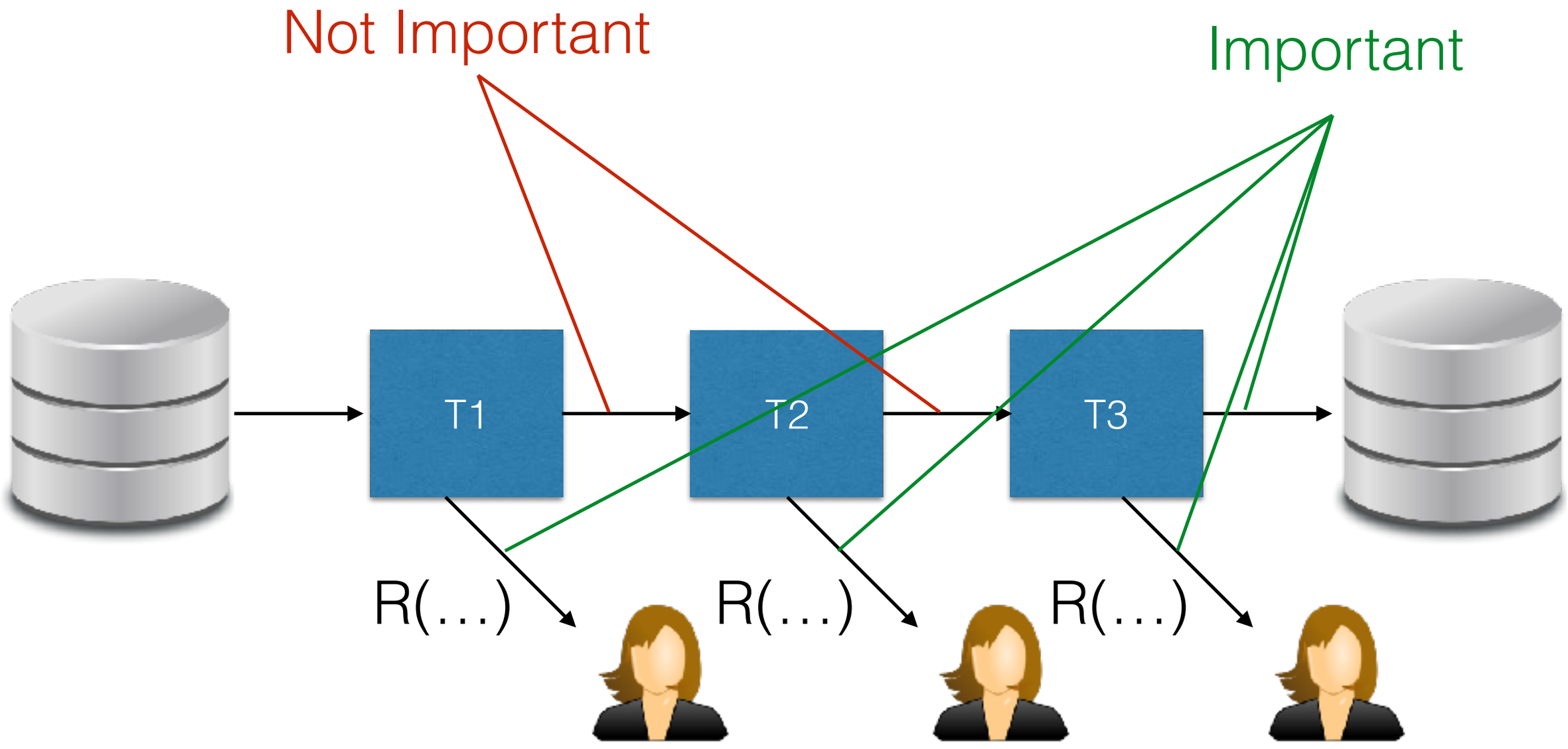

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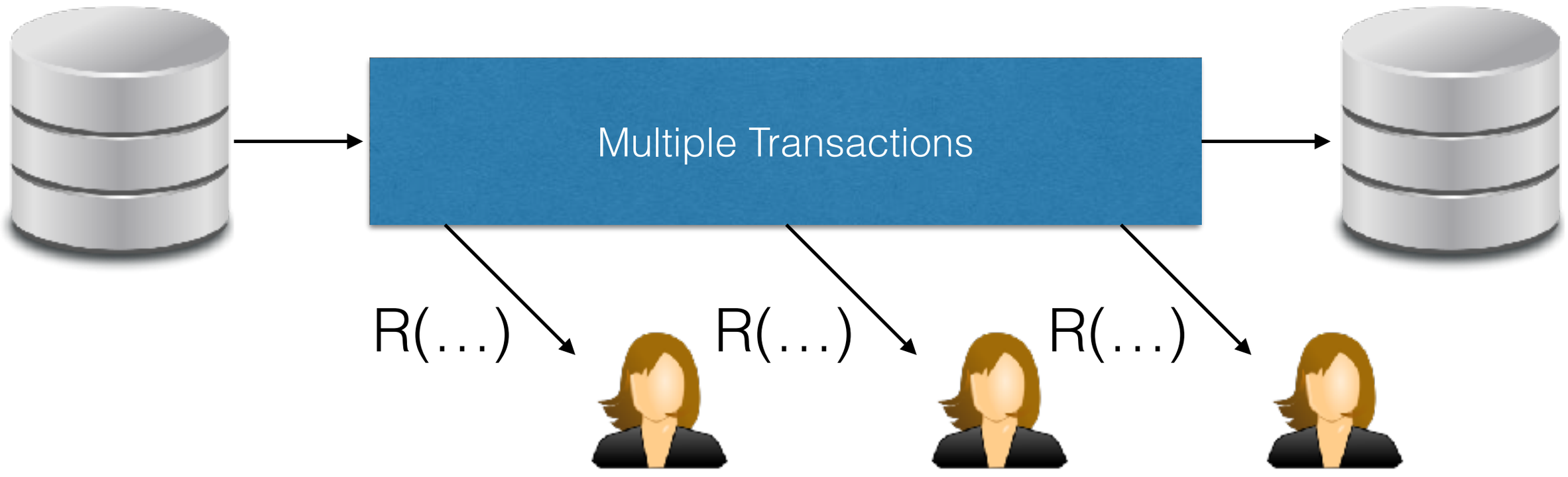


View Serializability

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.

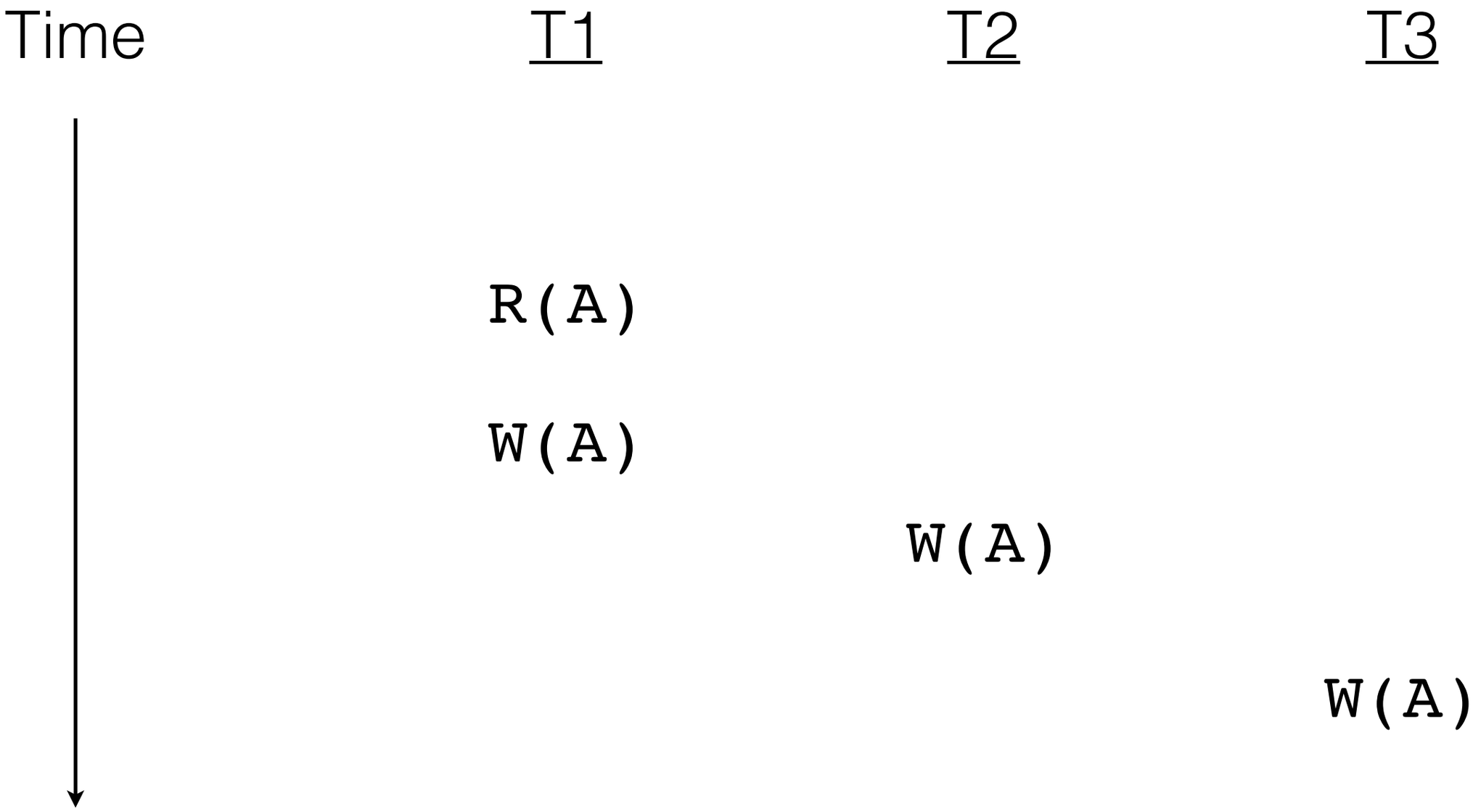
View Equivalence

- 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

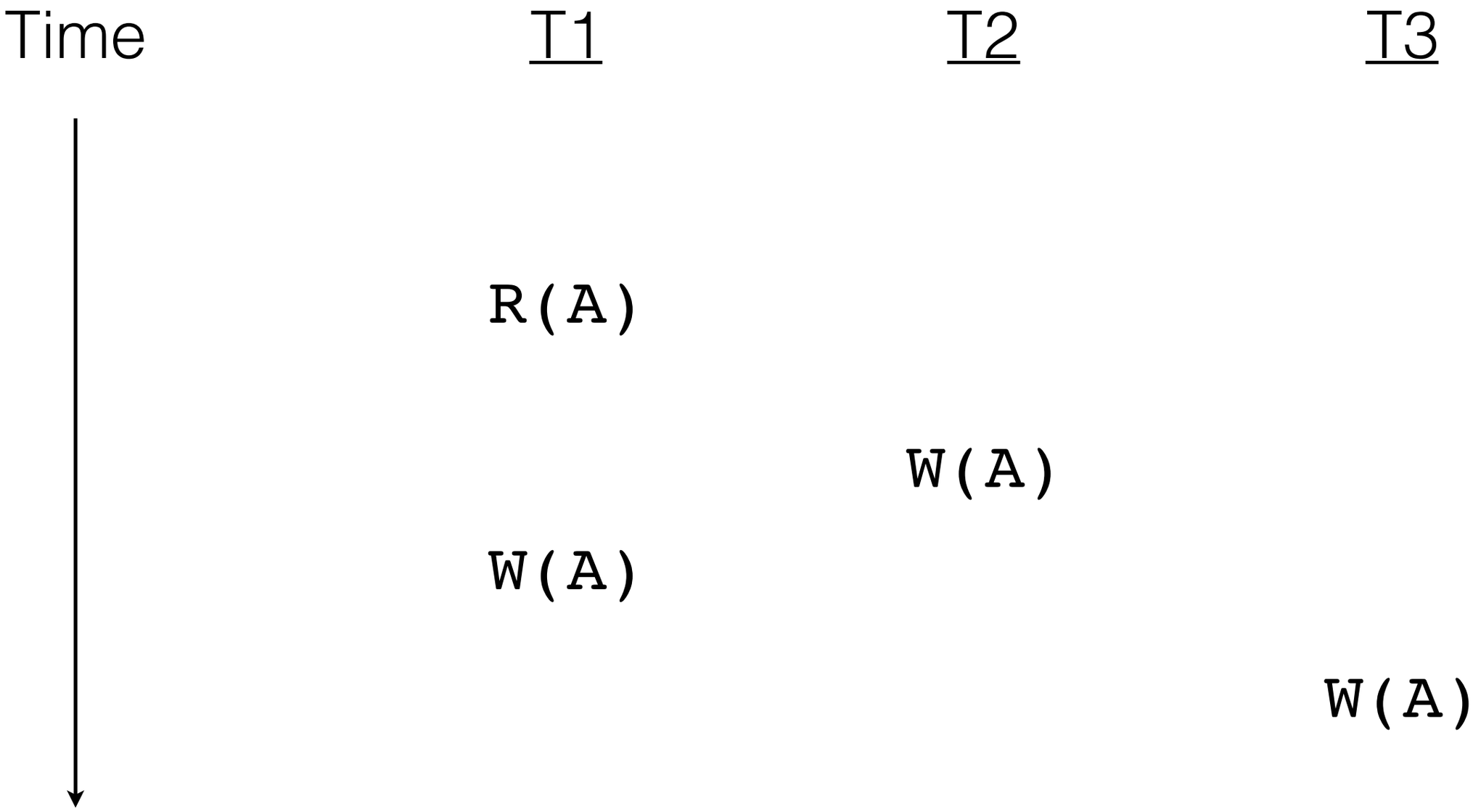
View Serializability

- **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



Example



Example

Time

T1

T2

T3

R(A)

W(A)

W(A)

Write order irrelevant
(T3 overwrites either way)

W(A)

Enforcing Serializability

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- Conflict Serializability:
  - Does locking enforce conflict serializability?

Enforcing Serializability

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- View Serializability
  - Is view serializability stronger, weaker, or incomparable to conflict serializability?

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?