# SQL – Transactions

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Based on Jennifer Widom slides

# Agenda

Introduction

Properties

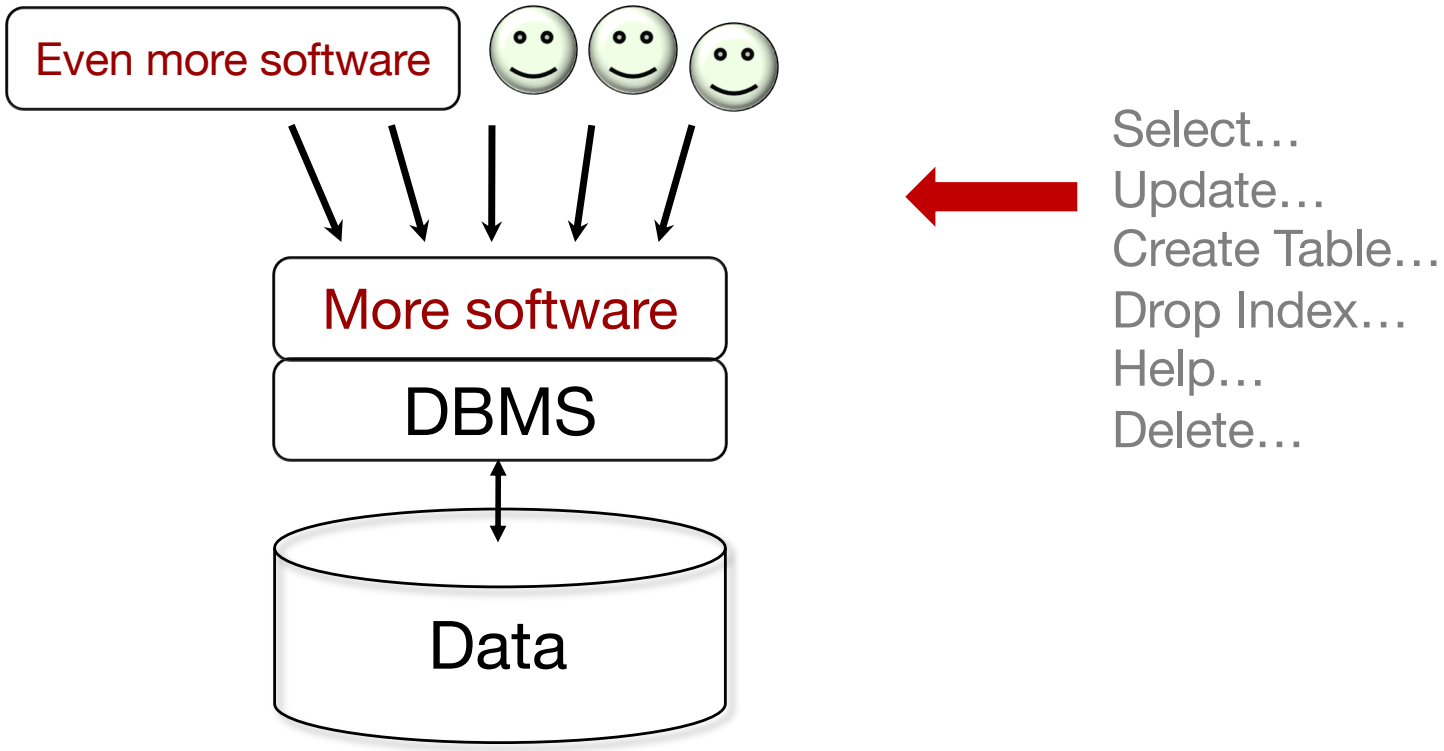
Isolation levels

# Motivation for transactions

Concurrent database access

Resilience to system failures

# Concurrent Database Access



# Attribute-level Inconsistency

Update College Set enr = enr + 1000 Where cName = ‘Stanford’

concurrent with …

Update College Set enr = enr + 1500 Where cName = ‘Stanford’

| | | |
|---|---|---|
| | | |
| | 15000 | |
| | | |
| | | |
| | | |

get; modify; put

15 000 + 2 500 = 17 500

15 000 + 1 000 = 16 000

15 000 + 1 500 = 16 500

# Tuple-level Inconsistency

Update Apply Set major = ‘CS’ Where sID = 123

concurrent with …

Update Apply Set dec = ‘Y’ Where sID = 123

| sID | major | dec |
|---|---|---|
| 123 | | |
| | | |
| | | |
| | | |

get; modify; put

both changes

One of the two changes

# Table-level Inconsistency

Update Apply Set decision = 'Y'

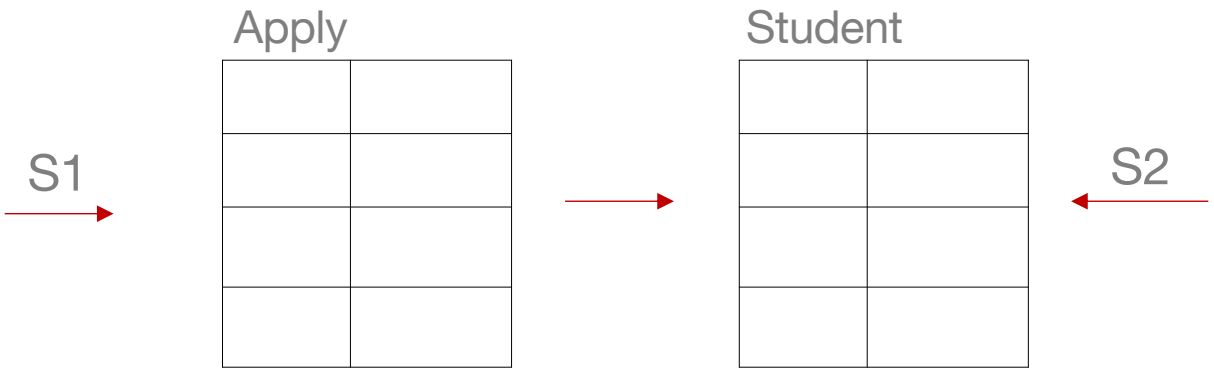
Where sID In (Select sID From Student Where GPA > 3.9)

S1

concurrent with …

Update Student Set GPA = (1.1) * GPA Where sizeHS > 2500

S2



# Multi-statement Inconsistency

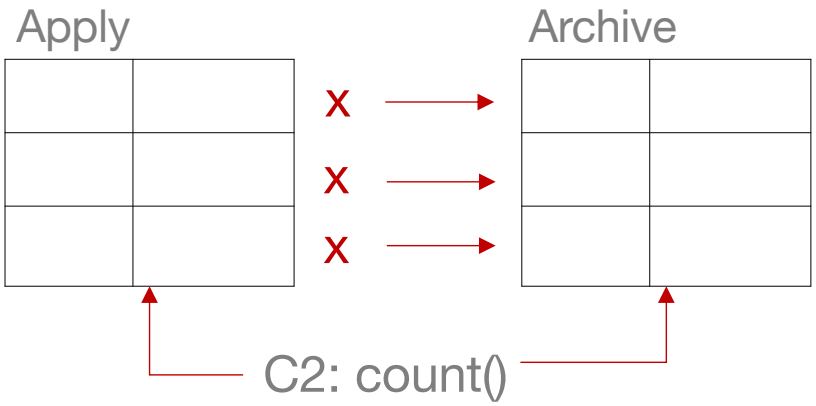
```
Insert Into Archive  Select * From Apply Where decision = 'N';
Delete From Apply Where decision = 'N';
```

C1

concurrent with …

```
Select Count(*) From Apply;
Select Count(*) From Archive;
```

C2



# Concurrency goal

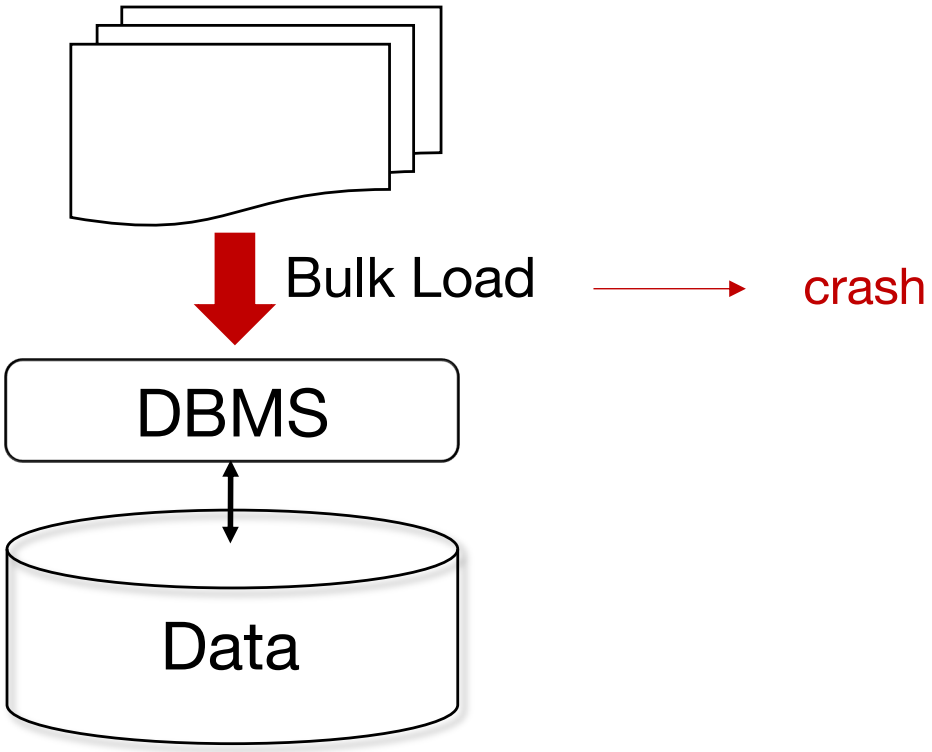
Execute sequence of SQL statements so they appear to be running in isolation

- Simple solution: execute them in isolation

But want to enable concurrency whenever safe to do so

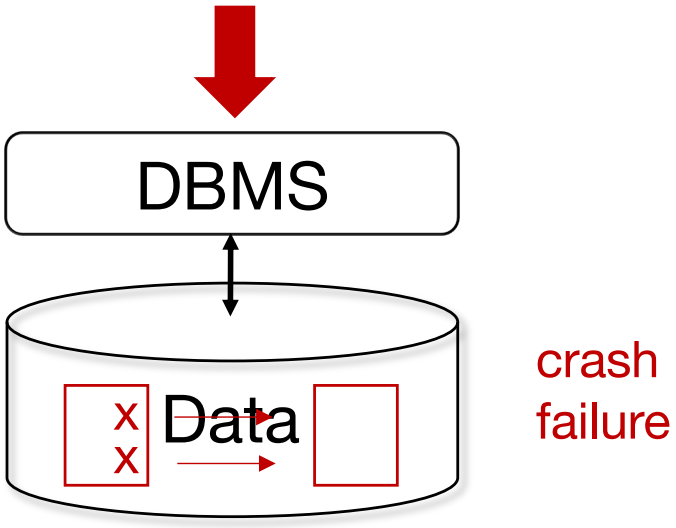
- Multiprocessor system
- Multithreaded system
- Asynchronous I/O

# Resilience to System Failures

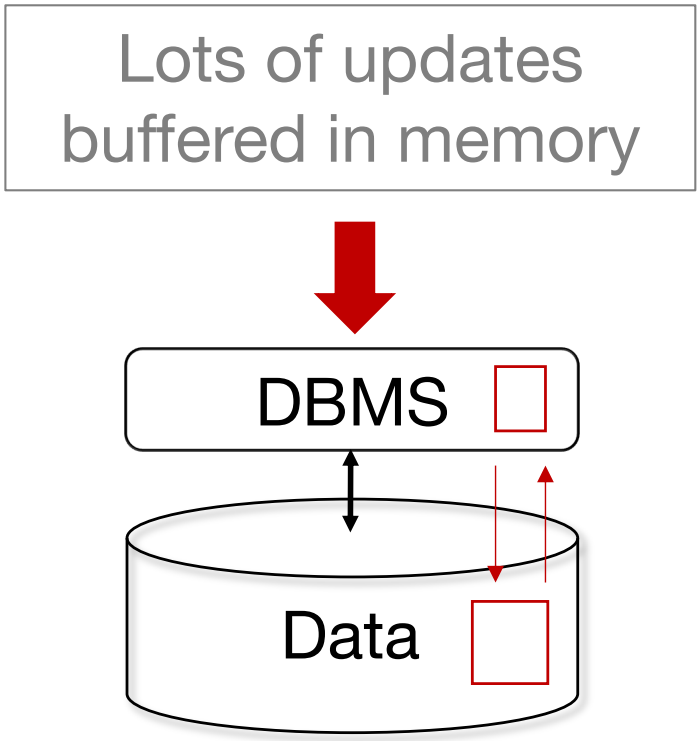


# Resilience to System Failures

```
Insert Into Archive
  Select * From Apply Where decision = 'N';
Delete From Apply Where decision = 'N';
```

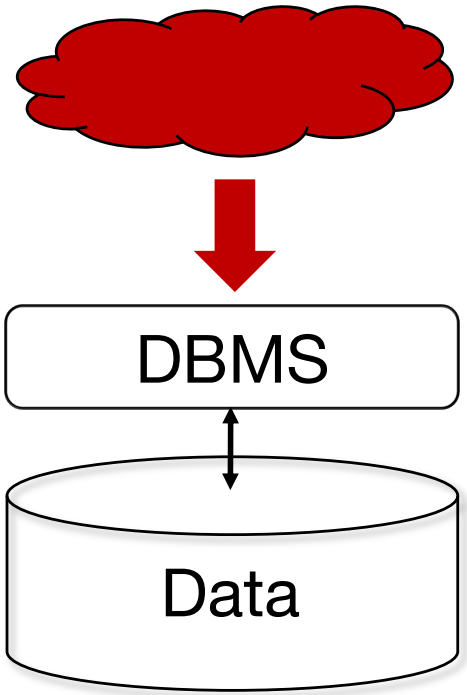


# Resilience to System Failures



# System-Failure Goal

Guarantee all-or-nothing execution, regardless of failures



# Transactions

Solution for both concurrency and failures

A transaction is a sequence of one or more SQL operations treated as a unit

- Transactions appear to run in isolation
- If the system fails, each transaction's changes are reflected either entirely or not at all

# Transactions: SQL standard

Transaction begins automatically on first SQL statement

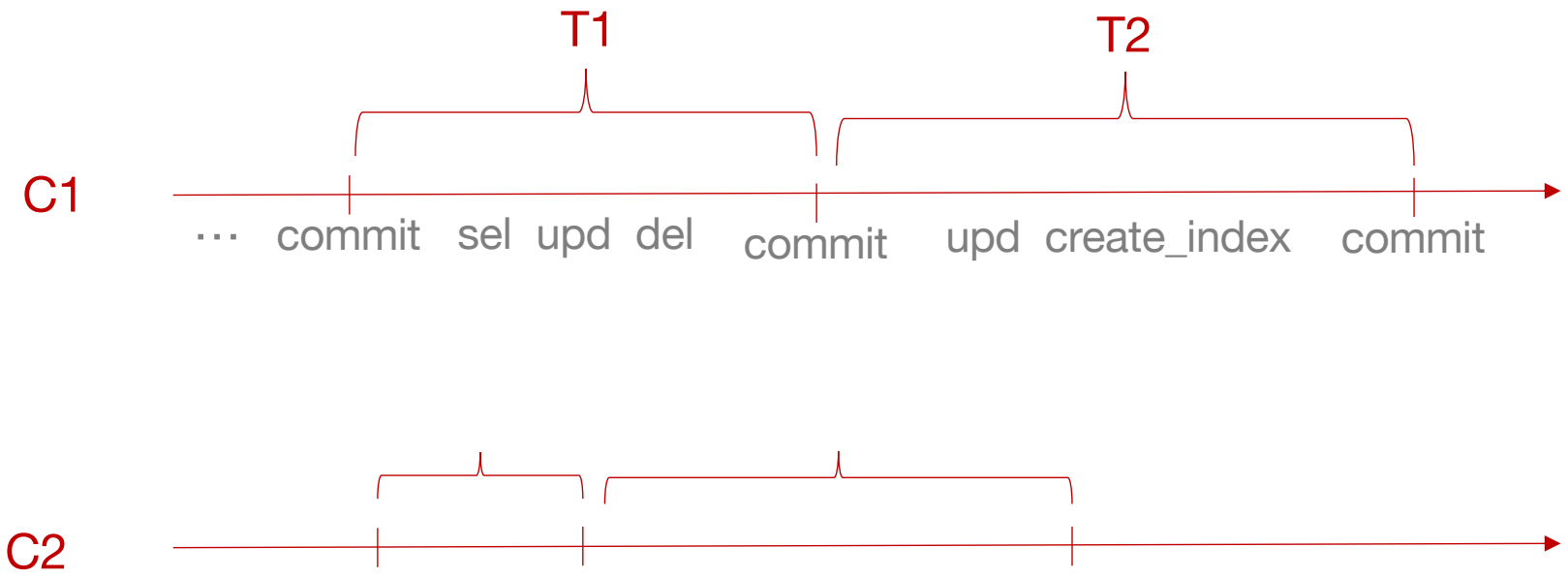
On “commit” transaction ends and new one begins

Current transaction ends on session termination

“Autocommit” turns each statement into transaction

# Transactions

A transaction is a sequence of one or more SQL operations treated as a unit



# Agenda

~~Introduction~~

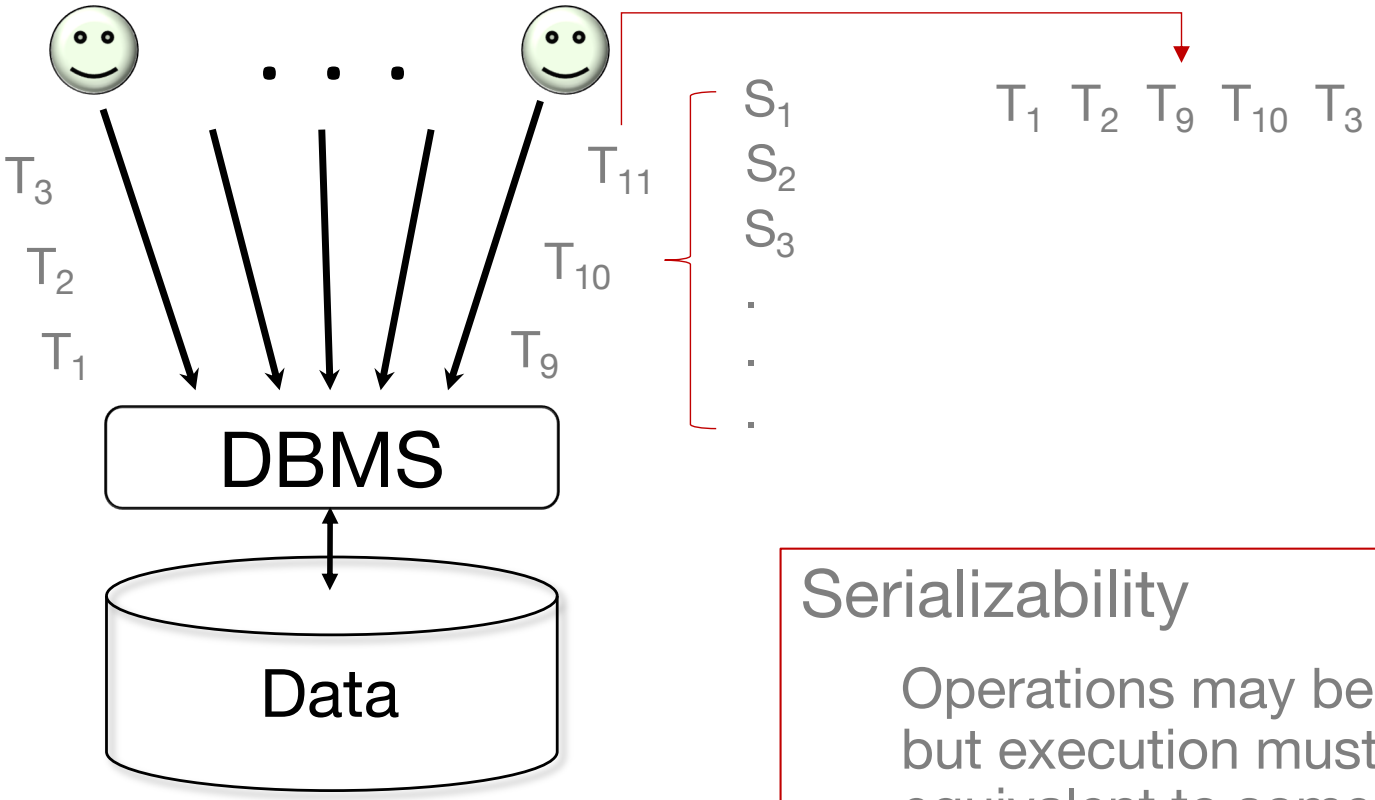
Properties

Isolation levels

# ACID Properties

| | |
|---|---|
| Atomicity | 3 |
| Consistency | 4 |
| Isolation | 1 |
| Durability | 2 |

# ACID Properties: Isolation




## Serializability

Operations may be interleaved, but execution must be equivalent to some sequential (serial) order of all transactions

# Attribute-level Inconsistency

Update College Set enr = enr + 1000 Where cName = ‘Stanford’ $T_1$

concurrent with …

Update College Set enr = enr + 1500 Where cName = ‘Stanford’ $T_2$

If serializability is guaranteed

$T_1$; $T_2$
$T_2$; $T_1$ ⟶ 15 000 → 17 500

# Tuple-level Inconsistency

Update Apply Set major = ‘CS’ Where sID = 123 $T_1$

concurrent with …

Update Apply Set dec = ‘Y’ Where sID = 123 $T_2$

If serializability is guaranteed

$T_1$; $T_2$
$T_2$; $T_1$ → Both changes

# Table-level Inconsistency

Update Apply Set decision = 'Y'

Where sID In (Select sID From Student Where GPA > 3.9)

$T_1$

concurrent with …

Update Student Set GPA = (1.1) * GPA Where sizeHS > 2500

$T_2$

If serializability is guaranteed

$T_1$; $T_2$

$T_2$; $T_1$

→ Order matters →

DBMS don't guarantee the exact sequential order if the transactions are being issued at the same time

# Multi-statement Inconsistency

```
Insert Into Archive  Select * From Apply Where decision = 'N';
Delete From Apply Where decision = 'N';
```

$T_1$

concurrent with …

```
Select Count(*) From Apply;
Select Count(*) From Archive;
```

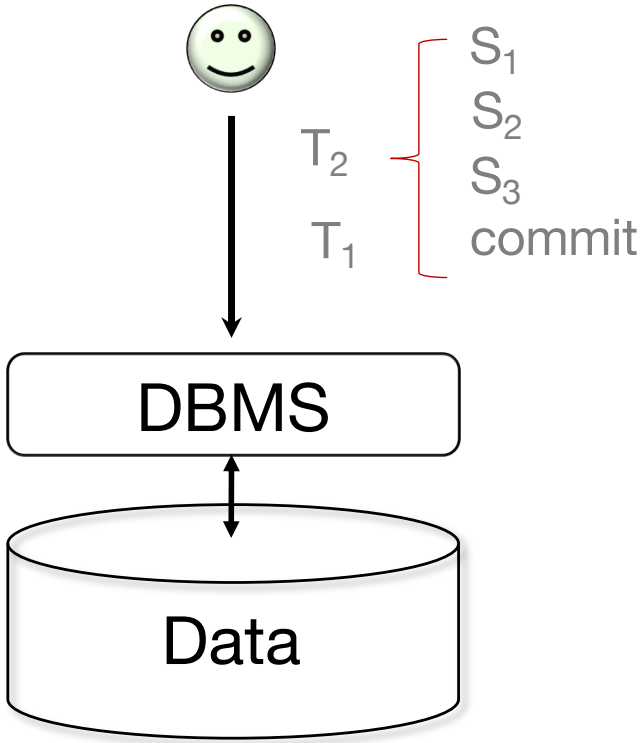
$T_2$

If serializability is guaranteed

$T_1$; $T_2$
$T_2$; $T_1$ → Order matters

# ACID Properties: Durability

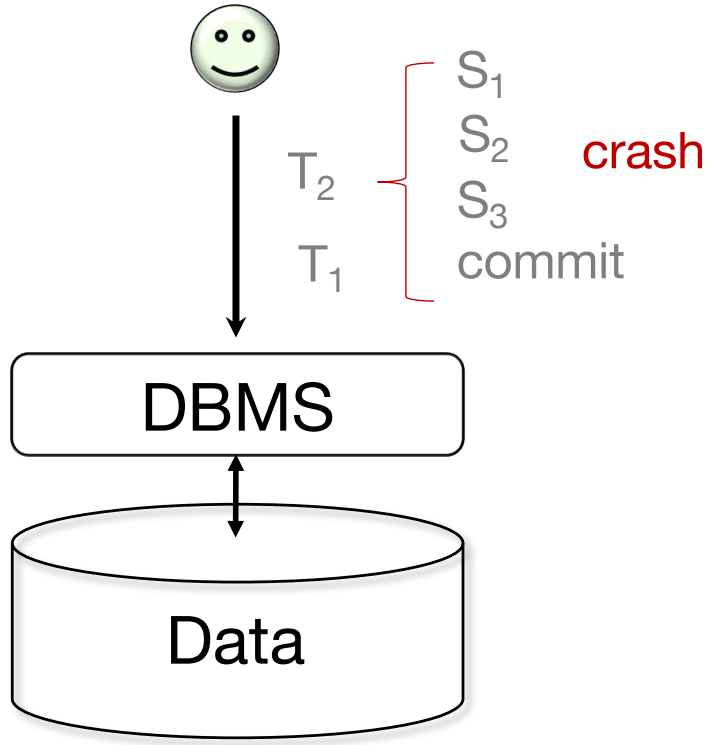
If system crashes after transaction commits, all effects of transaction remain in database



# ACID Properties: Atomicity

Each transaction is “all-or-nothing”, never left half done

Using a logging mechanism, partial effects of transactions at the time of crash are undone



# Transaction Rollback (= Abort)

Undoes partial effects of transaction

Can be system- or client-initiated

```
Begin Transaction;
<get input from user>
SQL commands based on input
<confirm results with user>
If ans='ok' Then Commit; Else Rollback;
```

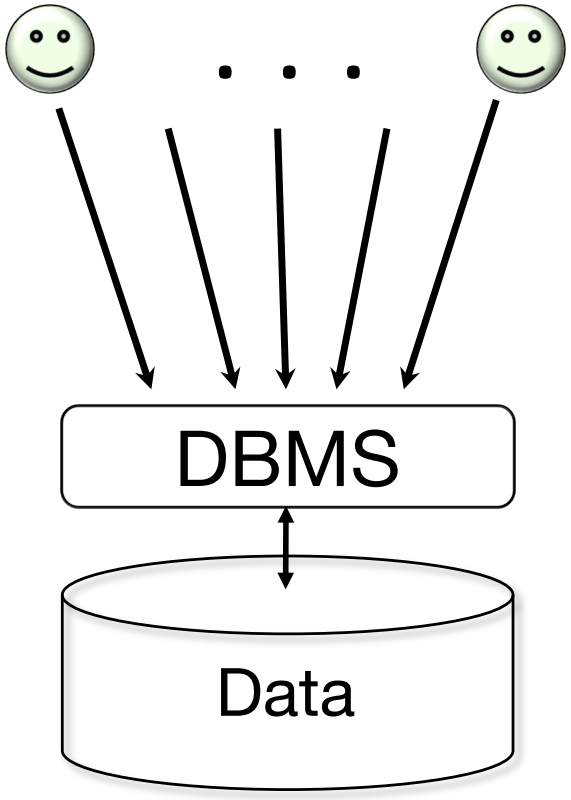
→ Transactions should be constructed to run quickly

→ Not wait arbitrary amounts of time

→ Locking

Only undoes effects on the data itself

# ACID Properties: Consistency




## Each client, each transaction:

- Can assume all constraints hold when transaction begins
- Must guarantee all constraints hold when transaction ends

## Serializability

- Constraints always hold

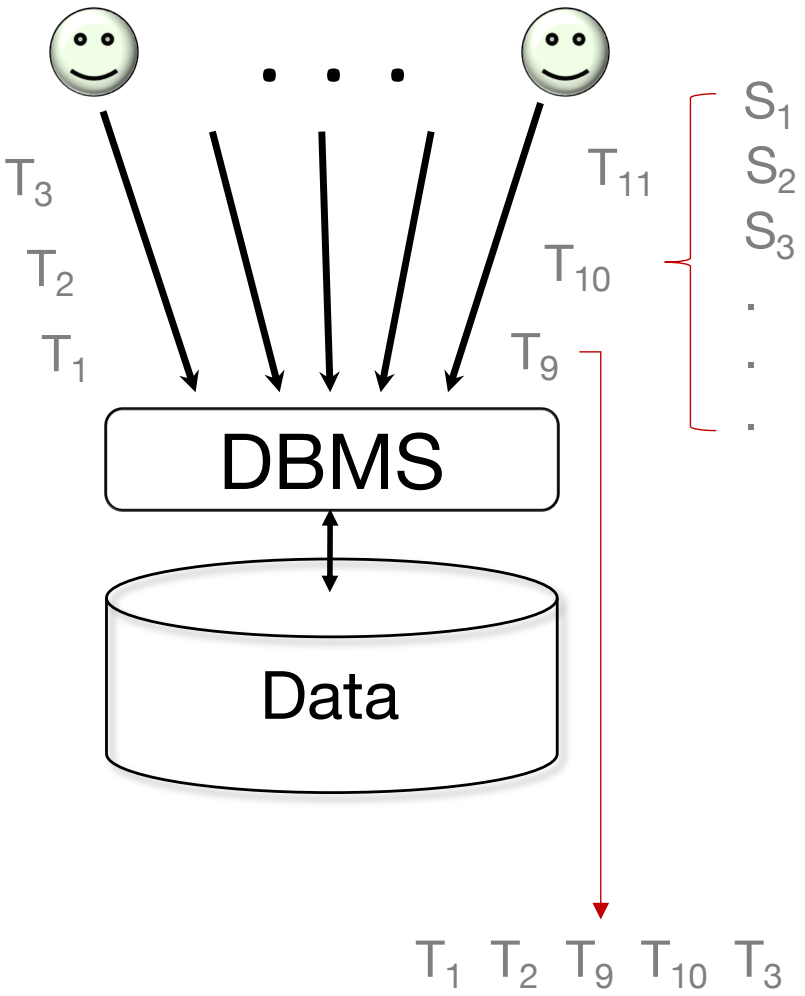
# Agenda

~~Introduction~~

~~Properties~~

Isolation levels

# ACID Properties: Isolation




## Serializability

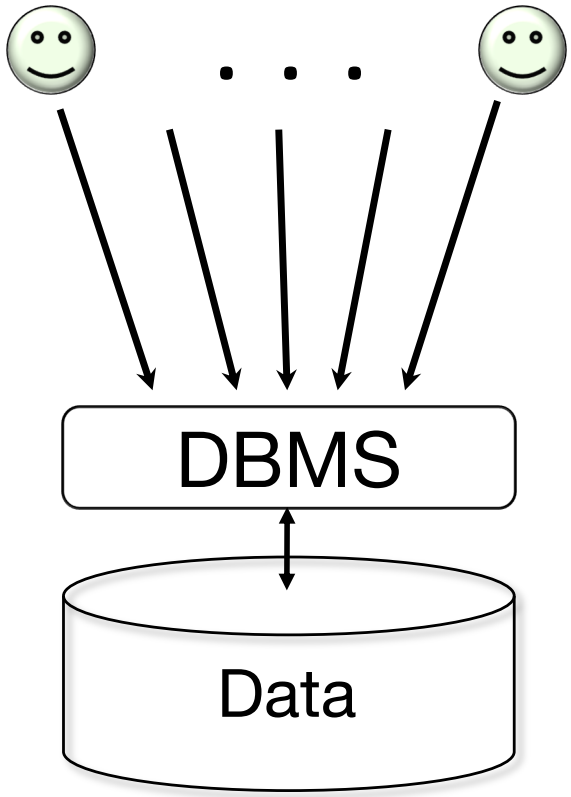
Operations may be interleaved, but execution must be equivalent to some sequential (serial) order of all transactions

## Disadvantages

Overhead in locking

Reduction in concurrency

# ACID Properties: Isolation




Weaker “Isolation Levels”

Read Uncommitted

Read Committed

Repeatable Read

Serializable

Weak
↓
Strong

↓Overhead in locking

↑Concurrency

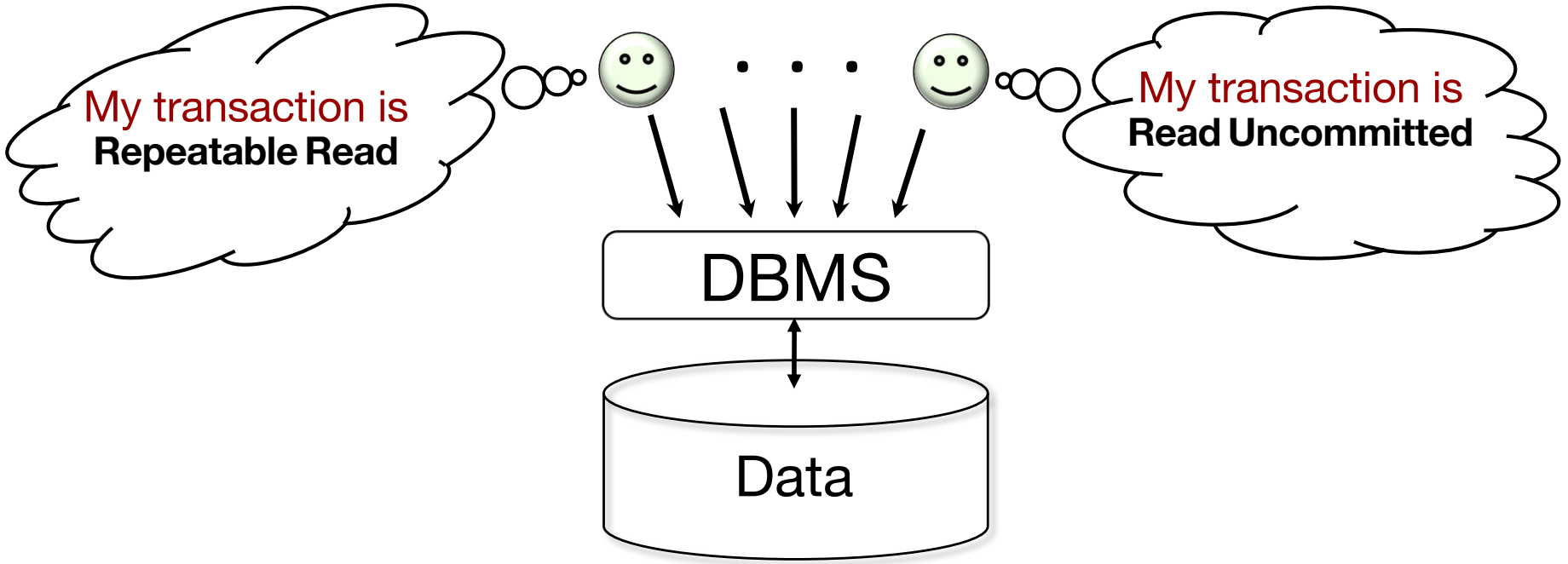
↓Consistency Guarantees

# Isolation Levels

Per transaction

It does not affect the behaviour of any other transaction

Specific to Reads



# Dirty Reads

"Dirty" data item: written by an uncommitted transaction

```
Update College Set enr = enr + 1000 Where cName = 'Stanford'
```

$T_1$

concurrent with …

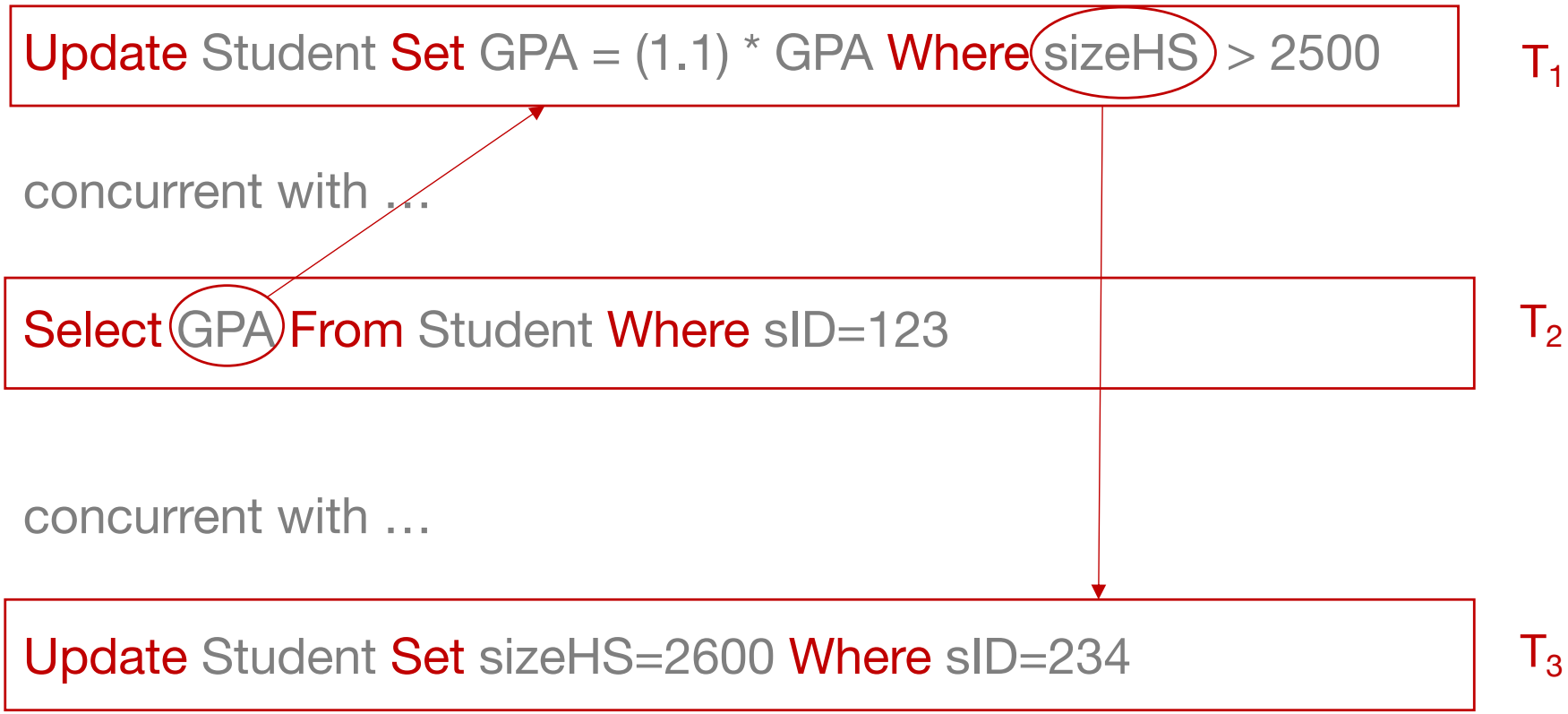
```
Select avg(enr) From College
```

$T_2$

If read before T1 commits, this value is known as dirty

Assume there is a commit at the end of each box

# Dirty Reads – Example 2




Where can we have dirty data items?

There are no dirty reads within the same transaction

# Read Uncommitted

A transaction may perform dirty reads

```
Update Student Set GPA = (1.1) * GPA Where sizeHS  > 2500
```

$T_1$

concurrent with …

```
Select avg(GPA) From Student
```

$T_2$

If transactions are serializable

T1; T2 or

T2; T1

# Read Uncommitted

```
Update Student Set GPA = (1.1) * GPA Where sizeHS  > 2500
```

$T_1$

concurrent with …

```
Set Transaction Isolation Level Read Uncommitted;
Select avg(GPA) From Student;
```

$T_2$

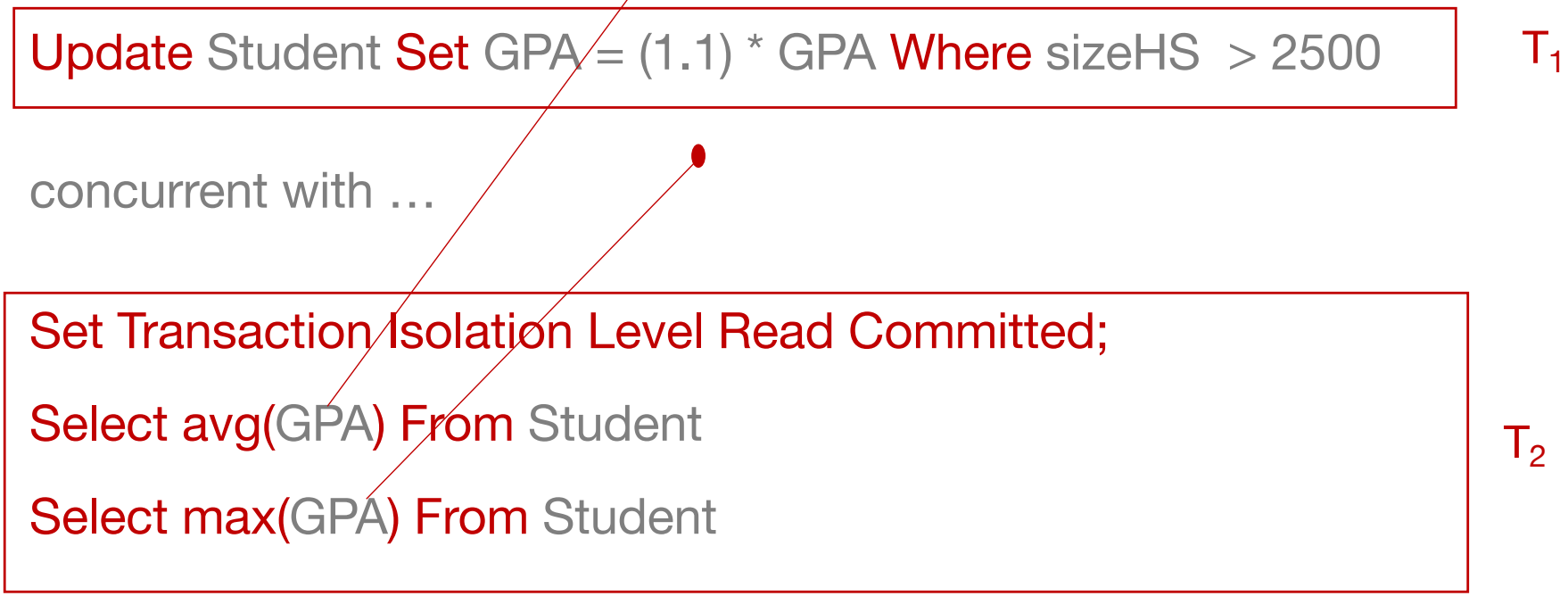
We don’t have serializable behaviour

We might don’t care that much about consistency

# Read Committed

A transaction may **not** perform dirty reads

Still does not guarantee global serializability

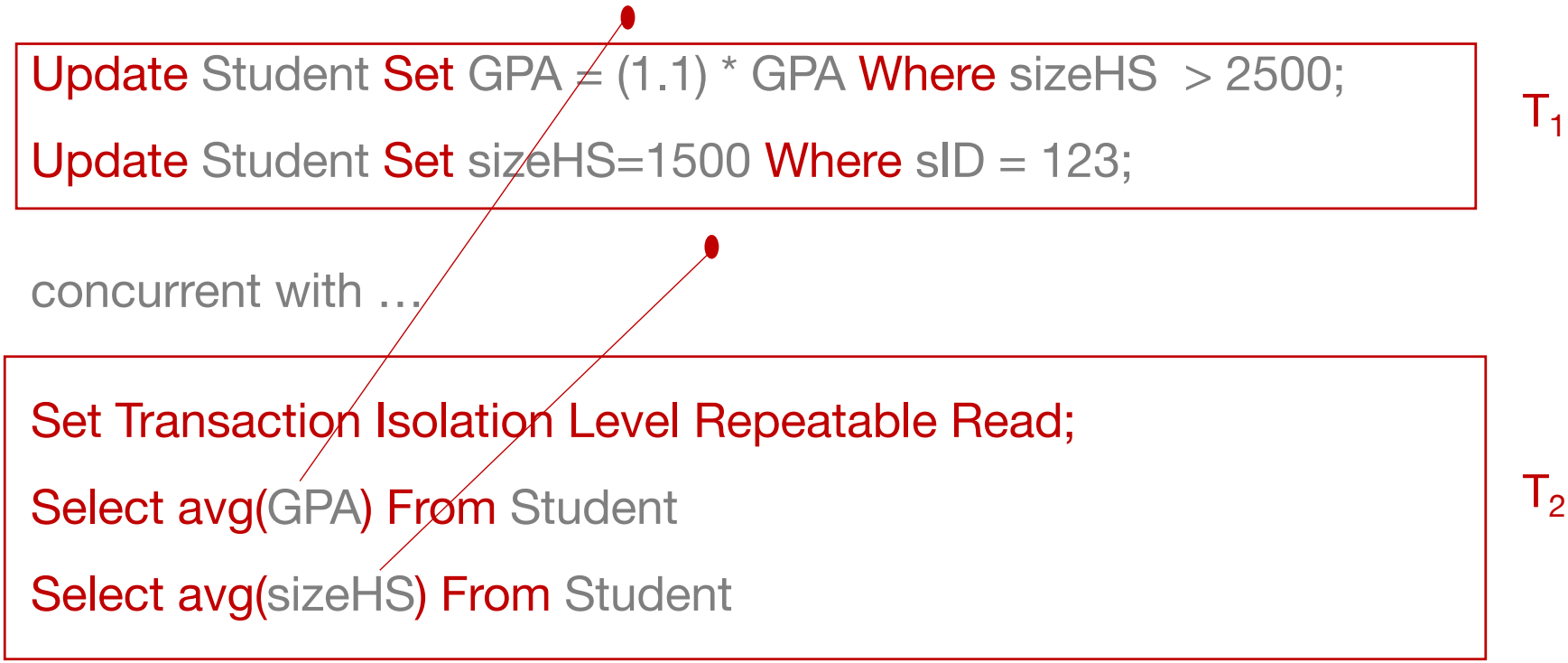


# Repeatable Read

A transaction may **not** perform dirty reads

An item read multiple times cannot change value

Still does not guarantee global serializability

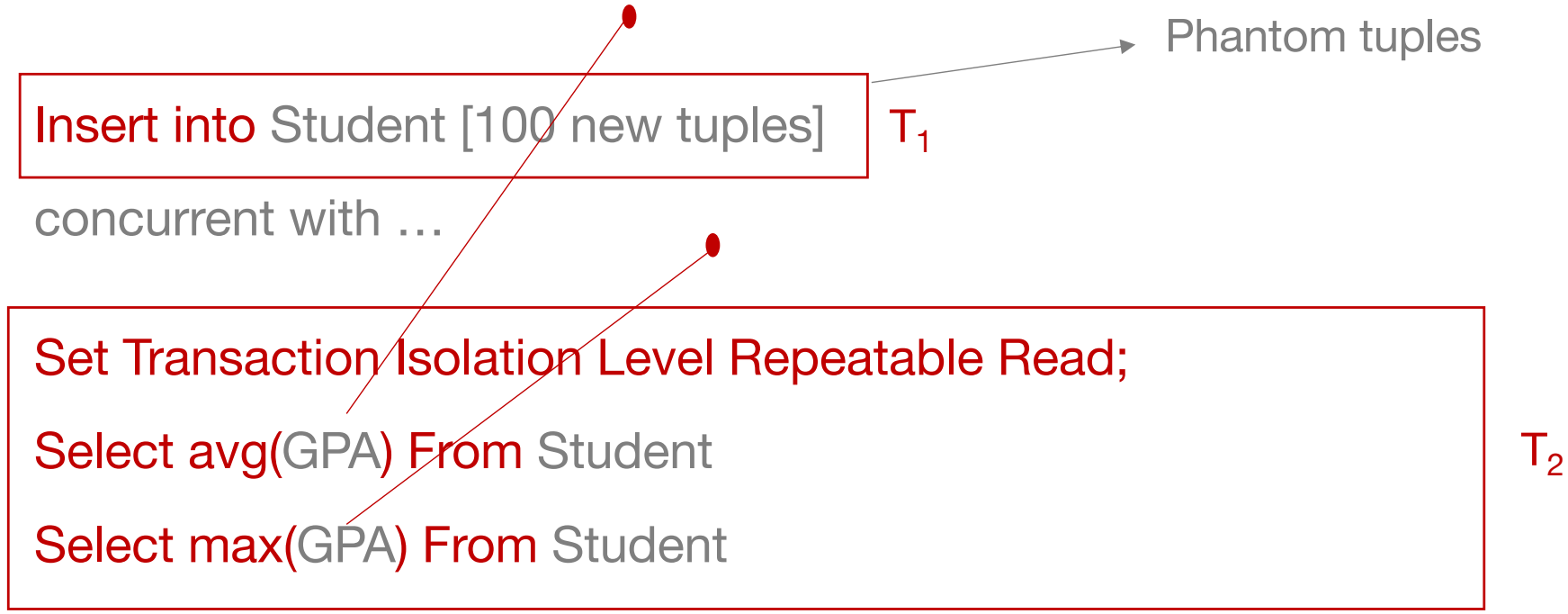


# Repeatable Read

A transaction may **not** perform dirty reads

An item read multiple times cannot change value

But a relation *can* change: “phantom” tuples



# Repeatable Read

A transaction may **not** perform dirty reads

An item read multiple times cannot change value

But a relation *can* change: “phantom” tuples

```
Delete from Student [100 new tuples]
```

$T_1$

concurrent with …

```
Set Transaction Isolation Level Repeatable Read;
Select avg(GPA) From Student
Select max(GPA) From Student
```

$T_2$

Once read, values get locked and deletion is not possible in the middle of $T_2$

# Read Only Transactions

Helps system optimize performance

Independent of isolation level

Not going to perform modifications to the database within the transaction

```
Set Transaction Read Only;
Set Transaction Isolation Level Repeatable Read;
Select avg(GPA) From Student
Select max(GPA) From Student
```

# Isolation Levels: Summary

weak

| | dirty reads | nonrepeatable reads | phantoms |
|---|---|---|---|
| Read Uncommitted | Y | Y | Y |
| Read Committed | N | Y | Y |
| Repeatable Read | N | N | Y |
| Serializable | N | N | N |

strong

# Isolation Levels: Summary

Standard default: Serializable

Weaker isolation levels

- Increased concurrency + decreased overhead = increased performance
- Weaker consistency guarantees
- Some systems have default Repeatable Read

Isolation level per transaction

- Each transaction’s reads must conform to its isolation level

# Kahoot time!

Any doubts?

# Readings

Jeffrey Ullman, Jennifer Widom, A first course in Database Systems 3rd Edition

Section 6.6 – Transactions in SQL