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Transaction Management and Concurrency Control

Agenda

- What are database transactions?
- What are the ACID properties of a transaction?
- How to write transaction-safe SQL code.
- What is concurrency control, and how is it related to transactions?
- Understand advanced concurrency issues like versioning, locking, and deadlocks.

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Transaction Management and Concurrency Control

The End

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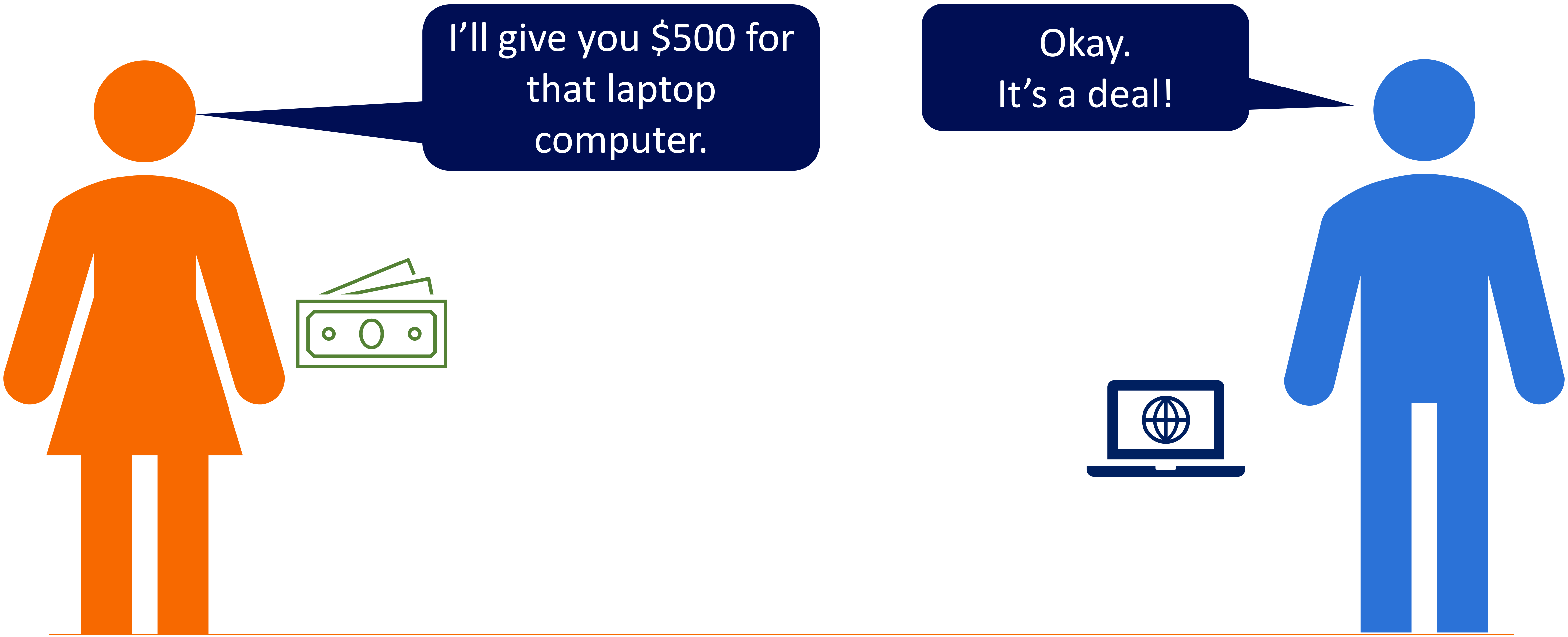
What Are Transactions?

Transaction

- Any logical unit of work in your database management system, read, write, or combination thereof
- It is data logic
- Typically consists of several read/write operations
- Must succeed or fail as a whole
- Operates independently from other units of work
- Doesn’t know about anything other than itself

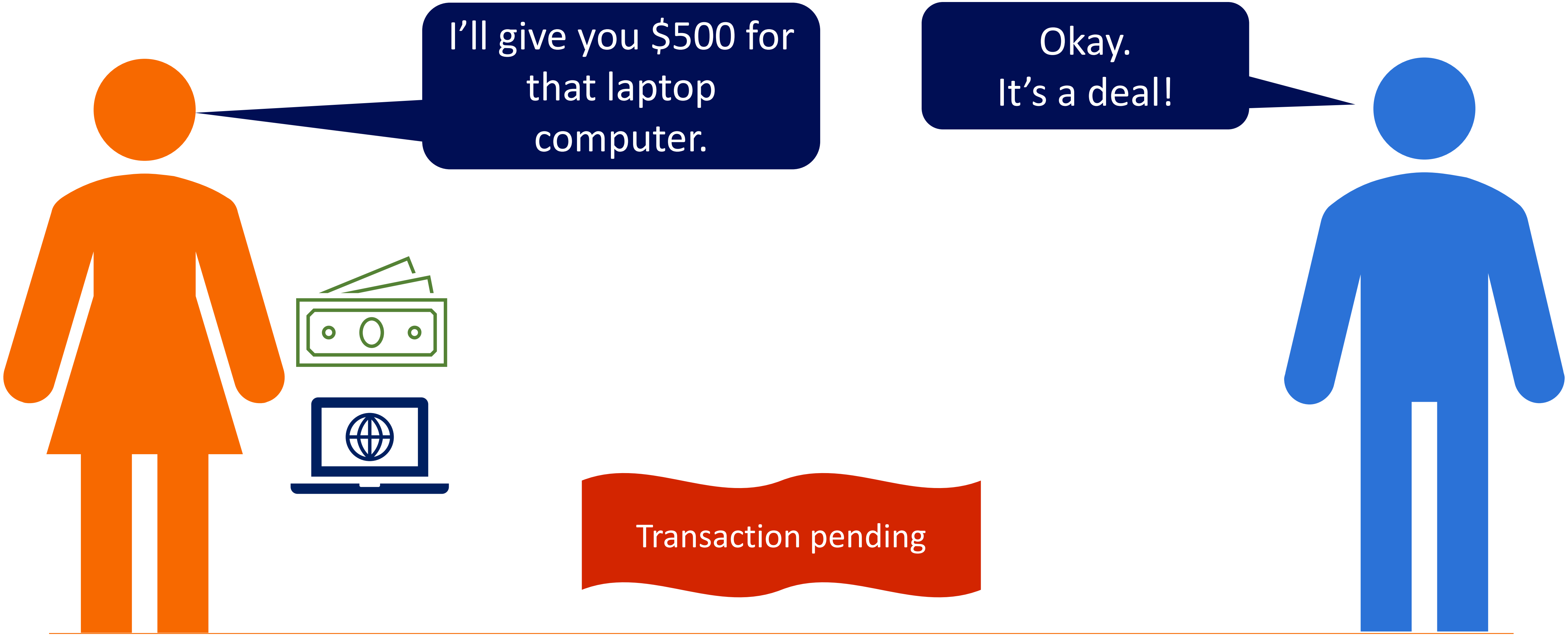
Real-Life Example



I'll give you $500 for that laptop computer.

Okay.
It's a deal!

Real-Life Example

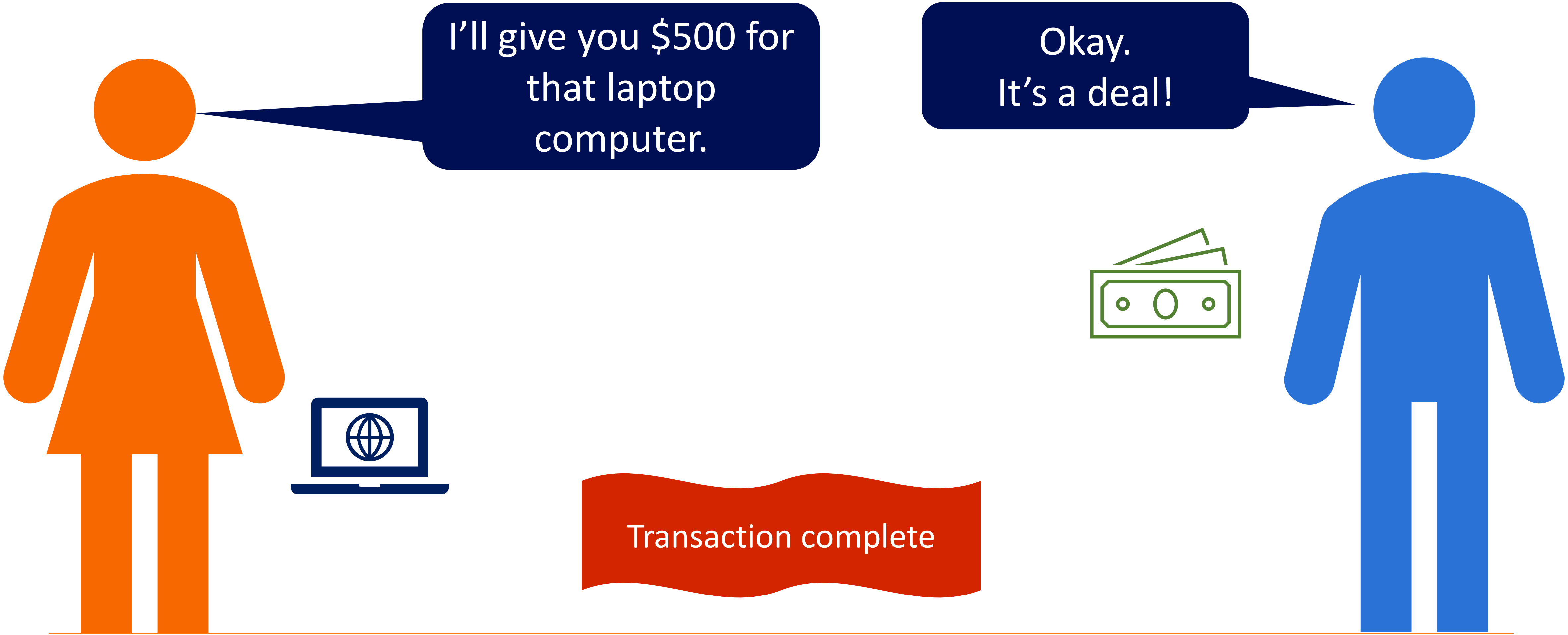


I’ll give you $500 for that laptop computer.

Okay.
It’s a deal!

Transaction pending

Real-Life Example

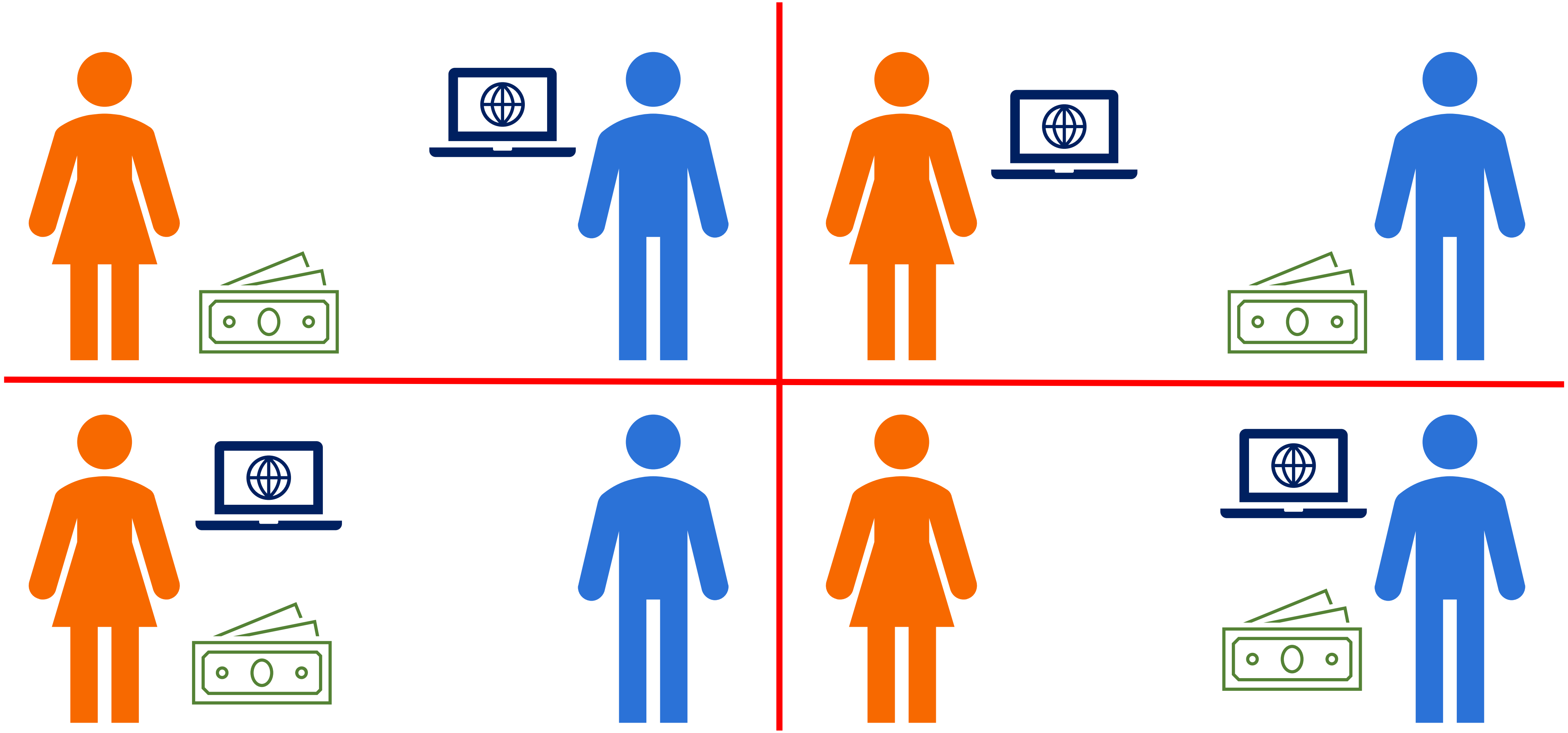


I’ll give you $500 for that laptop computer.

Okay.
It’s a deal!

Transaction complete

Database Transactions
Guarantee No Intermediary States



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What Are Transactions?

The End

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Demo

The Need for Transactions

Demo: The Need for Transactions

- We will use the Azure Data Studio application
- We will use the demo database
- Accounts table
- Understand the need for transactions and the problem of intermediary states
- This code does not use transactions, but what’s the problem?
    - Check constraint firing
    - No rows affected

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Demo: The Need for Transactions

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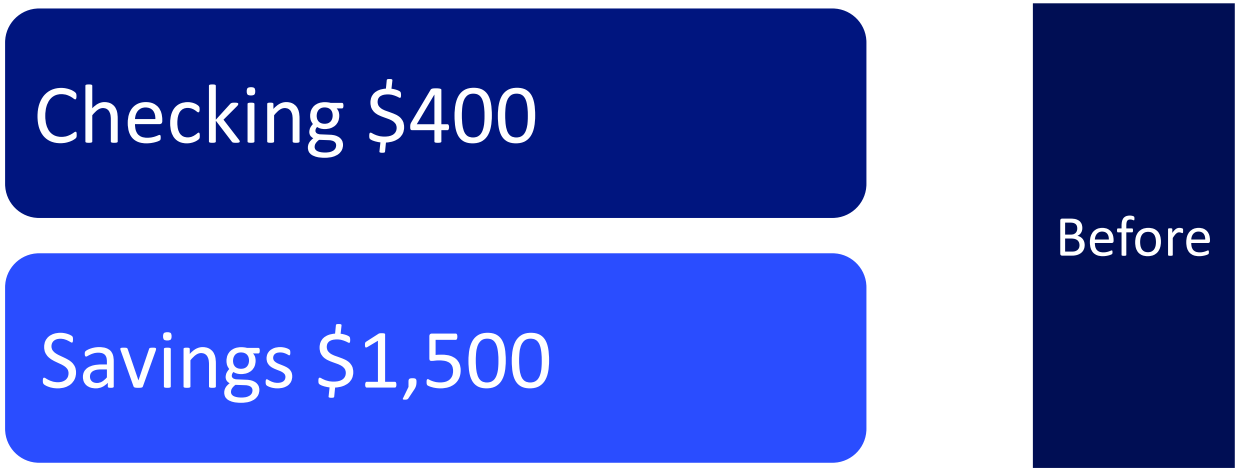
ACID Properties

Transaction ACID Properties

- Atomic
  - Transaction cannot be subdivided; logical unit of work; completes as a single unit or not at all
- Consistent
  - Transitions data from one state to another, constraints intact
- Isolated
  - Database changes not revealed to other users until after transaction has completed
- Durable
  - Database changes are permanent once committed

Example: Transfer Funds

- Transfer $1,000 from savings to checking



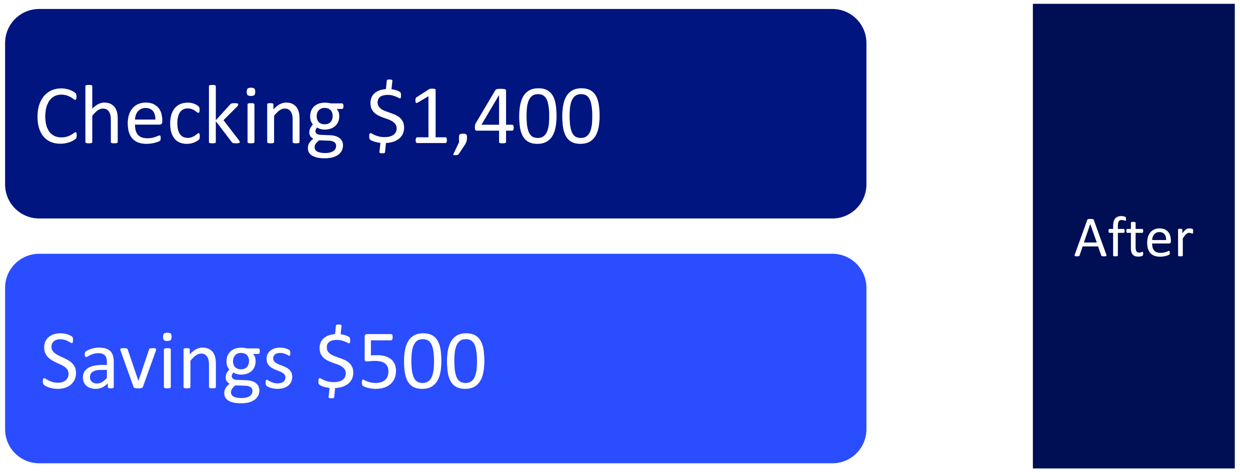
Checking $400

Savings $1,500

Before

Example: Transfer Funds (cont.)

- Transfer $1,000 from savings to checking



Checking $1,400

Savings $500

After

Atomic: Transfer Funds

- Transfer $1,000 from savings to checking
  - Step 1 remove $1,000 from savings
  - Step 2 add $1,000 to checking

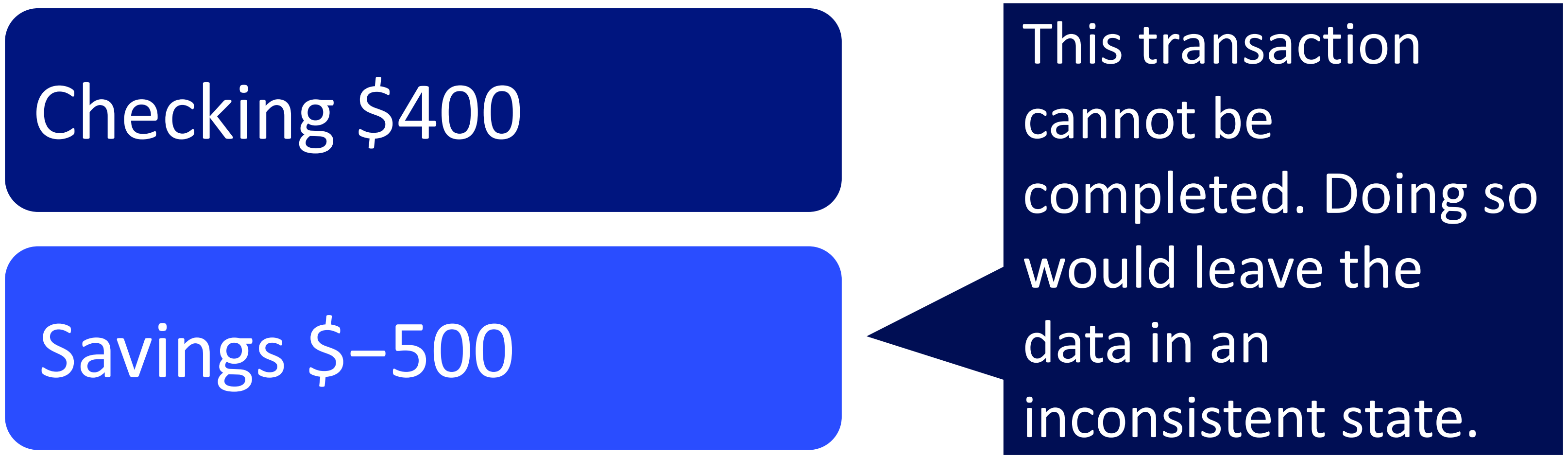
Checking $400

Savings $500

Nobody ever sees this step in the process since the transaction is treated as a single operation.

Consistent: Transfer Funds

- Transfer $2,000 from savings to checking
- Business rule accounts: 0 or more



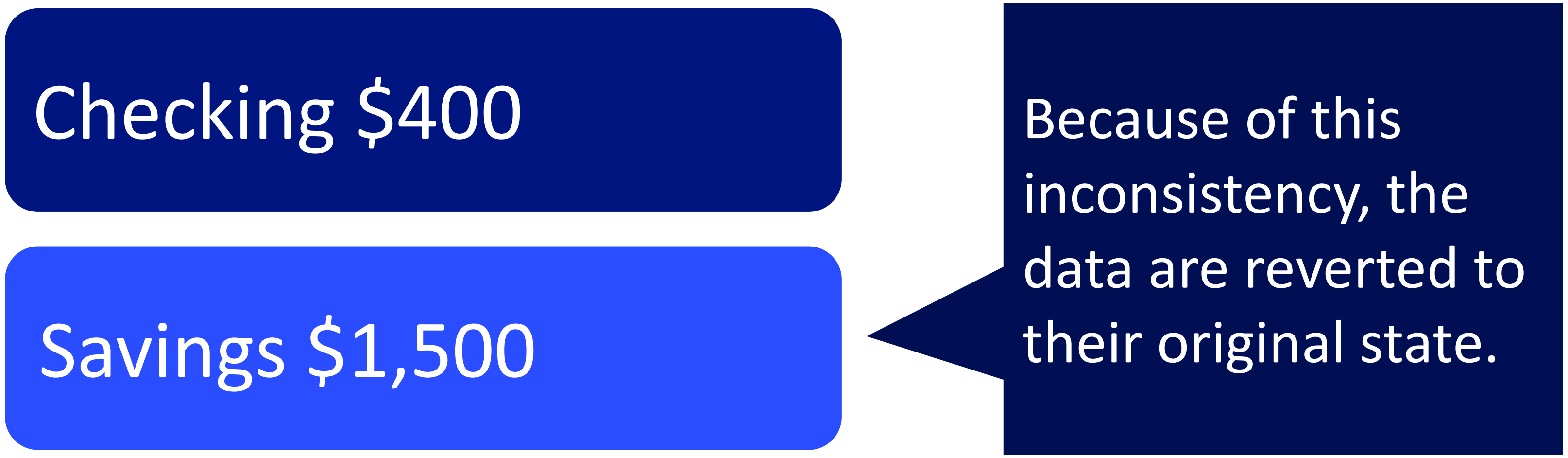
Checking $400

Savings $–500

This transaction cannot be completed. Doing so would leave the data in an inconsistent state.

Consistent: Transfer Funds (cont.)

- Transfer $2,000 from savings to checking
- Business rule accounts: 0 or more



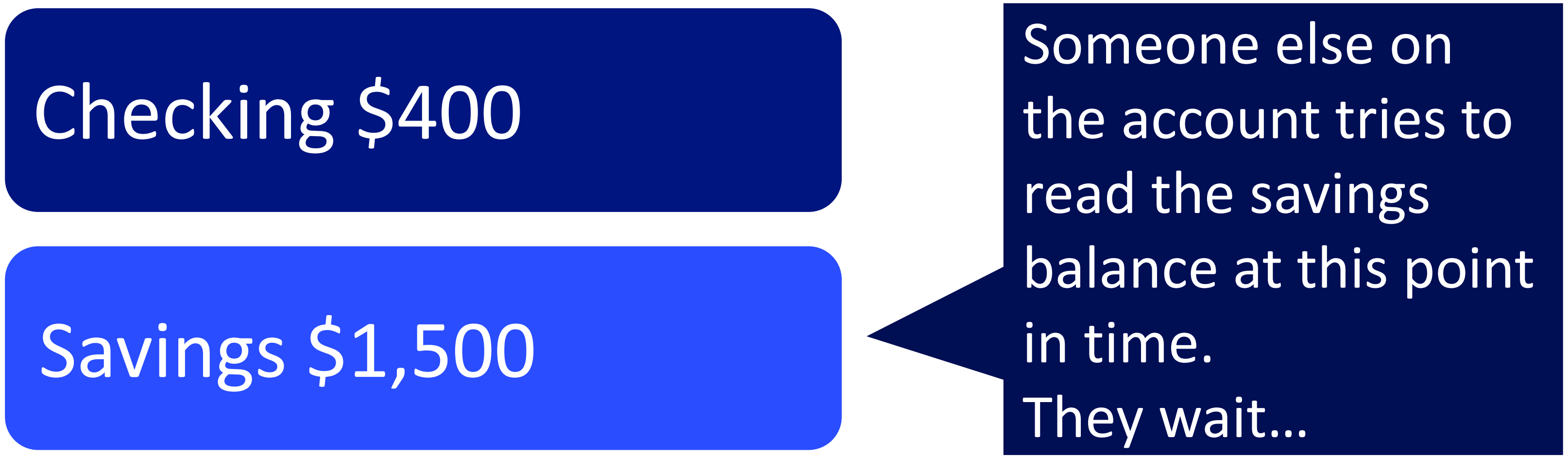
Checking $400

Savings $1,500

Because of this inconsistency, the data are reverted to their original state.

Isolated: Transfer Funds

- Transfer $1,000 from savings to checking



Checking $400

Savings $1,500

Someone else on the account tries to read the savings balance at this point in time.
They wait…

Isolated: Transfer Funds (cont.)

- Transfer $1,000 from savings to checking

Checking $1,400

Savings $500

… until the transaction is completed, then they see the savings balance of $500.

Durable: Transfer Funds

- Transfer $1,000 from savings to checking

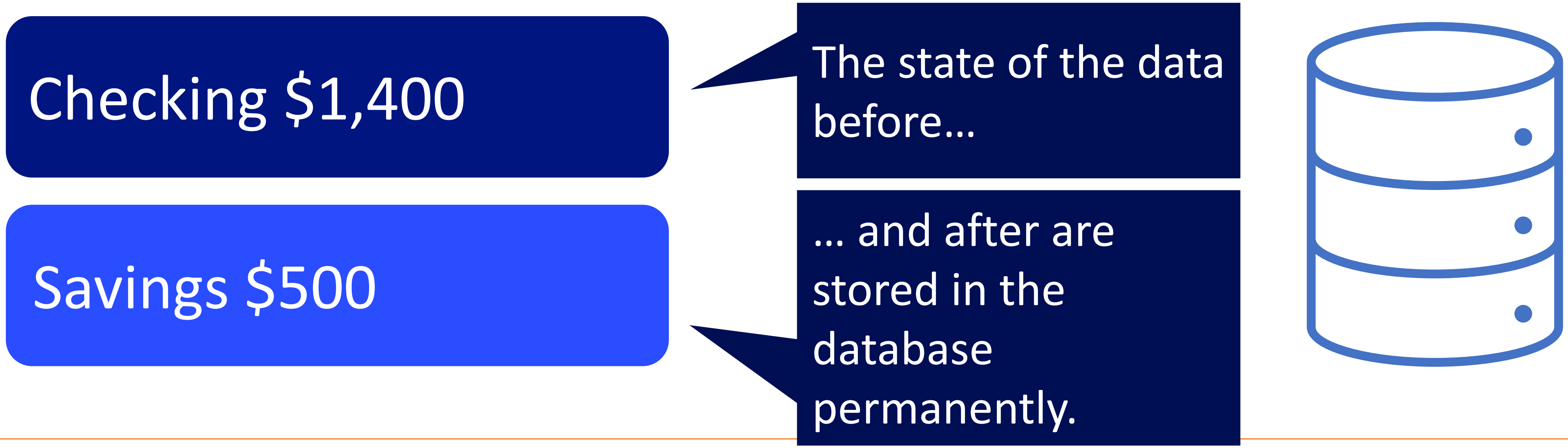
Checking $400

Savings $1,500

The state of the data before…

Durable: Transfer Funds (cont.)

- Transfer $1,000 from savings to checking



Checking $1,400

Savings $500

The state of the data before…

… and after are stored in the database permanently.

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ACID Properties

The End

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Transaction Support in SQL Server

Transactions in SQL Server

- We simply take the code we have:

```
BEGIN TRANSACTION
UPDATE accounts SET checking …
UPDATE accounts SET checking …
COMMIT TRANSACTION
```

- And tell SQL Server to group them as a transaction—sort of

T-SQL Transaction Commands

- `BEGIN TRAN[SACTION]`
  - Starts the marking point of a transaction; any data manipulation statements after this point are not durable
- `COMMIT [TRAN[SACTION]]`
  - Marks the end of a successful transaction; at this point, all data changes to become durable
- `ROLLBACK [TRAN[SACTION]]`
  - Undoes any data manipulation statements since the beginning of the transaction
- @@TRANCOUNT
  - A T-SQL Internal variable that identifies pending transactions

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Transaction Support in SQL Server

The End

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Demo

SQL Transactions

Demo: SQL Transations

- We will use the Azure Data Studio application
- We will use the demo database
- Without BEGIN TRANSACTION, all commands are durable
- With BEGIN TRANSACTION, they are not!
- @@TRANCOUNT
- COMMIT and ROLLBACK
- Transactions are isolated, consistent, atomic, and durable

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Demo: SQL Transactions

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Transaction Safe Code

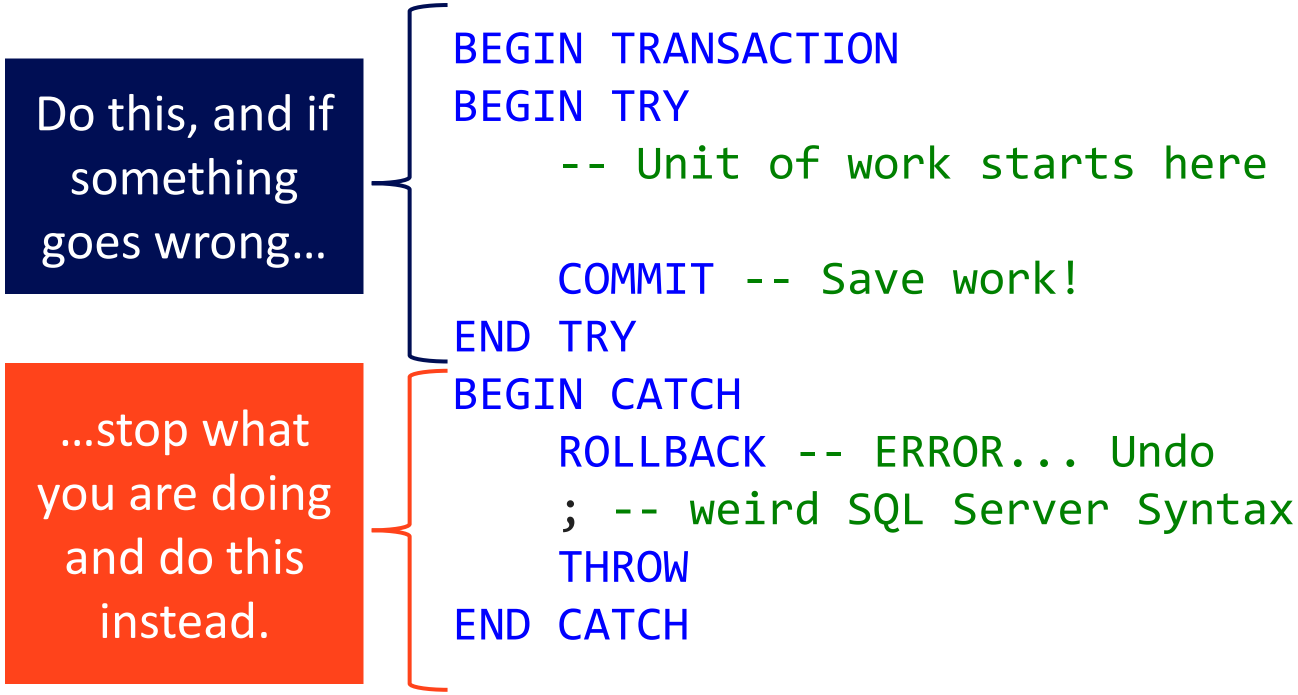
Transaction Safe Code 101: How Do You Know When to Rollback?

We want to rollback when:

- An error occurs
  - Database cannot write to the table (disk is full)
  - There is a physical hardware/operating system issue
  - A database constraint is violated (check, PK, FK, etc.), which will result in an inconsistency
- There is custom data logic
  - The expected number of rows are not affected, for example

SQL Error Handling: TRY… CATCH

The SQL TRY… CATCH statement makes transaction management of errors simple.



Do this, and if something goes wrong…

```
BEGIN TRANSACTION
BEGIN TRY
    -- Unit of work starts here

    COMMIT -- Save work!
END TRY
BEGIN CATCH
    ROLLBACK -- ERROR... Undo
    ; -- weird SQL Server Syntax
    THROW
END CATCH
```

…stop what you are doing and do this instead.

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Transaction Safe Code

The End

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Demo

Transactions TRY/CATCH

Demo: Transactions TRY/CATCH

- We will use the Azure Data Studio application.
- We will use the demo database.
- Re-write our p_transfer_funds to use transactions.
- Test it out:.
  - Check constraint firing
  - No rows affected
- Not perfect, but better!

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Demo: Transactions TRY/CATCH

The End

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Rollback on Custom Data Logic

Rollback From Custom Data Logic

- We might want to rollback based on custom data logic
- For example, when you update a row but no rows are affected, how do you handle this?

@@ROWCOUNT—reports number of rows affected from an SQL statement

```
SELECT * FROM accounts
(2 rows affected)
PRINT @@ROWCOUNT
2
```

SQL THROW a Custom Error

Use the SQL THROW statement to launch a custom user-defined error

```
THROW error_number, message, state
```

- `error_number` — a customer number >= 50000
- `Message` — a string error message
- `State` — a number 0–255 for message state, usually a 1

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Rollback on Custom Data Logic

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Demo

Rollback On Custom Data Logic

Demo: Rollback on Custom Data Logic

- We will use the Azure Data Studio application.
- We will use the demo database.
- Re-write our p_transfer_funds to use transactions.
- Handle custom business logic for rows affected.

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Demo: Rollback Custom Data Logic

The End

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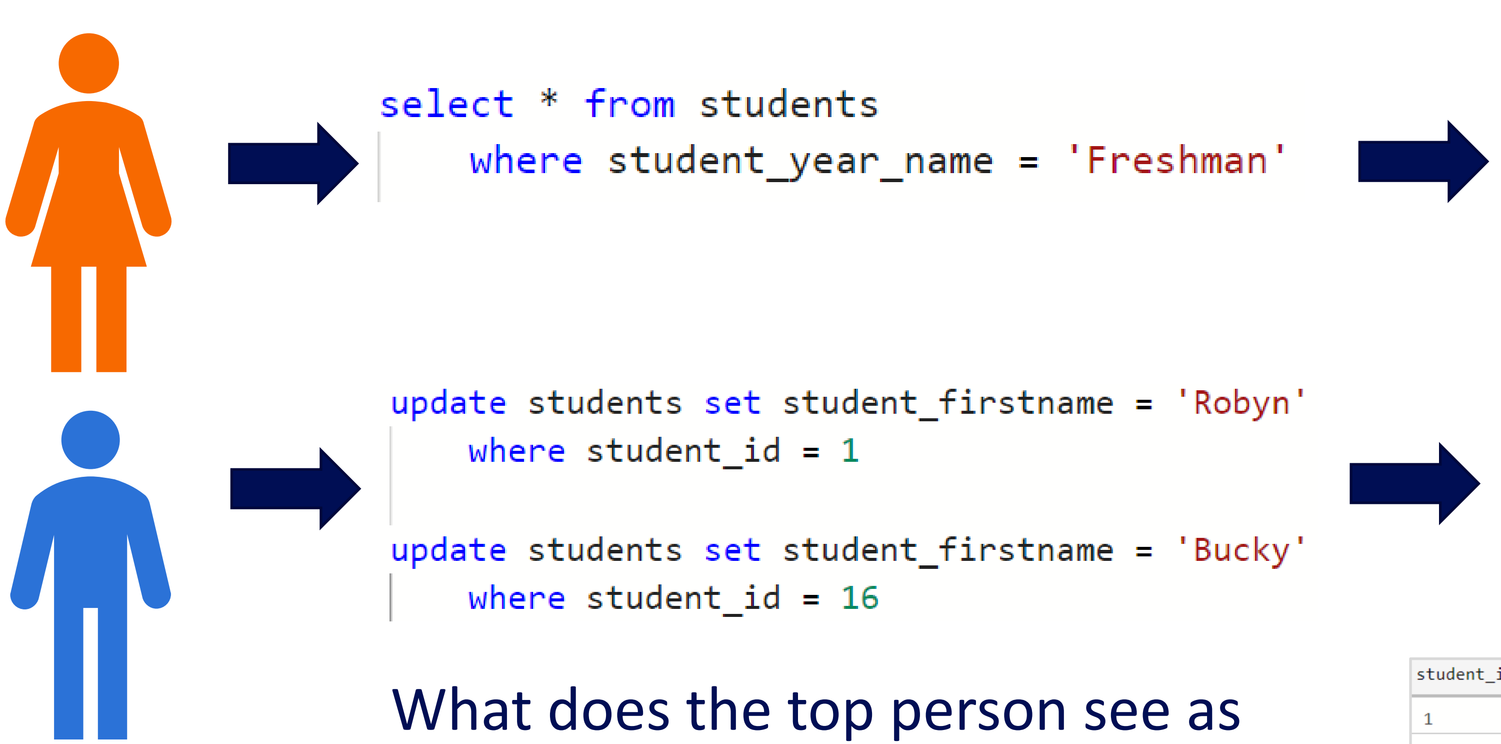
Concurrency Control

Concurrency Control

- Problem: in a multiuser environment, simultaneous access to data can result in interference and data loss
- Solution: concurrency control
  - The process of managing simultaneous transactions against a database so that data integrity is maintained, and the operations do not interfere with each other in a multi-user environment.
  - Concurrency control helps keep transactions isolated.
  - Concurrency control is a part of every modern DBMS.

Example: Concurrency Question



```
select * from students
    where student_year_name = 'Freshman'
```

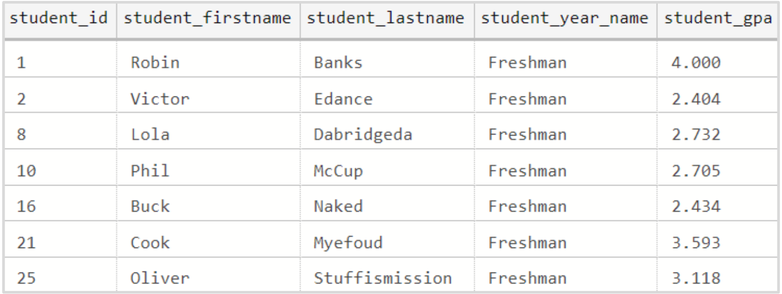
```
update students set student_firstname = 'Robyn'
    where student_id = 1

update students set student_firstname = 'Bucky'
    where student_id = 16
```

What does the top person see as output?

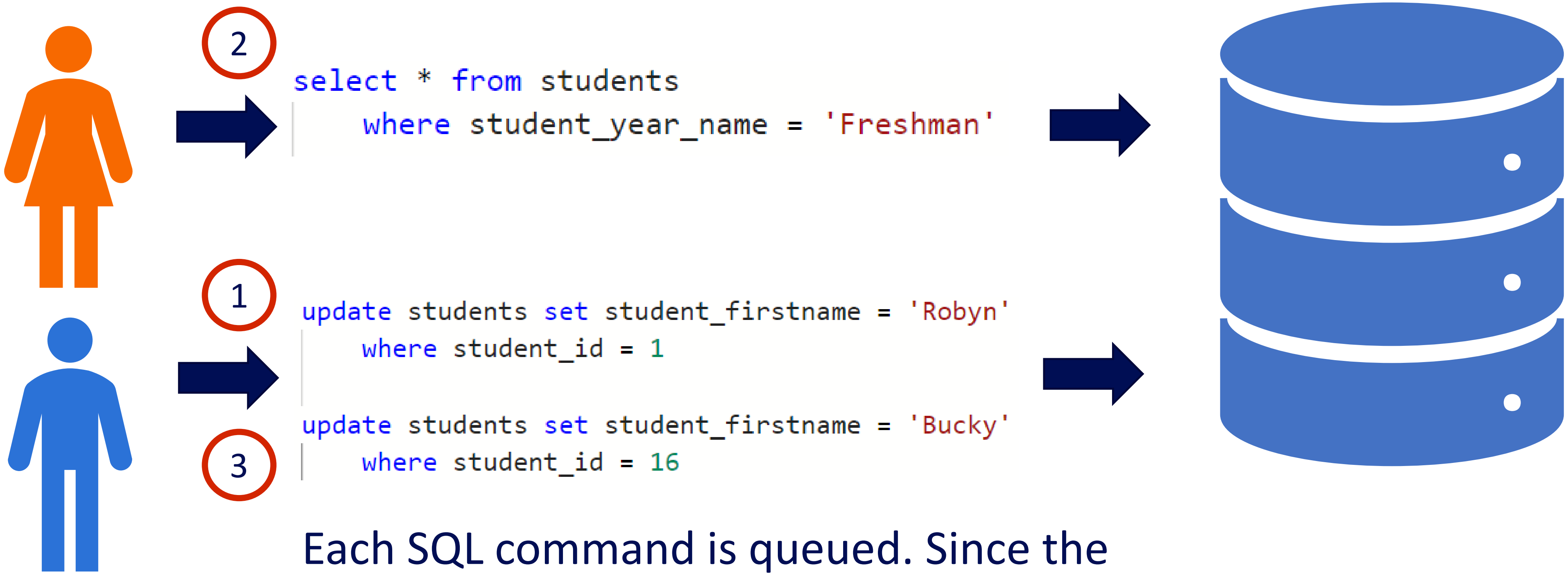
Robin Robyn Robyn

Buck Buck Bucky



student_id	student_firstname	student_lastname	student_year_name	student_gpa
1	Robin	Banks	Freshman	4.000
2	Victor	Edance	Freshman	2.404
8	Lola	Dabridgeda	Freshman	2.732
10	Phil	McCup	Freshman	2.705
16	Buck	Naked	Freshman	2.434
21	Cook	Myefoud	Freshman	3.593
25	Oliver	Stuffismission	Freshman	3.118

Example: Concurrency Answer



```sql
select * from students
    where student_year_name = 'Freshman'
```

```sql
update students set student_firstname = 'Robyn'
    where student_id = 1
```

```sql
update students set student_firstname = 'Bucky'
    where student_id = 16
```

Each SQL command is queued. Since the bottom person did not use a transaction, they could get ordered:

Robyn
Bucky

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Concurrency Control

The End

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DBMS Without Concurrency Control

Lost Update Problem

Occurs when one update overwrites another

Transaction A	Time	Transaction B
READ Balance = $500	1	---
---	2	READ Balance = $500
---	3	Withdrawal $300 WRITE Balance = $200
Withdrawal $100 WRITE Balance = $400	4	---
	5	READ Balance = $400?!

Balance should be $100, but it’s $400!

Dirty/Inconsistent Read Problem

Occurs when a transaction reads uncommitted data

Transaction A	Time	Transaction B
---	1	READ City = ‘Utica’
---	2	UPDATE City = ‘Rome’
READ City = ‘Rome’	3	---
---	4	FAIL: Rollback

A’s city = ‘Rome’ and B’s city = ‘Utica’

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DBMS Without Concurrency Control

The End

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Serializability and Locking

How Do DBMS Maintain Concurrency Control?

- Serializability
  - Finish one transaction before starting another
- Locking mechanisms
  - The most common way of achieving serialization
  - Data that are retrieved for the purpose of updating are locked for the updater
  - No other user can perform a write operation until unlocked

Serializability and Locking

This demonstrates an exclusive lock.

Transaction A	Time	Transaction B
Request account, lock acquired	1	---
READ Balance = $500	2	Request account, waiting for lock release
---	3	---
Withdrawal $100 WRITE Balance = $400	4	---
Lock released	5	---
---	6	Lock acquired
---	7	READ Balance = $400

Locking Mechanisms

- Locking granularity
  - Database: used during database updates, ALTER DATABASE
  - Table: used for bulk updates, or ALTER TABLE
  - Block or page: very commonly used
  - Record: only requested row; fairly commonly used
  - Field: requires significant overhead; impractical
- Types of locks
  - Shared lock: read but no update permitted; used when just reading to prevent another user from placing an exclusive lock on the record
  - Exclusive lock: no access permitted; used when preparing to update

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Serializability and Locking

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Versioning and Isolation Levels

Versioning

- DBMS maintains multiple versions of the data to be modified as part of the transaction.
- Concurrent reads are allowed to the data.
- Attempts to write are allowed, but subsequent writes are rolled back and restarted.

Versioning Example

Transaction A	Time	Transaction B
READ Balance = $500	1	---
---	2	READ Balance = $500
Withdrawal $100 Begin transaction WRITE Balance = $400	3	---
---	4	Withdrawal $300 Begin transaction WRITE Balance = $200
Commit	5	Other version pending, rollback
---	6	Restart transaction

Isolation Levels in SQL Server

- We change concurrency control by setting an isolation level in the database
- Read uncommitted: any transaction can read any uncommitted data; no locks, no concurrency control.
- Read committed: no transaction can read uncommitted data; default
- Serializable: like read committed but also locks related data across foreign keys
- Read committed snapshot: uses versioning so that there are no locks on the read operation

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Versioning and Isolation Levels

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Demo

Concurrency Control

Demo: Concurrency Control

- We will use the Azure Data Studio application.
- We will use the demo database.
- Let’s demonstrate a dirty read by playing with the isolation levels.
  - Update a row
  - Witness a lock on the table read committed
  - No lock with read uncommitted—but you read pending transaction data
  - When transaction is rolled back—yikes!

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Demo: Concurrency Control

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Deadlocks

Deadlocks

- A deadlock situation occurs when two or more transactions are waiting for each other to give up locks
- Row level locks help mitigate this issue, but there is still a possibility
- Set the lock timeout in milliseconds
- **`SET LOCK_TIMEOUT 5000–five seconds`**
- Read it with **`@@LOCK_TIMEOUT`**
- Default is –1 (never)

Deadlock Example

Transaction A	Time	Transaction B
Begin transaction	1	---
---	2	Begin transaction
Update users where id = 1	3	---
---	4	Update blogs where id = 7
Update blogs where id = 7 (Locked by B, waiting…)	5	---
---	6	Update users where id = 1 (Locked by A, waiting…)
---	7	---

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Deadlocks

The End

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Demo

Deadlock

Demo: Deadlock

- We will use the Azure Data Studio application.
- We will use the tinyu database.
- Let’s demonstrate a deadlock scenario.
    - Transaction 1: Update row in table A, then row in table B.
    - Transaction 1: Update row in table B, then row in table A.

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Demo: Deadlock

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Summary

Summary

- Transactions are multiple SQL statements treated as a single unit of work.
- Transactions are atomic, consistent, isolated, and durable.
- To make SQL transaction safe, you must rollback on error, or when the expected data logic results do not match the actual results.
- Concurrency control is how multiple transactions are managed within the DBMS.
- Deadlocks occur when two or more transactions are waiting to give up locks.

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Summary

The End