CS50 Beyond

Databases

origin	destination	duration
New York	London	415
Shanghai	Paris	760
Istanbul	Tokyo	700
New York	Paris	435
Moscow	Paris	245
Lima	New York	455

SQL

SQL Databases

- MySQL
- PostgreSQL
- SQLite
- ...

Data Types

- INTEGER
- DECIMAL
- SERIAL
- VARCHAR
- TIMESTAMP
- BOOLEAN
- ENUM
- …

CREATE TABLE

```
CREATE TABLE flights (
    id SERIAL PRIMARY KEY,
    origin VARCHAR NOT NULL,
    destination VARCHAR NOT NULL,
    duration INTEGER NOT NULL
);
```

```
CREATE TABLE flights (
    id SERIAL PRIMARY KEY,
    origin VARCHAR NOT NULL,
    destination VARCHAR NOT NULL,
    duration INTEGER NOT NULL
);
```

```
CREATE TABLE flights (
    id SERIAL PRIMARY KEY,
    origin VARCHAR NOT NULL,
    destination VARCHAR NOT NULL,
    duration INTEGER NOT NULL
);
```

```
CREATE TABLE flights (
    id SERIAL PRIMARY KEY,
    origin VARCHAR NOT NULL,
    destination VARCHAR NOT NULL,
    duration INTEGER NOT NULL
);
```

```
CREATE TABLE flights (
    id SERIAL PRIMARY KEY,
    origin VARCHAR NOT NULL,
    destination VARCHAR NOT NULL,
    duration INTEGER NOT NULL
);
```

```
CREATE TABLE flights (
    id SERIAL PRIMARY KEY,
    origin VARCHAR NOT NULL,
    destination VARCHAR NOT NULL,
    duration INTEGER NOT NULL
);
```

```
CREATE TABLE flights (
    id SERIAL PRIMARY KEY,
    origin VARCHAR NOT NULL,
    destination VARCHAR NOT NULL,
    duration INTEGER NOT NULL
);
```

Constraints

- NOT NULL
- UNIQUE
- PRIMARY KEY
- DEFAULT
- CHECK
- …

INSERT

```
INSERT INTO flights
    (origin, destination, duration)
    VALUES ('New York', 'London', 415);
```

```
INSERT INTO flights
    (origin, destination, duration)
    VALUES ('New York', 'London', 415);
```

```
INSERT INTO flights
    (origin, destination, duration)
    VALUES ('New York', 'London', 415);
```

```
INSERT INTO flights
    (origin, destination, duration)
    VALUES ('New York', 'London', 415);
```

```
INSERT INTO flights
    (origin, destination, duration)
    VALUES ('New York', 'London', 415);
```

```
INSERT INTO flights
    (origin, destination, duration)
    VALUES ('New York', 'London', 415);
```

SELECT

```
SELECT * FROM flights;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT origin, destination FROM flights;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT origin, destination FROM flights;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights WHERE id = 3;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights WHERE id = 3;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights WHERE origin = 'New York';
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights WHERE origin = 'New York';
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights WHERE duration > 500;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights WHERE duration > 500;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights
WHERE destination = 'Paris' AND duration > 500;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights
WHERE destination = 'Paris' AND duration > 500;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights
WHERE destination = 'Paris' OR duration > 500;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights
WHERE destination = 'Paris' OR duration > 500;
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights
WHERE origin IN ('New York', 'Lima');
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights
WHERE origin IN ('New York', 'Lima');
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights
WHERE origin LIKE '%a%';
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

```
SELECT * FROM flights
WHERE origin LIKE '%a%';
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

Functions

- SUM
- COUNT
- MIN
- MAX
- AVG
- …

UPDATE

```
UPDATE flights
    SET duration = 430
    WHERE origin = 'New York'
    AND destination = 'London';
```

DELETE

```
DELETE FROM flights
     WHERE destination = 'Tokyo';
```

Other Clauses

- `LIMIT`
- `ORDER BY`
- `GROUP BY`
- `HAVING`
- …

Foreign Keys

flights

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

flights

id	origin	origin_code	destination	destination_code	duration
1	New York	JFK	London	LHR	415
2	Shanghai	PVG	Paris	CDG	760
3	Istanbul	IST	Tokyo	NRT	700
4	New York	JFK	Paris	CDG	435
5	Moscow	SVO	Paris	CDG	245
6	Lima	LIM	New York	JFK	455

locations

id	code	name
1	JFK	New York
2	PVG	Shanghai
3	IST	Istanbul
4	LHR	London
5	SVO	Moscow
6	LIM	Lima
7	CDG	Paris
8	NRT	Tokyo

flights

id	origin_id	destination_id	duration
1	1	4	415
2	2	7	760
3	3	8	700
4	1	7	435
5	5	7	245
6	6	1	455

passengers

id	name	flight_id
1	Alice	1
2	Bob	1
3	Charlie	2
4	Dave	2
5	Erin	4
6	Frank	6
7	Grace	6

JOIN

Types of JOINs

- JOIN / INNER JOIN
- LEFT OUTER JOIN
- RIGHT OUTER JOIN
- FULL OUTER JOIN

CREATE INDEX

Nested Queries

flights

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

passengers

id	name	flight_id
1	Alice	1
2	Bob	1
3	Charlie	2
4	Dave	2
5	Erin	4
6	Frank	6
7	Grace	6

```
SELECT flight_id FROM passengers
GROUP BY flight_id HAVING COUNT(*) > 1;
```

```
SELECT flight_id FROM passengers
GROUP BY flight_id HAVING COUNT(*) > 1;
```

id	name	flight_id
1	Alice	1
2	Bob	1
3	Charlie	2
4	Dave	2
5	Erin	4
6	Frank	6
7	Grace	6

```
SELECT flight_id FROM passengers
GROUP BY flight_id HAVING COUNT(*) > 1;
```

id	name	flight_id
1	Alice	1
2	Bob	1
3	Charlie	2
4	Dave	2
5	Erin	4
6	Frank	6
7	Grace	6

flight_id
1
2
6

```
SELECT flight_id FROM passengers
GROUP BY flight_id HAVING COUNT(*) > 1;
```

flight_id
1
2
6

```
SELECT * FROM flights WHERE id IN
(SELECT flight_id FROM passengers
GROUP BY flight_id HAVING COUNT(*) > 1);
```

flight_id
1
2
6

```
SELECT * FROM flights WHERE id IN
(SELECT flight_id FROM passengers
GROUP BY flight_id HAVING COUNT(*) > 1);
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

flight_id
1
2
6

```
SELECT * FROM flights WHERE id IN
(SELECT flight_id FROM passengers
GROUP BY flight_id HAVING COUNT(*) > 1);
```

id	origin	destination	duration
1	New York	London	415
2	Shanghai	Paris	760
3	Istanbul	Tokyo	700
4	New York	Paris	435
5	Moscow	Paris	245
6	Lima	New York	455

flight_id
1
2
6

SQL Injection

Username:

Password:

```
SELECT * FROM users
    WHERE (username = username)
    AND (password = password);
```

Username:

alice

Password:

12345

```
SELECT * FROM users
    WHERE (username = username)
    AND (password = password);
```

```
SELECT * FROM users
    WHERE (username = 'alice')
    AND (password = '12345');
```

Username:

hacker

Password:

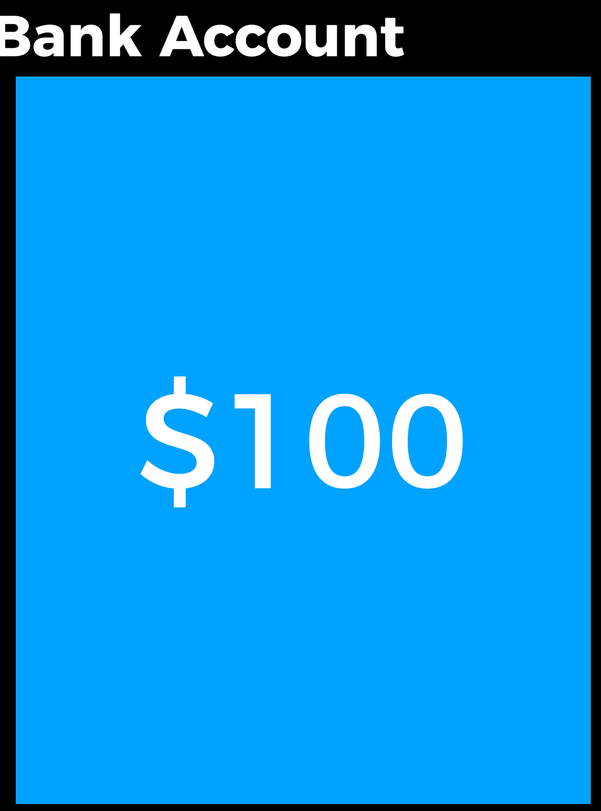
1' OR '1' = '1

```
SELECT * FROM users
    WHERE (username = username)
    AND (password = password);
```

```
SELECT * FROM users
    WHERE (username = 'hacker')
    AND (password = '1' OR '1' = '1');
```

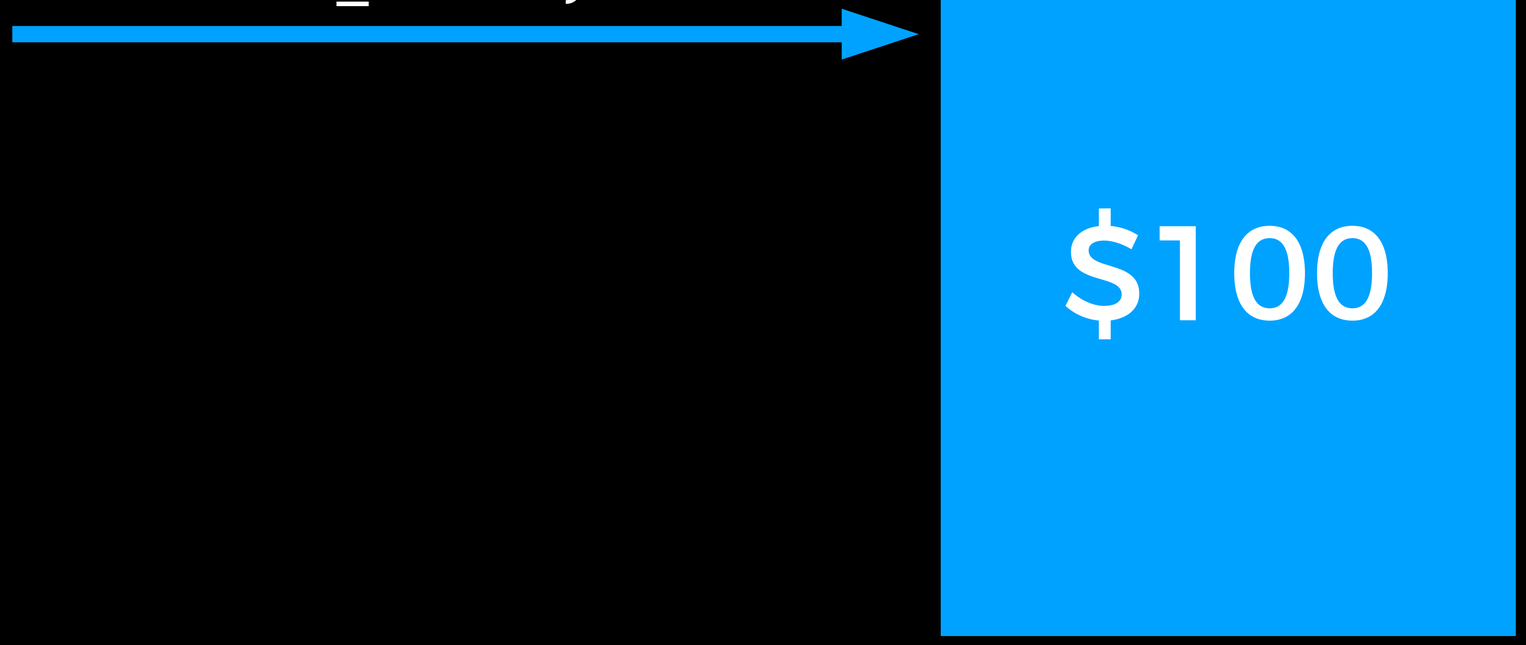
Race Conditions

Race Conditions



Race Conditions

```
SELECT balance FROM bank
WHERE user_id = 1;
```



Race Conditions

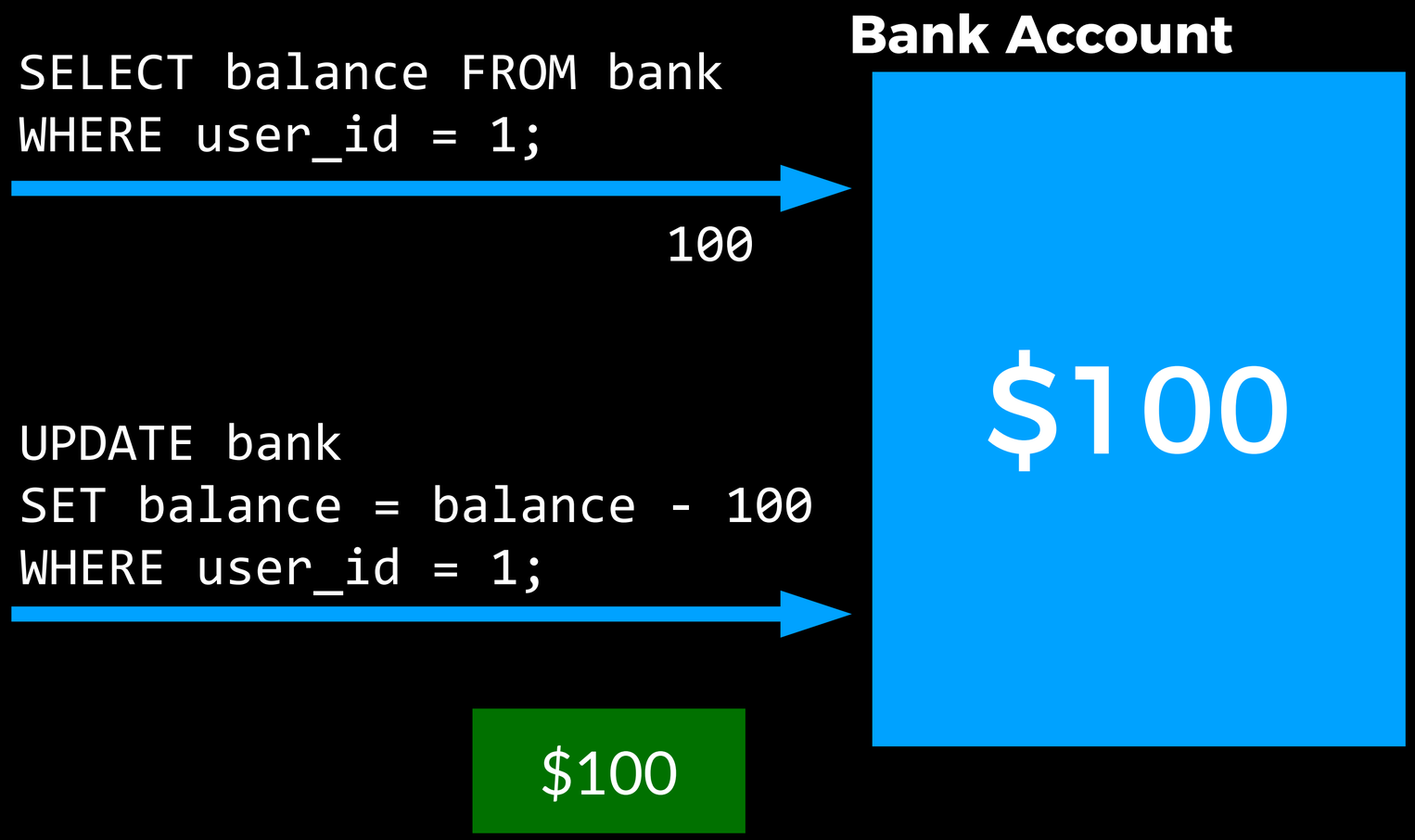
```
SELECT balance FROM bank
WHERE user_id = 1;
```

100

Bank Account

$100

Race Conditions



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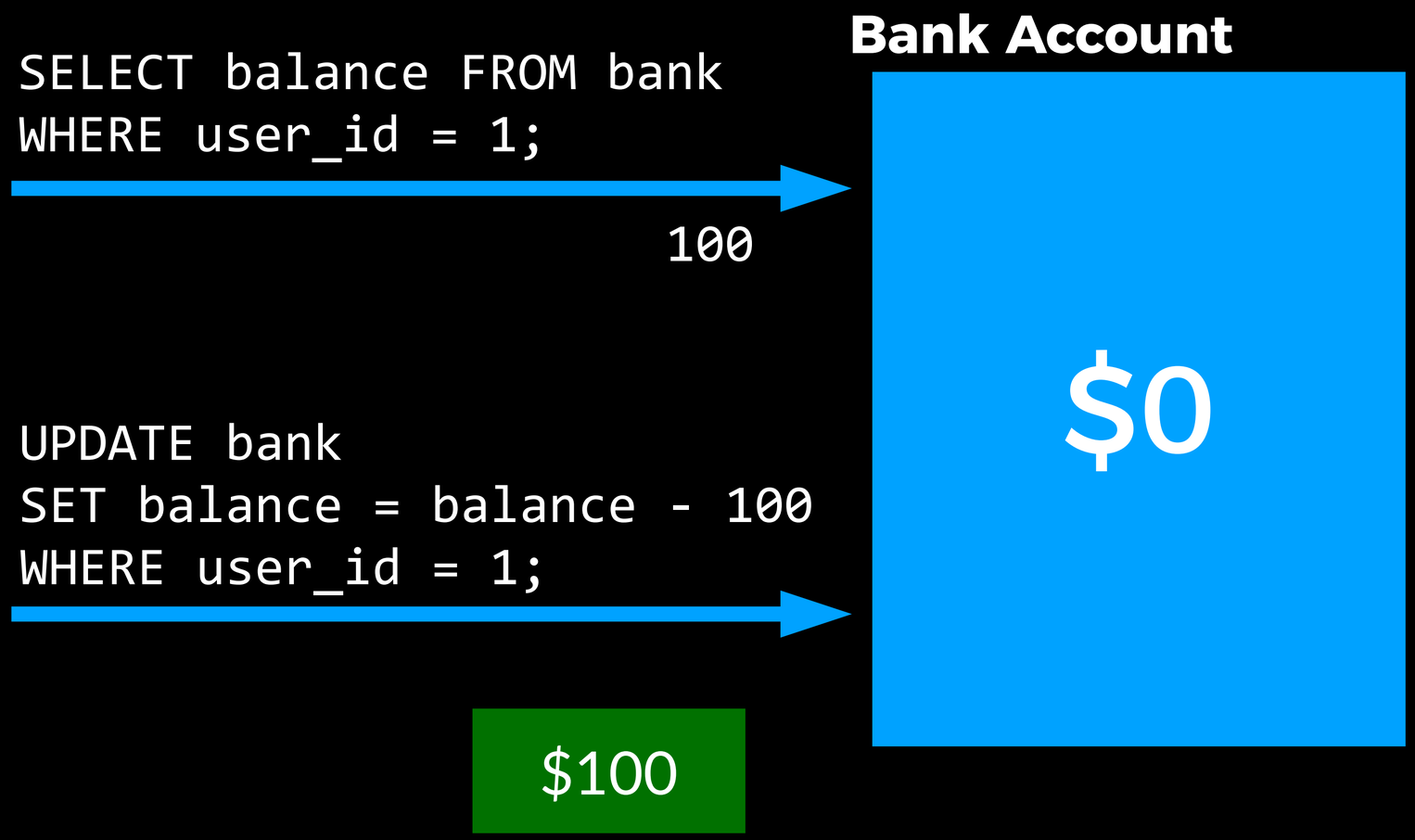

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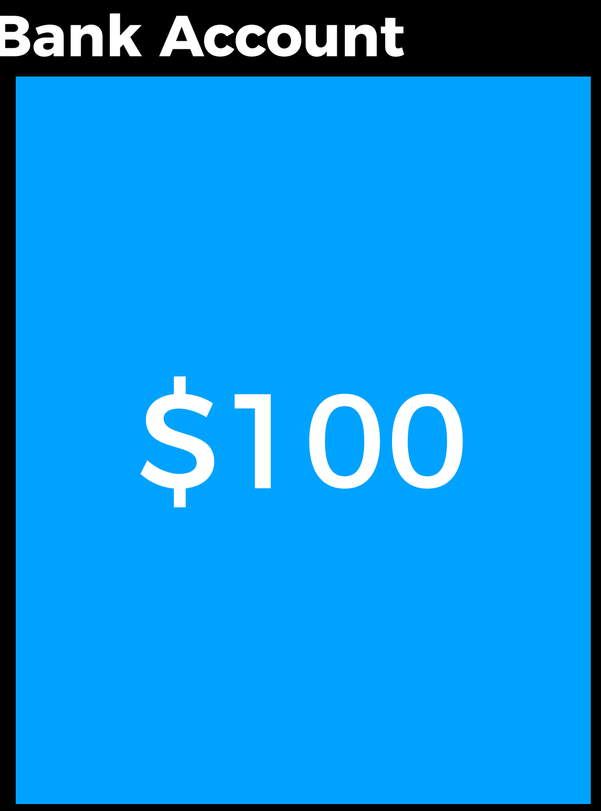
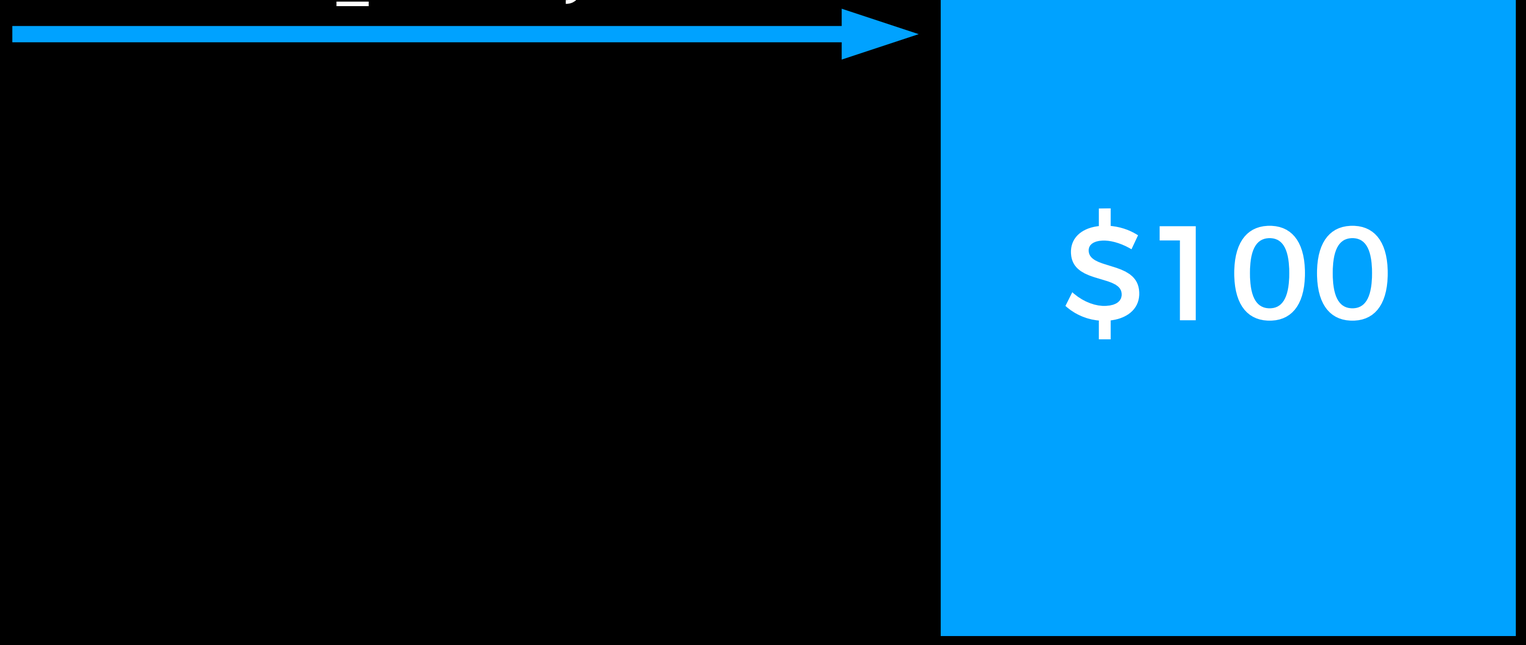


Race Conditions

```
SELECT balance FROM bank
WHERE user_id = 1;
```



Race Conditions

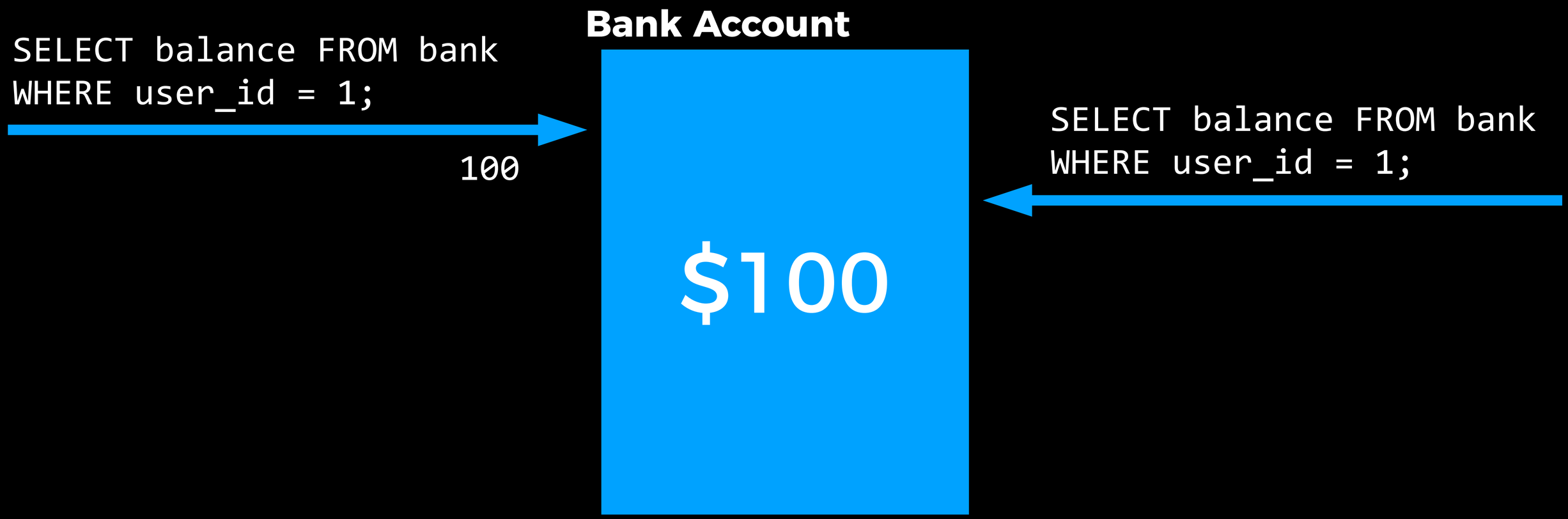
```
SELECT balance FROM bank
WHERE user_id = 1;
```

100

Bank Account

$100

Race Conditions



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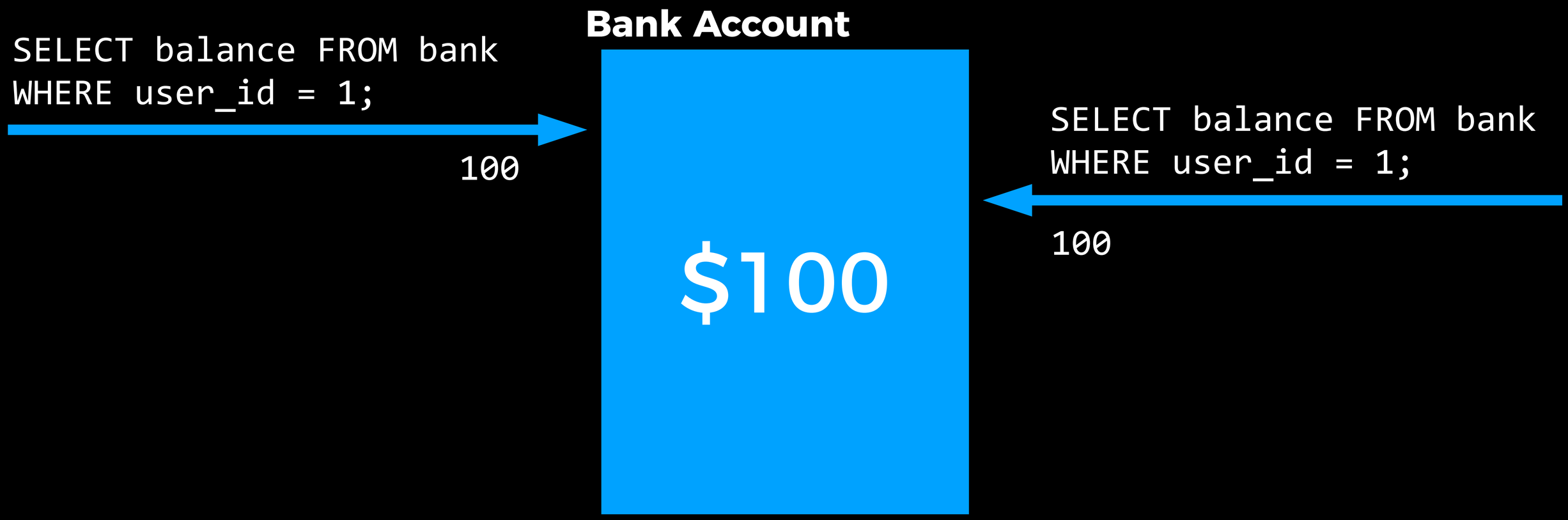

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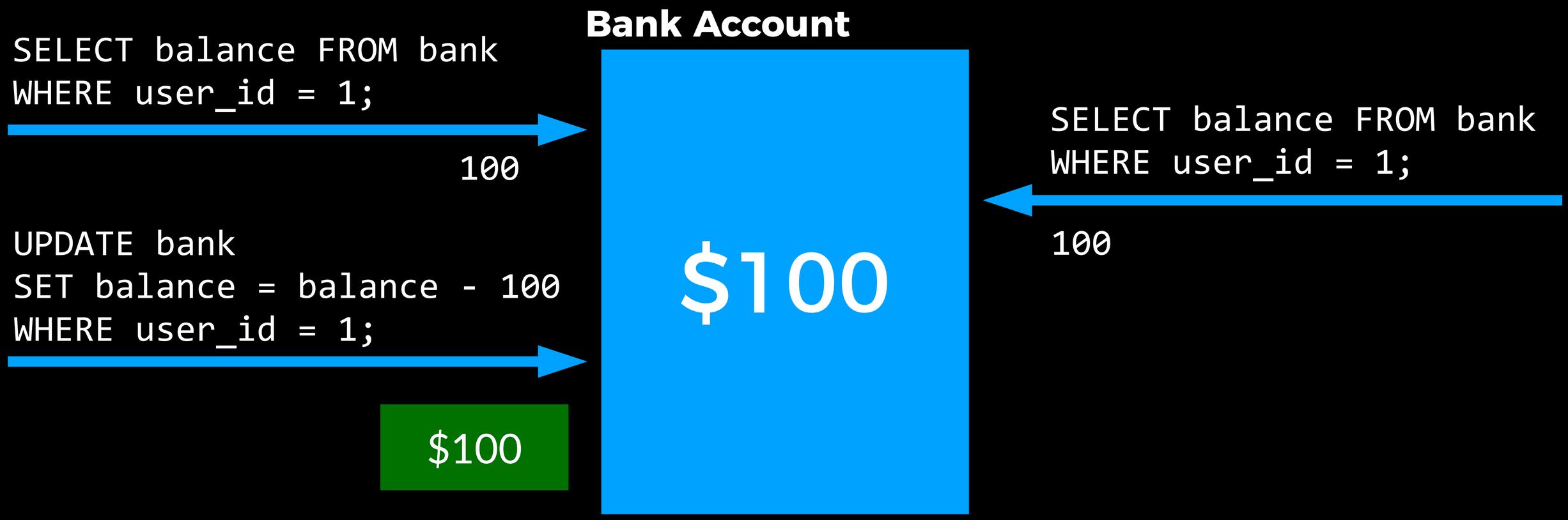

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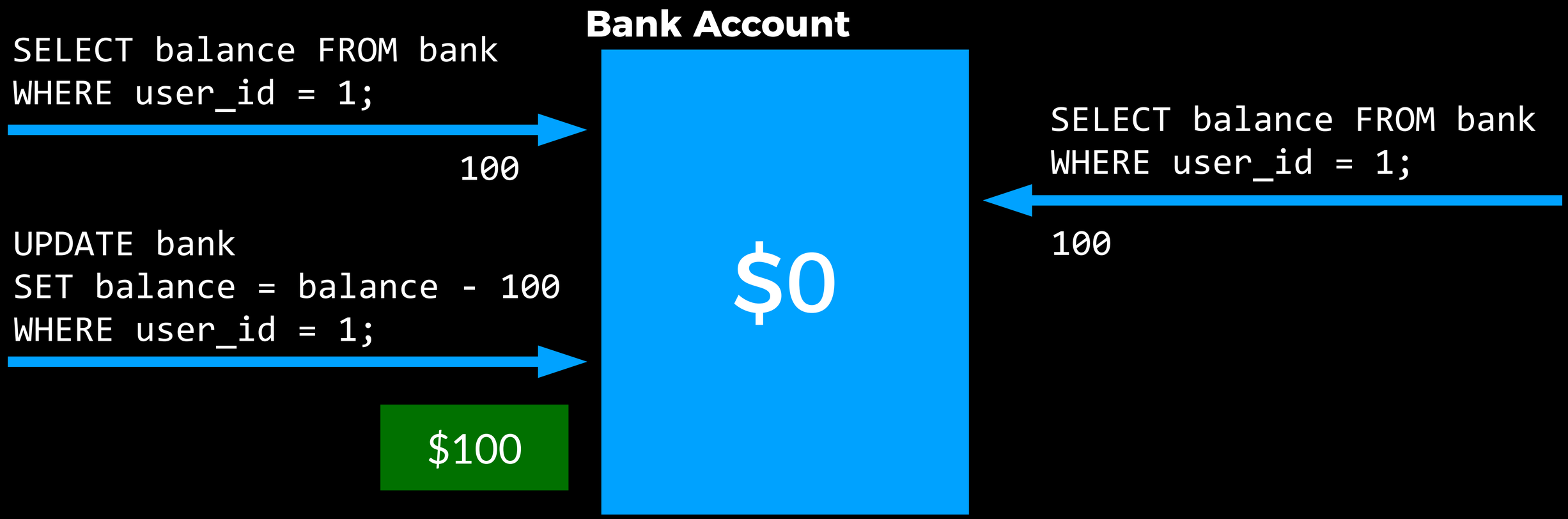

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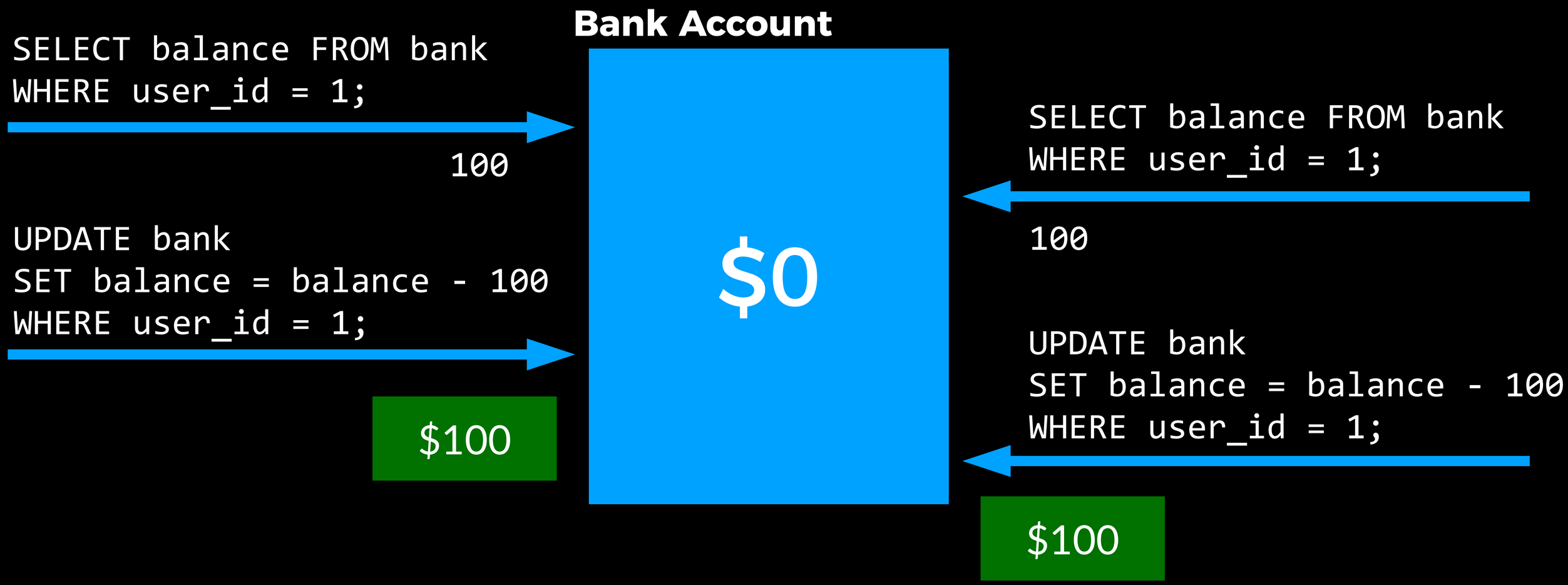
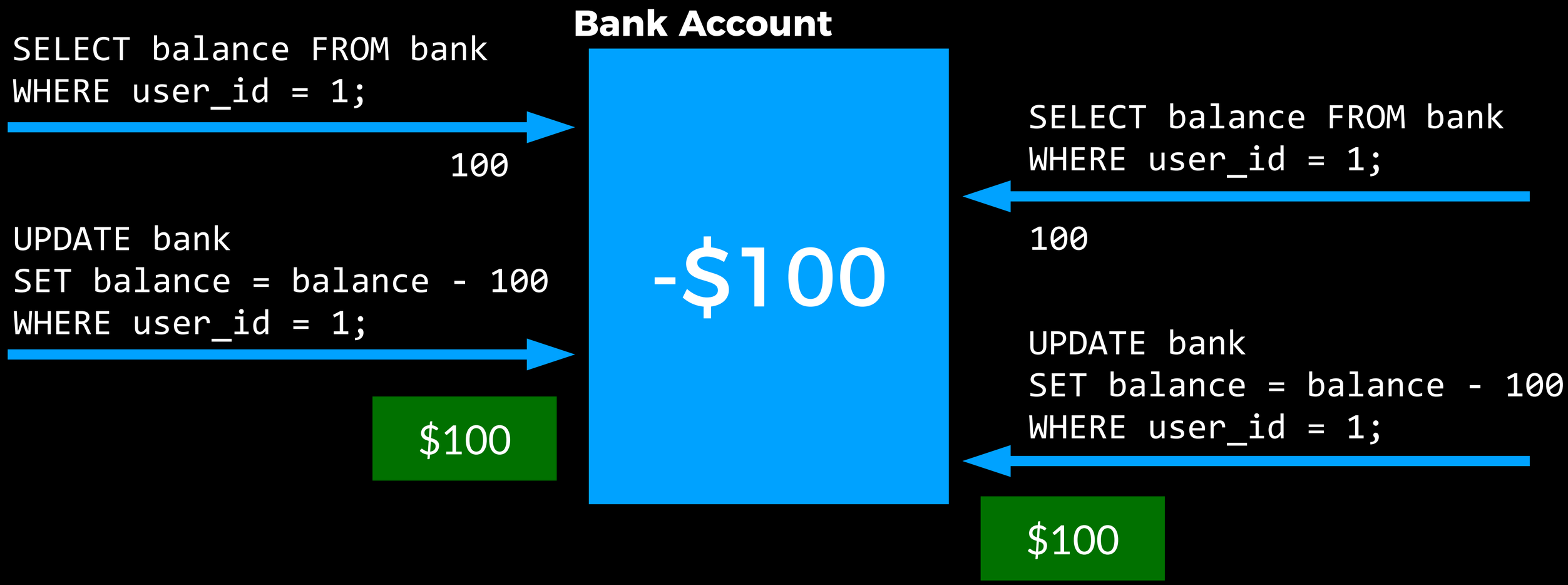


Race Conditions



SQL Transactions

- `BEGIN`
- `COMMIT`

SQLAlchemy

Morning Project

- Create a database on Heroku.
- Decide on a database schema and create tables: one for authors and one for books.
- Write a Python program to import data into the database.
- Write a Python program that queries the database for a book by its (partial) title or author.

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