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Indexes

- Structure that improves data retrieval
- Separate table to store a sorted values of one or more columns
- Index is created automatically for primary key
  - Other columns are optional
- Indexes are useful for
  - Reducing query time
  - Grouping
  - Sorting
  - Minimum and maximum values

Index

Primary key (`prog_id`) index
Values are sorted

idx_prog_id(prog_id)
2
3
7
10

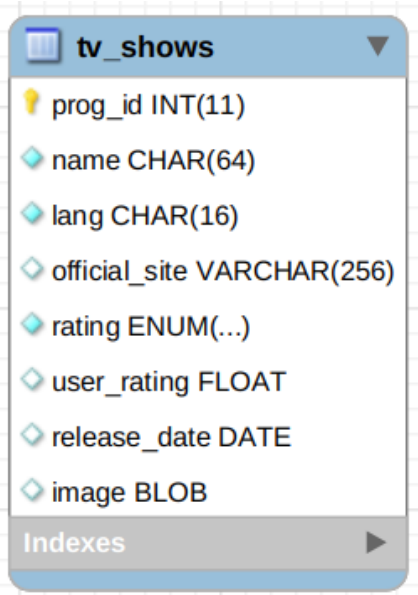
prog_id	name	release_date
10	Game of Thrones	2011-04-17
2	Get Smart	1965-09-18
7	Twin Peaks	1990-04-08
3	Hinterland	2013-10-29

An indexed column

```
select * from tv_shows where prog_id = 3;
```

Search the index of `prog_id`. Since the values are sorted, only 2 entries are search.
If we have to search the `prog_id` from `tv_show` table, we will have to search 4 entries to get the result

Creating Index



- Creating an index

Index's name

For this column

```
create index idx_name
   on tv_shows(name)
```

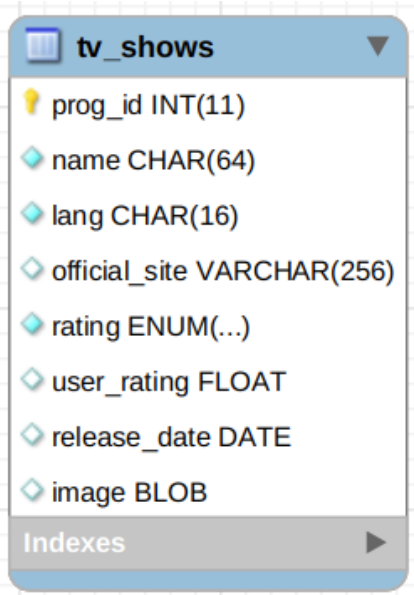
- Speed up all queries where the predicate involves the `name` column only

```
select * from tv_shows where name like 'Game%';
```

- Index will slow down inserts
  - Have to insert into the index at the correct (sorted) location

Multi Column Index

```
create index lang_release_date_idx
   on tv_shows(release_date, lang);
```



release_date	lang
2008-11-30	EN
2015-10-10	EN
2015-09-20	IS
2010-09-26	SE

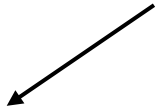
prog_id	name	lang	release_date
20	Borgen	SE	2010-09-26
9	Wallander	EN	2008-11-30
25	The Last Kingdom	EN	2015-10-10
5	Ófærð	IS	2015-09-20

```
select * from tv_shows
   where release_date > '2014-01-10' and lang like 'is'
```

Multi Column Index

- Column with higher cardinality should be placed first
  - Index cardinality means the number of unique values
  - A unique

`release_date` has a higher cardinality than `lang`
Should be placed at the left most



release_date	lang
2008-11-30	EN
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2015-09-20	IS
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prog_id	name	lang	release_date
20	Borgen	SE	2010-09-26
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25	The Last Kingdom	EN	2015-10-10
5	Ófærð	IS	2015-09-20

Using Multi Column Index

- Order is important

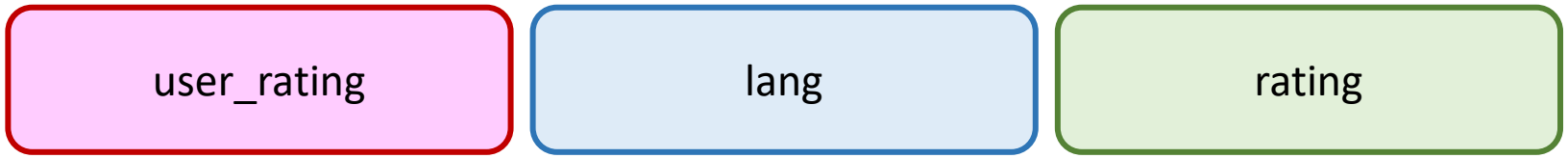
```
select * from tv_shows
   where release_date > '2014-01-01' and lang like 'is'
```

- Use of index from left to right

```
select * from tv_shows
   where release_date > '2010-01-01'
```

```
select * from tv_shows
   where lang = 'en'
```

Using Multi Column Index



```
where user_rating > 5

where user_rating > 5 and lang = 'EN'

where user_rating > 5 and lang = 'EN' and rating = 'NC16'
```

```
where lang = 'EN'

where lang = 'EN' and rating = 'NC16'

where lang = 'EN' and user_rating > 5
```

Covering Index

- Results can be returned by just querying the index
  - Index contains all the columns to fulfil the query
  - The index holds all the data

```
create index lang_release_date_idx
  on tv_shows(release_date, lang);
```

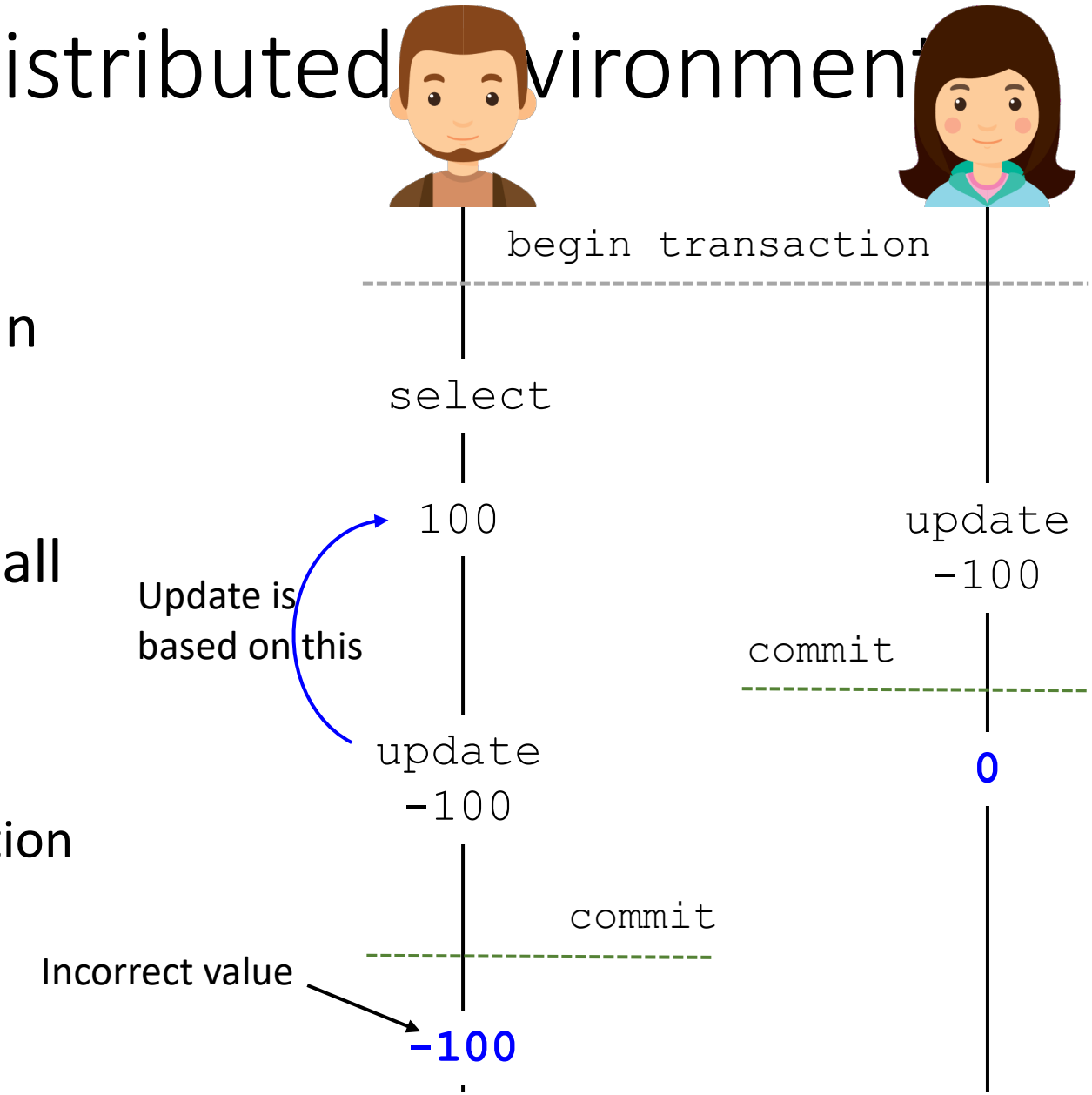
```
select distinct(lang) from tv_shows
  where release_date > '2019-01-01'
```

Result can be returned from query

```
select release_date from tv_shows
  where lang like 'en'
```

Values Changes in Distributed Environment

- What happens when you perform a commit based on an old value?
  - When the record has changed
- Use pessimistic locks to eject all changes until you have completed your update
  - Bad because will slow the application because of contention



Conditional Update

- Updating a single record may be incorrect if the original value of the read has changed
- Perform the update based on an expected value of a field
  - Eg a timestamp
  - Compare and set method
- Eg. Withdrawing $70 from an account
  - Current account balance is $100
  - Update balance to $30 provided the balance is still $100

```
select @old_balance := balance,
       @last_update := update_time
   from accounts
   where acct_id = 'abc123';

insert into accounts
   set balance = balance - @amount
   where balance = @old_balance and
      update_time = @last_update
```

Implementing Conditional Update

- Using a extra column to hold the timestamp of the last update
  - Column will be automatically updated when the record is updated

```
create table accounts (
    acct_id varchar(8) not null,
    balance decimal(10,2),
    last_update default current_timestamp
           on update current_timestamp,
    primary key(acct_id)
)
```

Update this field with the timestamp whenever the record is updated

```
select * from accounts
    where acct_id = 'abc123'`
```

```
update accounts
    set balance = <new_balance>
    where last_update = <last_update from select>
```

What are Transactions?

- Group multiple operations into a single atomic unit of work
  - All operations within this group must succeed or not performed at all
  - Keep the database in a consistent state
- At the end of a transaction
  - Commit - save all the work performed inside the transaction
  - Rollback - discard all the work performed inside the transaction
- Transactions are isolated and independent of any other transactions
  - Happening at the same time
- Transactions must exhibit ACID property

ACID Properties

Atomicity

Each transaction is all or nothing

Consistency

Data should be valid according to the all defined rules

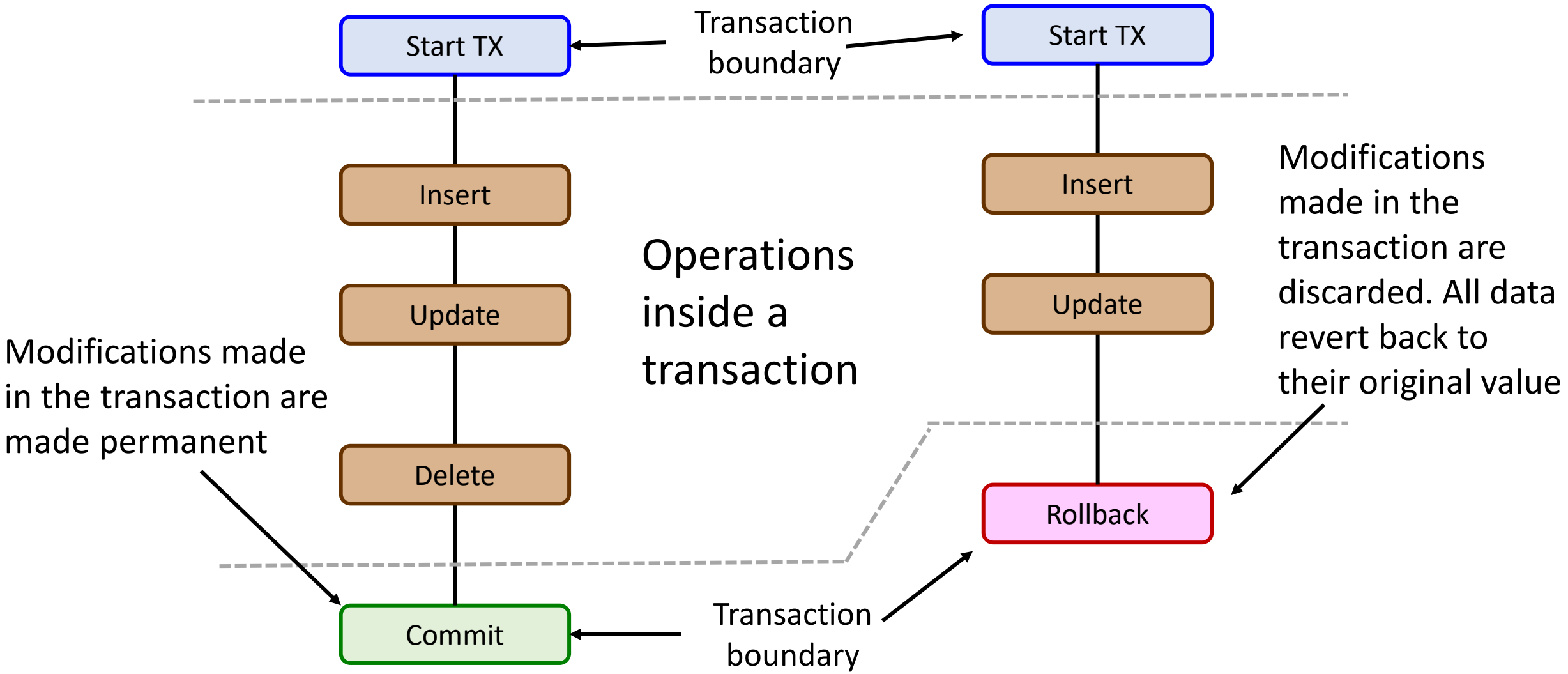
Isolation

Transactions do not affect each other

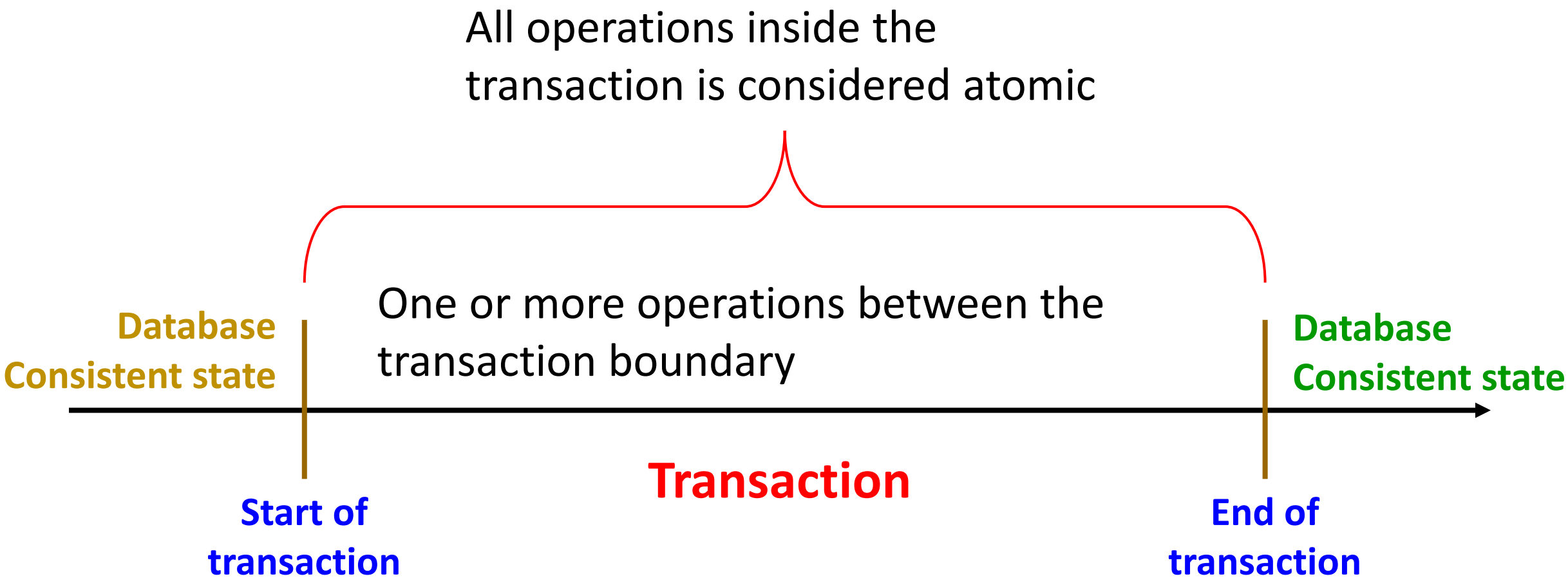
Durability

Committed data would not be lost

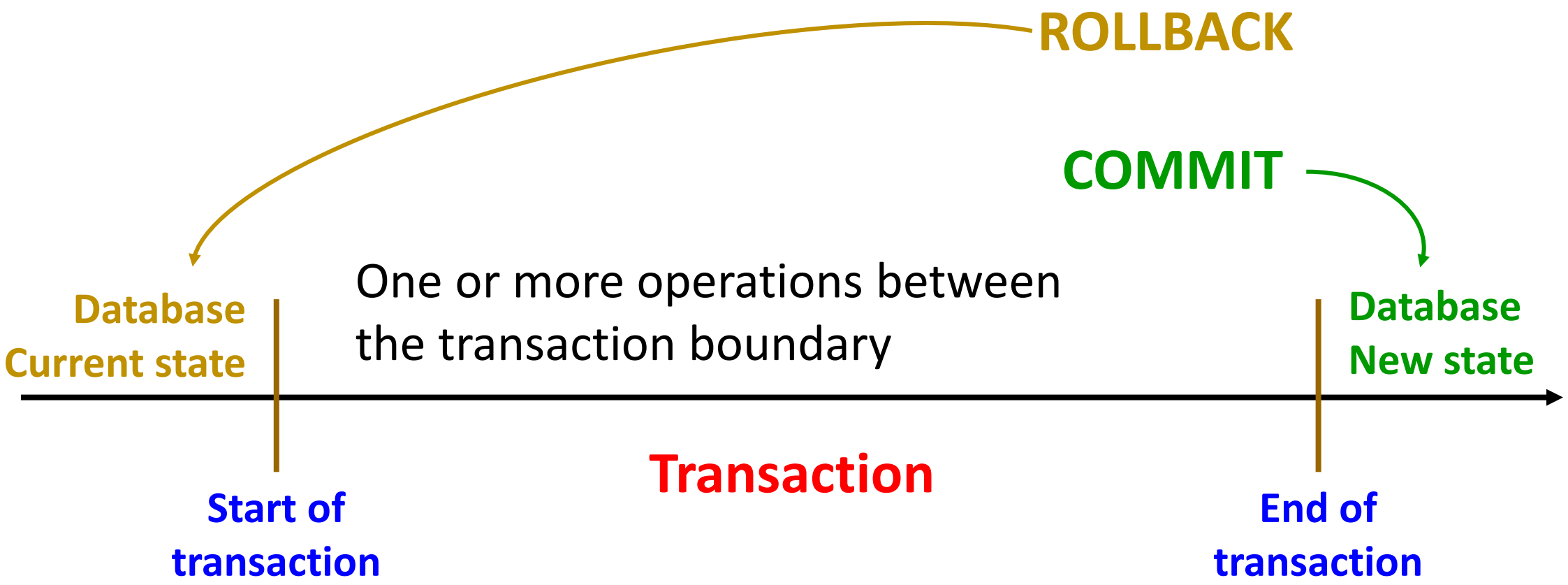
Transaction



Transaction



Transaction



When to Use Transaction?

- When you have to modify related data from a few different tables from the same database
- If anyone of the operation fails, then must revert all the modified data back to its original value
  - Eg. Funds transfer from one account to another
- Prevent another operation from interfering with you operation before you commit your data
  - Eg. Prevent others from reading your new address before you finish the update

Funds Transfer - Atomicity

Fred

Transfer $100

Barney

Balance: $500

Balance: $300

$100

Balance: $400

$100

Balance: $400

Funds Transfer - Atomicity

Fred

Transfer $100

Barney

Balance: $500

Balance: $300

$100

Balance: $400

Inconsistent

Balance: $300

Transaction in SQL

Assume that there are enough funds in `from_acct` for the transfer

```
set @from_acct = 'fred';
set @to_acct = "barney";
set @amount = 100;

start transaction

   update account set balance = balance - @amount
      where acct_id = @from_acct;

   update account set balance = balance + @amount
      where acct_id = @to_acct;

commit;
```

The 2 update statement must complete successfully or not executed at all

Performing Transaction

- Methods that are annotated with `@Transaction`
  - Typically methods in `@Service` but may also be present on other bean eg. `@Repository`
- Transaction are automatically committed when the method completes successfully
- Transaction will rollback when an unchecked exception is thrown
  - Exceptions subclass from `RuntimeException`
- Can specify a specific transaction with `rollbackFor` attribute

Example - Funds Transfer

begin transaction

update account set balance = balance - amount where acct_id = ‘fred’

update account set balance = balance + amount where acct_id = ‘barney’

commit

Example - Funds Transfer

```
@Repository
public class AccountRepository {

    @Autowired private JdbcTemplate template;

    // May throw unchecked exception DataAccessException
    public boolean withdraw(String acctId, double amount) {
        final int rowCount = template.update(
            "update account set balance = balance - ? where acct_id = ?",
            amount, accountId);
        return rowCount > 0;
    }

    public boolean deposit(String acctId, double amount) {
        final int rowCount = template.update(
            "update account set balance = balance + ? where acct_id = ?",
            amount, accountId);
        return rowCount > 0;
    }
}
```

Example - Funds Transfer

```
@Repository
public class AccountRepository {

    @Autowired private JdbcTemplate template;

    ...

    public Optional<double> getBalance(String acctId) {
        final SqlRowSet rs = template.query(
            'select balance from account where acct_id = ?', acctId);
        return Optional.ofNullable(
            rs.next()? rs.getDouble("balance"): null);
    }
}
```

Example - Funds Transfer

```
@Service
public class FundsTransfer {
    @Autowired AccountRepository acctRepo;

    @Transactional
    public void transfer(String fromAcct, String toAcct, double amount) {

        final Optional<double> optFrom = acctRepo.getBalance(fromAcct);
        final Optional<double> optTo = acctRepo.getBalance(toAcct);
        if (optFrom.isEmpty() || optTo.isEmpty() || (optFrom.get() < amount))
            throw new IllegalArgumentException("Incorrect parameters");

        if !(acctRepo.withdraw(fromAcct, amount) ||
                acctRepo.deposit(toAcct, amount))
            throw new DataAccessException("Cannot perform transfer");

    }
}
```

Transaction boundary

Transaction will rollback when these exceptions are thrown

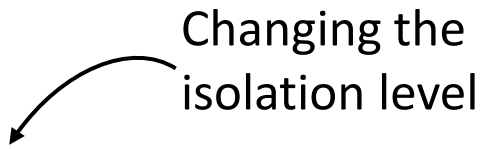
Transaction commits when exit.
Updates are now permanent

Isolation

- Multiple transactions can occur independently at the same time without interfering each other
- The intermediate states of an inflight transaction is invisible to other transactions
  - Partially updated records in a fund transfer should not be visible to another transaction or any queries happening at the same time
- Types of isolation
  - Dirty reads – transaction B can read uncommitted data in transaction A
  - Non repeatable reads – a record that is read more than once in a transaction cannot guarantee to return the same value
  - Phantom reads – reading a set of records more than once in a transaction can return more or less records, non repeatable reads at a record level

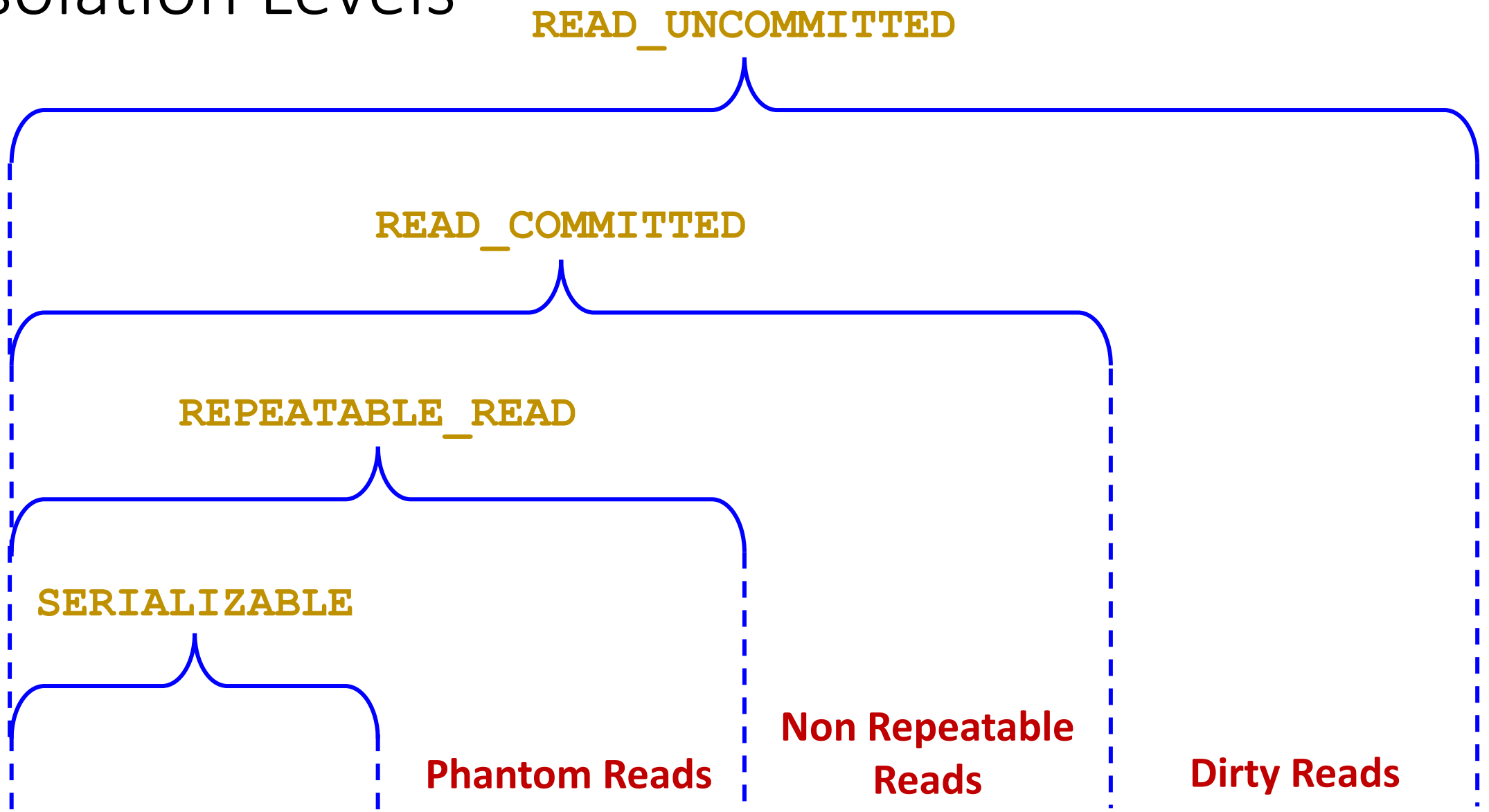
Isolation Level

- JDBC drivers uses isolation level to provide data integrity during a transaction
  - `READ_UNCOMMITTED`
  - `READ_COMMITTED`
  - `REPEATABLE_READ`
  - `SERIALIZABLE`
- MySQL JDBC driver default isolation level is set to `REPEATABLE_READ`




```
@Transactional(isolation=Isolation.SERIALIZABLE)
public void transfer(String fromAcct, String toAcct, double amount) {
```

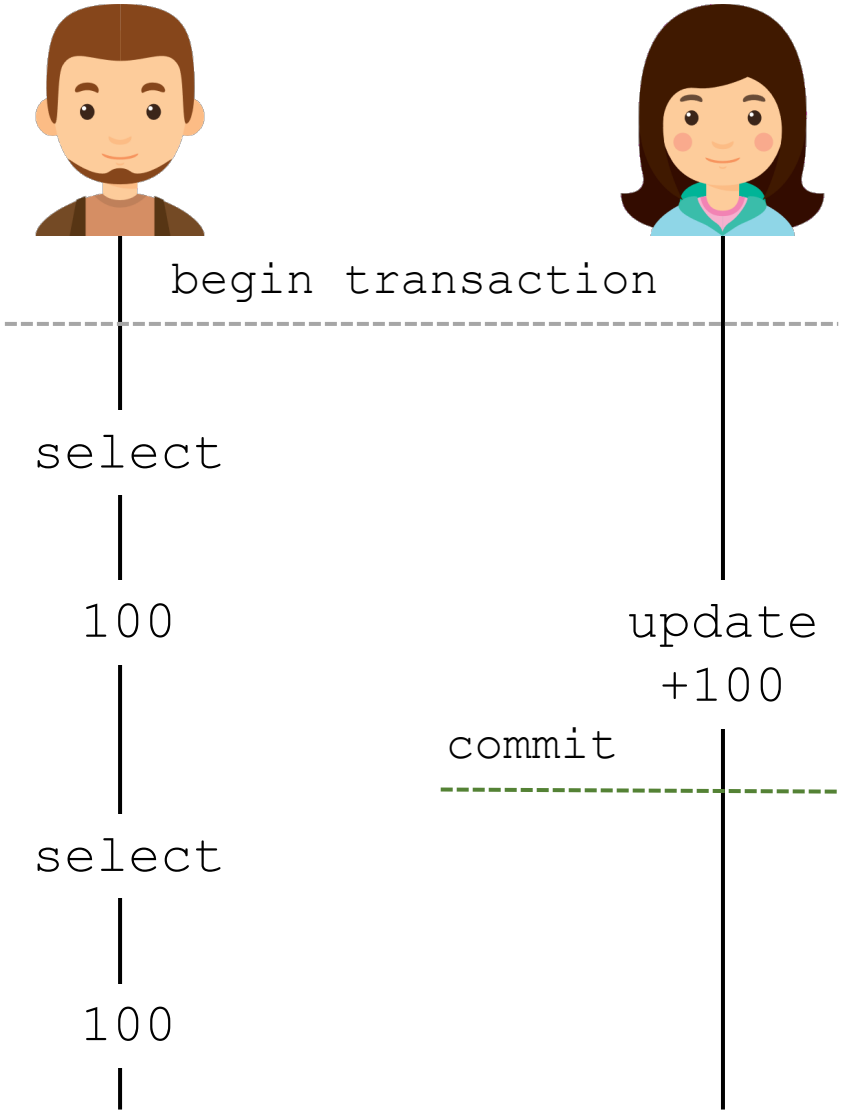
Isolation Levels



Unused

Isolation Level - Repeatable Read

- Refers to the visibility of uncommitted results inside a transaction
- Default is Repeatable Reads
- Reads of in flight transactions are isolated from changes
- Defaults to JDBC driver when not set
  - MySQL defaults to repeatable read (TRANSACTION_READ_COMMITTED)



Locks in Transaction

- MySQL will lock the required resources inside a transaction to ensure data consistency
- Row locking for tables with the required index(s)
  - Other sessions can access other rows except for the locked row

```
update account set balance = balance - amount
   where acct_id like 'fred'
```

Primary key has index

- Table locking if the table does not have the appropriate index(s)
  - No session can access any records from the table until transaction completes

```
update account set balance = balance - amount
   where name like 'fred'
```

Non primary key might not have index