We have Multiple Concurrent Versions of this Title Trying to Understand MVCC

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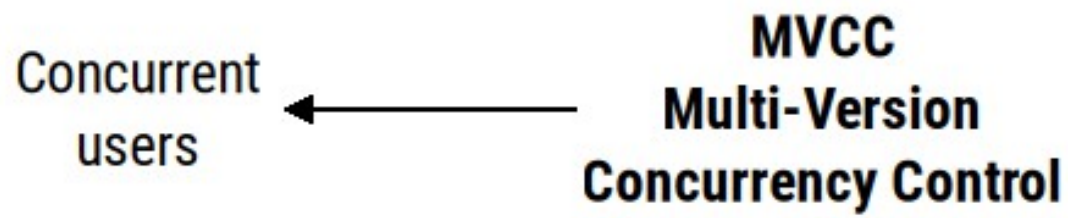
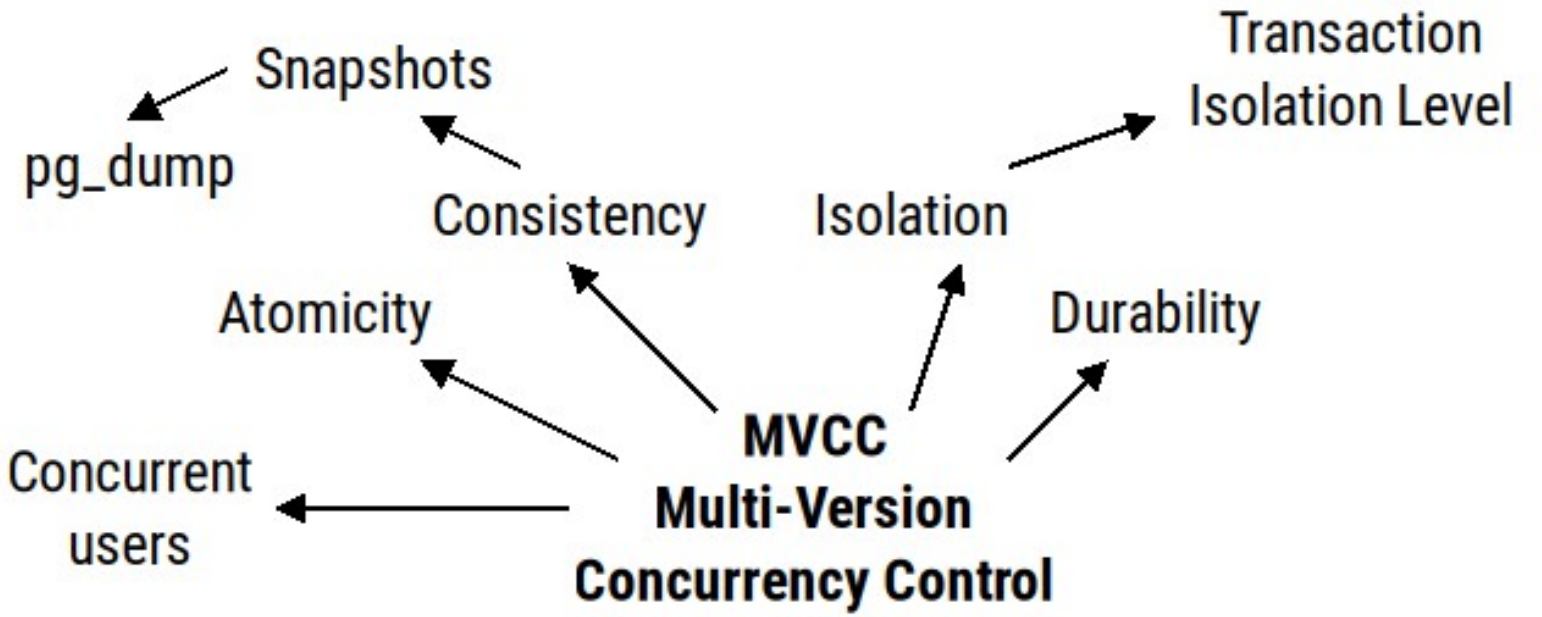
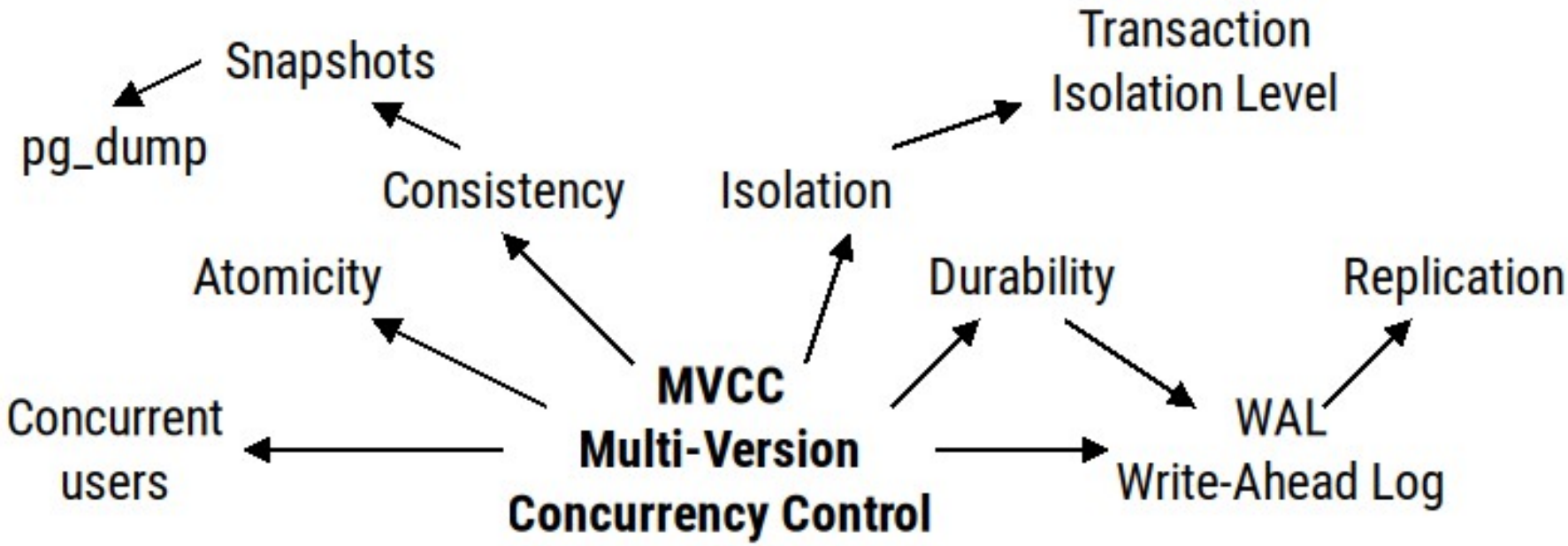
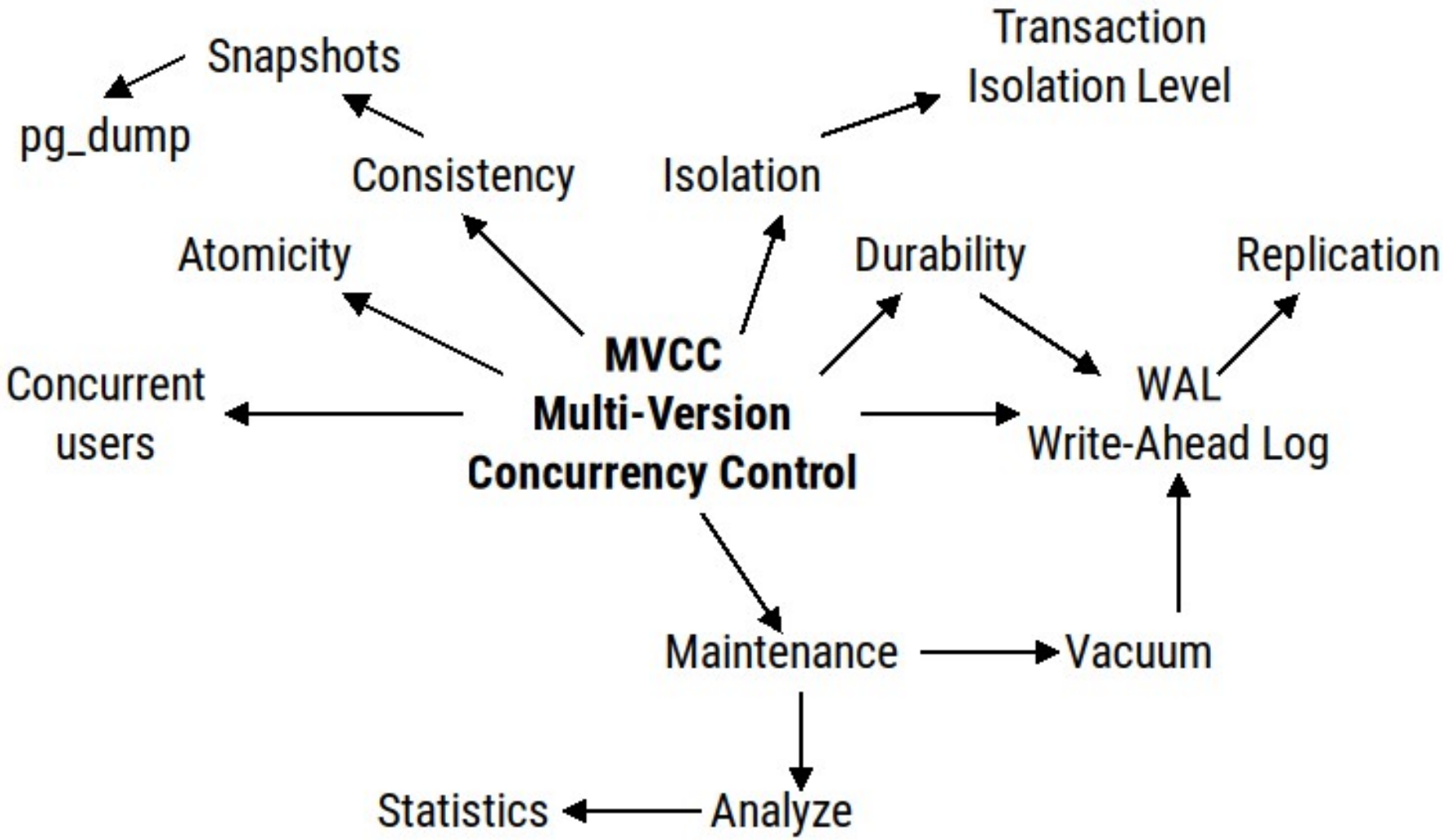
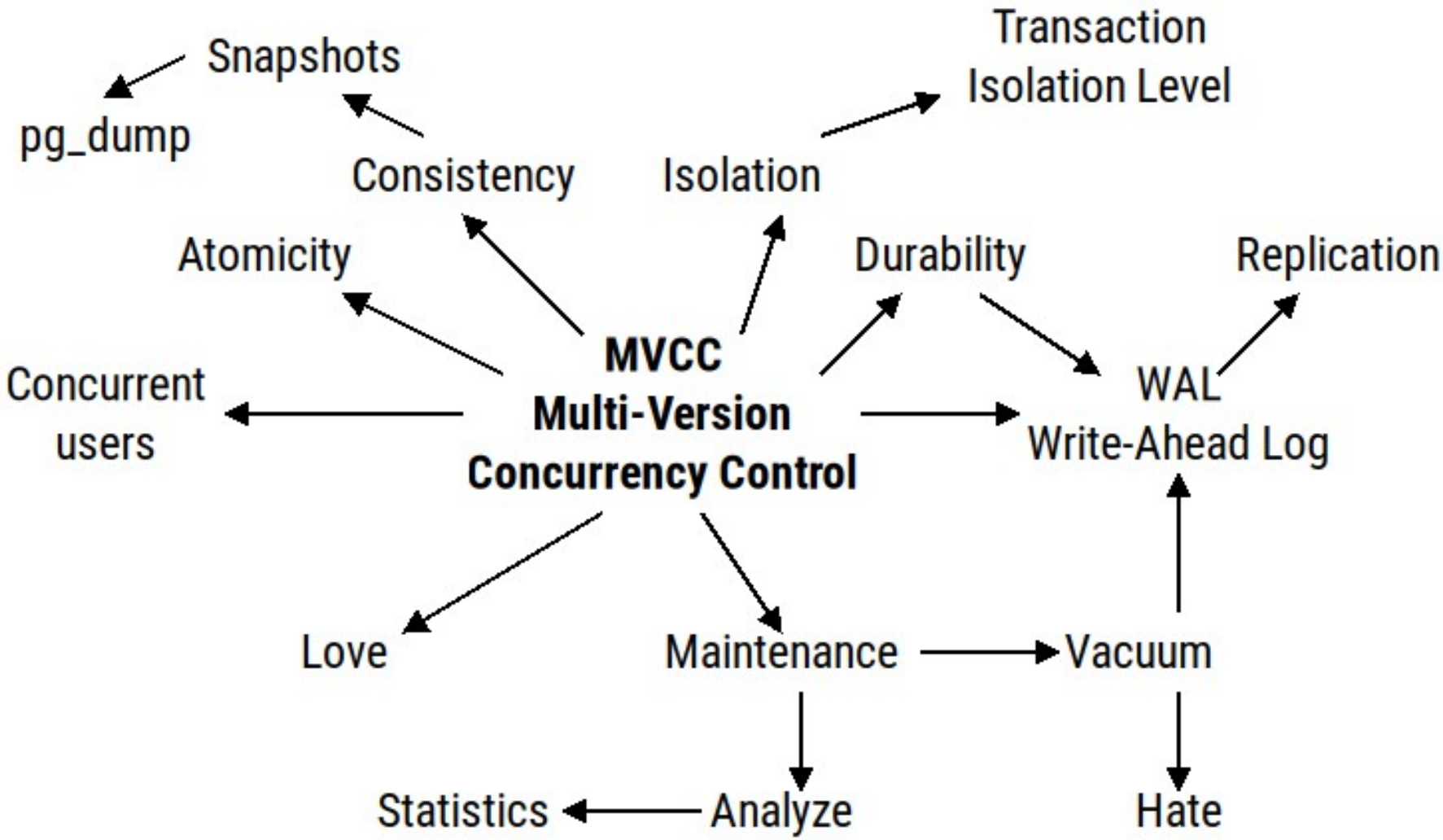
MVCC
Multi-Version
Concurrency Control











A cold but beautiful
autumn day in Riga
with fresh air and crispy grass

No user (client backend)
was connected to the database
but we observed
a large replication lag (several GB)

autovacuum was running
cleaning **dead rows**
as the gardeners in the park
were cleaning the dead leaves

Multi-Version Concurrency Control

Each row can have multiple versions
Only one version is visible to each observer
Time consistent view of the whole database
Snapshot

Everything runs in a transaction

```
INSERT INTO key_value
VALUES (1867, 'Mikhail Eisenstein');
```

Everything runs in a transaction

```
BEGIN;
INSERT INTO key_value
VALUES (1867, 'Mikhail Eisenstein');
COMMIT;
```

Concurrency

```
BEGIN;



SELECT value
  FROM key_value
 WHERE key = 1867;


COMMIT;
```

```
BEGIN;
UPDATE key_value
SET value = 'Mihails Eizenšteins'
WHERE key = 1867;


COMMIT;
```

Time

MVCC Basic Concepts

Each transaction has an identifier
`txid_current()`

Each row has visibility information
`xmin` and `xmax`

Each transaction has a status
`txid_status(txid)`

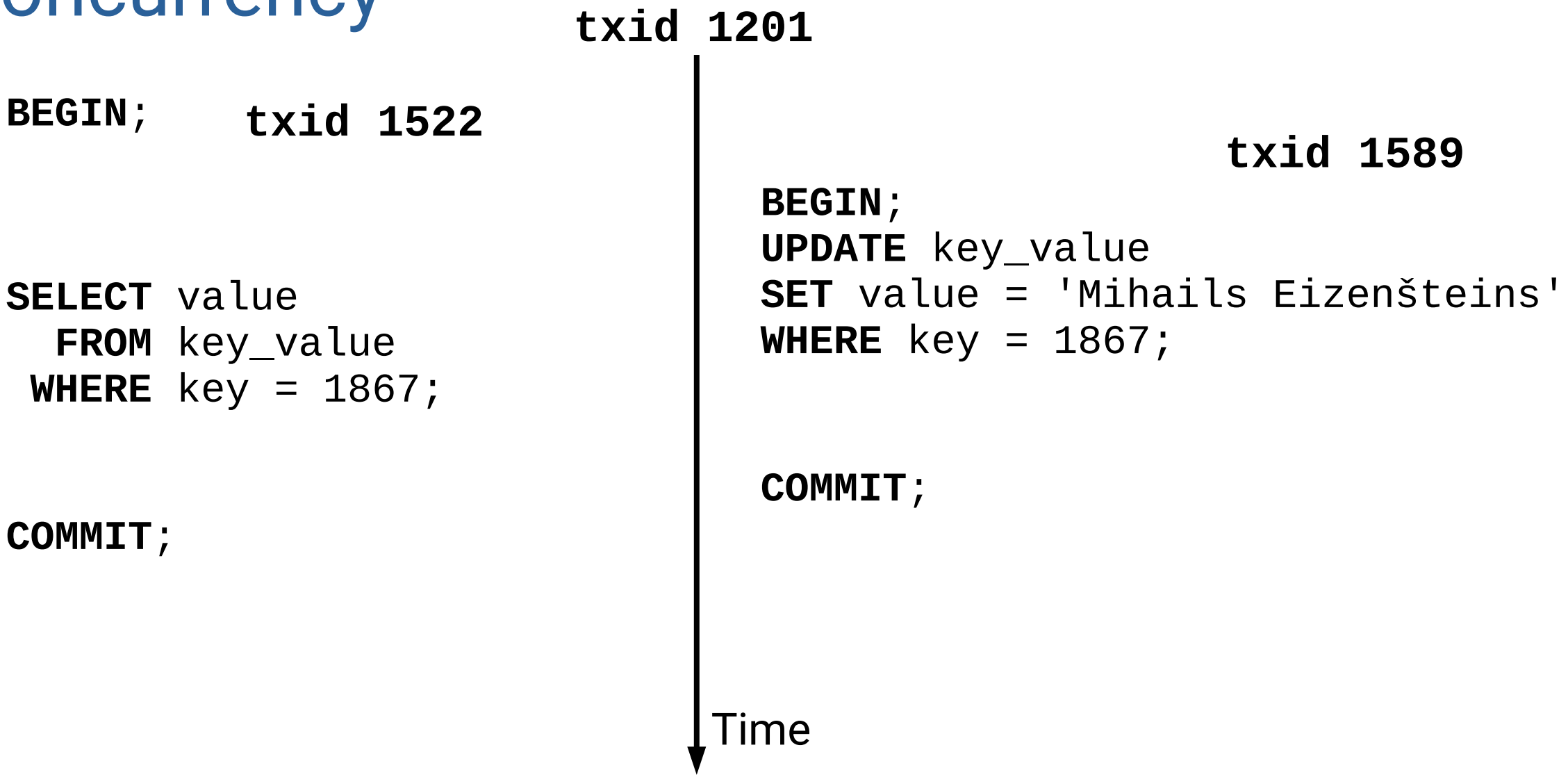
SQL write statements

`INSERT` sets **`xmin`**

`DELETE` sets **`xmax`**

`UPDATE` is delete and insert
sets **`xmax`**
creates a new version with **`xmin`**

Concurrency



Multi-Versions of the Row

```
xmin xmax    key   value
1201 0       1867  'Mikhail Eisenstein'

UPDATE →
xmin xmax    key   value
1201 1589    1867  'Mikhail Eisenstein'
1589 0       1867  'Mihails Eizenšteins'
```

Commit state of txid 1589 will be
“in progress”, “committed” or “aborted”

Dead rows

Dead rows

DELETE creates a dead row

UPDATE: *delete* and insert → dead row

ROLLBACK of writes → dead row

Too many dead rows → bloated table

Isolation Levels

Transaction Isolation Level

READ COMMITTED
REPEATABLE READ
SERIALIZABLE
READ UNCOMMITTED

Transaction Isolation Level

READ COMMITTED
REPEATABLE READ
SERIALIZABLE
~~READ UNCOMMITTED~~

Concurrency

```
BEGIN;


SELECT value
  FROM key_value
 WHERE key = 1867;



SELECT value
  FROM key_value
 WHERE key = 1867;

COMMIT;
```

```
BEGIN;
UPDATE key_value
SET value = 'Mihails Eizenšteins'
WHERE key = 1867;


COMMIT;
```

Time

Vacuum

VACUUM

VACUUM <table_name>;
Removes dead rows
Unless they are still potentially visible

Vacuum

```
BEGIN;
```

```
SELECT value
  FROM key_value
 WHERE key = 1867;
```

```
SELECT value
  FROM key_value
 WHERE key = 1867;
```

```
BEGIN;
UPDATE key_value
SET value = 'Mihails Eizenšteins'
WHERE key = 1867;

COMMIT;
```

Vacuum

```
BEGIN;
```

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SELECT value
  FROM key_value
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SELECT value
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```

```
BEGIN;
UPDATE key_value
SET value = 'Mihails Eizenšteins'
WHERE key = 1867;

COMMIT;

VACUUM;
```

Time

Table pg_catalog.pg_stat_all_tables

```
-[ RECORD 1 ]-------+-----------
relid               | 24652
schemaname          | riga
relname             | key_value
n_tup_ins           | 11284004
n_tup_upd           | 6712
n_tup_del           | 425152
n_tup_hot_upd       | 713
n_live_tup          | 10858852
n_dead_tup          | 5666
n_mod_since_analyze | 6210
n_ins_since_vacuum  | 4851
```

VACUUM riga.key_value;

```
-[ RECORD 1 ]-------+-----------
relid               | 24652
schemaname          | riga
relname             | key_value
n_tup_ins           | 11284004
n_tup_upd           | 6712
n_tup_del           | 425152
n_tup_hot_upd       | 713
n_live_tup          | 10858852
n_dead_tup          | 0
n_mod_since_analyze | 6210
n_ins_since_vacuum  | 0
```

VACUUM ANALYZE riga.key_value;

```
-[ RECORD 1 ]-------+-----------
relid               | 24652
schemaname          | riga
relname             | key_value
n_tup_ins           | 11284004
n_tup_upd           | 6712
n_tup_del           | 425152
n_tup_hot_upd       | 713
n_live_tup          | 10858852
n_dead_tup          | 0
n_mod_since_analyze | 0
n_ins_since_vacuum  | 0
```

VACUUM

VACUUM <table_name>;
Removes dead rows
Unless they are still potentially visible

Hunt ‘idle in transaction’ sessions!!
And long running queries!!

Use pg_catalog.pg_stat_activity

```
SELECT pid
FROM pg_stat_activity
WHERE state = 'idle in transaction';

SELECT pid
     , query
     , wait_event_type
     , wait_event
     , now() - query_start
FROM pg_stat_activity
WHERE state='active'
AND now()-query_start > interval '15 minutes';
```

Use pg_catalog.pg_stat_activity

```
SELECT pg_terminate_backend(pid)
FROM pg_stat_activity
WHERE state = 'idle in transaction';

SELECT pg_cancel_backend(pid)
     , query
     , wait_event_type
     , wait_event
     , now() - query_start
FROM pg_stat_activity
WHERE state='active'
AND now()-query_start > interval '15 minutes';
```

VACUUM effects

VACUUM locks against DDL
INSERT, DELETE, UPDATE can still run
It does not reduce size of tables

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Divertimento or delude

VACUUM FULL
Locks Everything

VACUUM effects

VACUUM locks against DDL
INSERT, DELETE, UPDATE can still run
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Divertimento or delude

VACUUM FULL
Locks Everything
It creates a new table

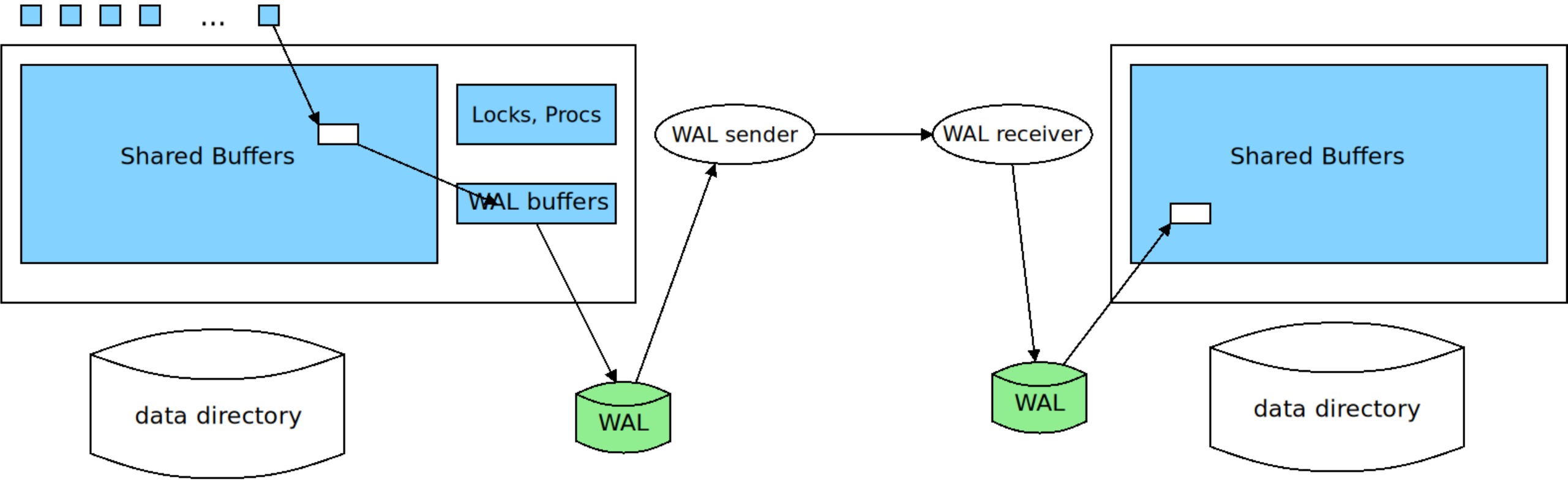
VACUUM effects

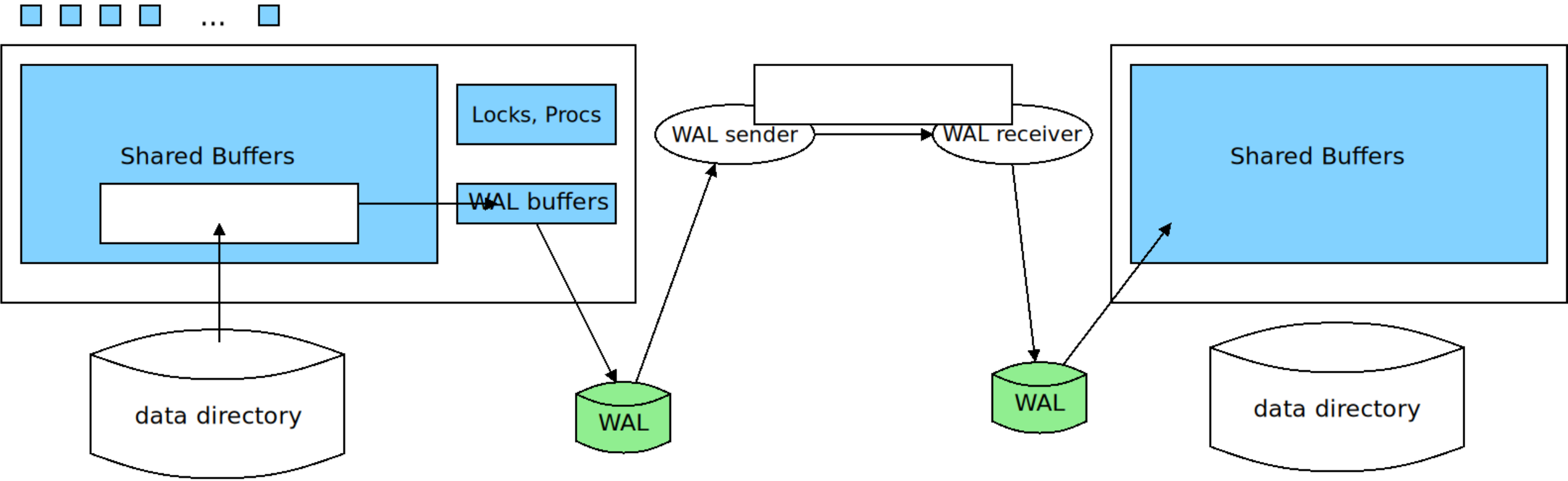
VACUUM locks against DDL
INSERT, DELETE, UPDATE can still run
It does not reduce size of tables

Divertimento or delude

VACUUM FULL
Locks Everything
It creates a new table
Think of a butterfly

Replication


...
Shared Buffers
Locks, Procs
WAL buffers
WAL sender
WAL receiver
Shared Buffers
data directory
WAL
WAL
data directory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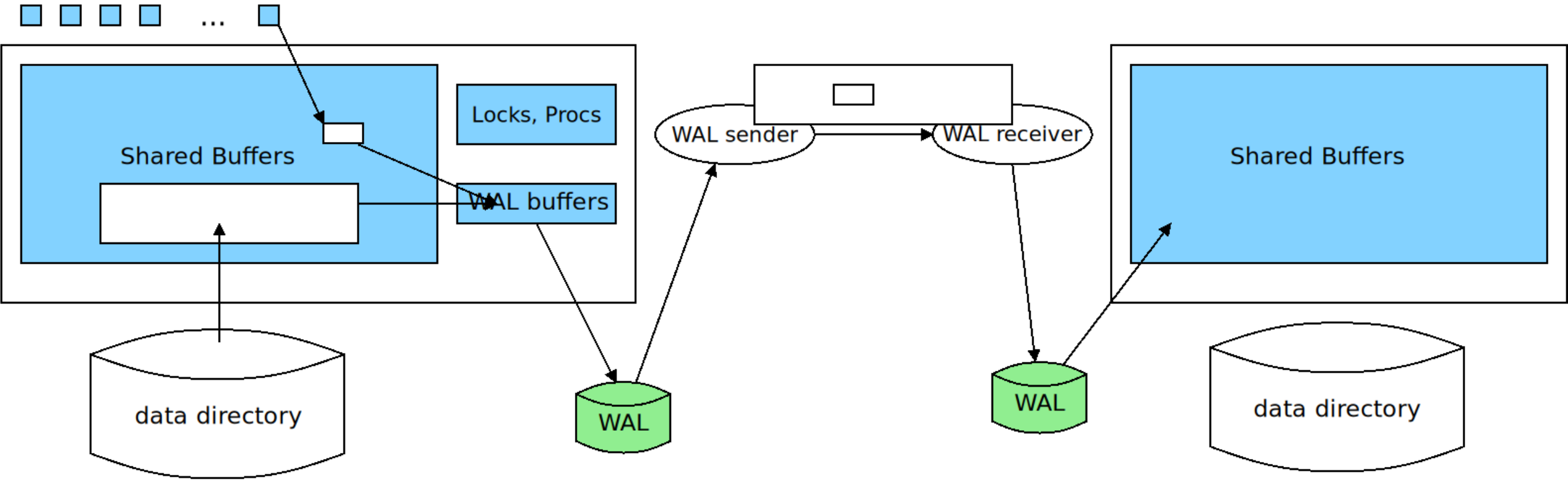
...
Shared Buffers
Locks, Procs
WAL buffers
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WAL receiver
Shared Buffers
data directory
WAL
WAL
data directory

autovacuum

Autovacuum

It runs **VACUUM** and **ANALYZE**
Runs all the time
No scheduling, just nap times
It cancels itself to avoid blocking user’s actions

Table pg_catalog.pg_stat_all_tables

```
-[ RECORD 1 ]-------+-----------
relid               | 24652
schemaname          | riga
relname             | key_value
last_vacuum         | 2025-10-17 14:18:24
last_autovacuum     | 2025-10-23 06:23:16
last_analyze        | 2025-03-13 12:58:42
last_autoanalyze    | 2025-10-23 06:23:16
vacuum_count        | 7
autovacuum_count    | 6128
analyze_count       | 10676
autoanalyze_count   | 10
```

Check the progress

Table pg_catalog.pg_stat_progress_vacuum

```
-[ RECORD 1 ]------+-----------
pid                | 27666
datid              | 18613
datname            | riga
relid              | 24652
phase              | performing final cleanup
heap_blks_total    | 1
heap_blks_scanned  | 1
heap_blks_vacuumed | 1
index_vacuum_count | 0
max_dead_tuples    | 291
num_dead_tuples    | 0
```

Table pg_catalog.pg_stat_progress_analyze

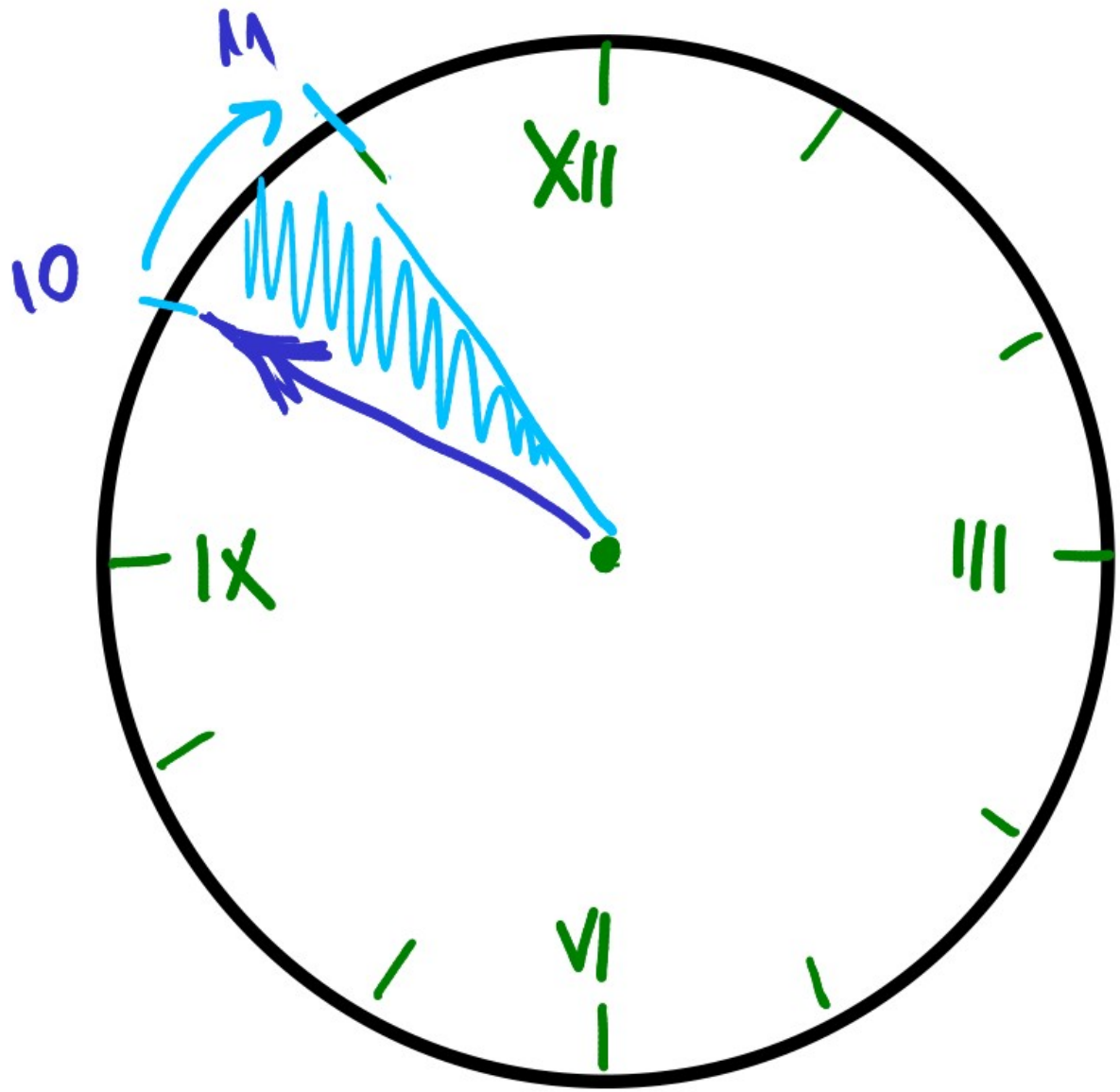
```
-[ RECORD 1 ]----------+-----------
pid                    | 3012146
datid                  | 18613
datname                | riga
relid                  | 66209
phase                  | acquiring sample rows
sample_blks_total      | 30000
sample_blks_scanned    | 3454
ext_stats_total        | 0
ext_stats_computed     | 0
child_tables_totals    | 0
child_tables_done      | 0
current_child_table_relid | 0
```

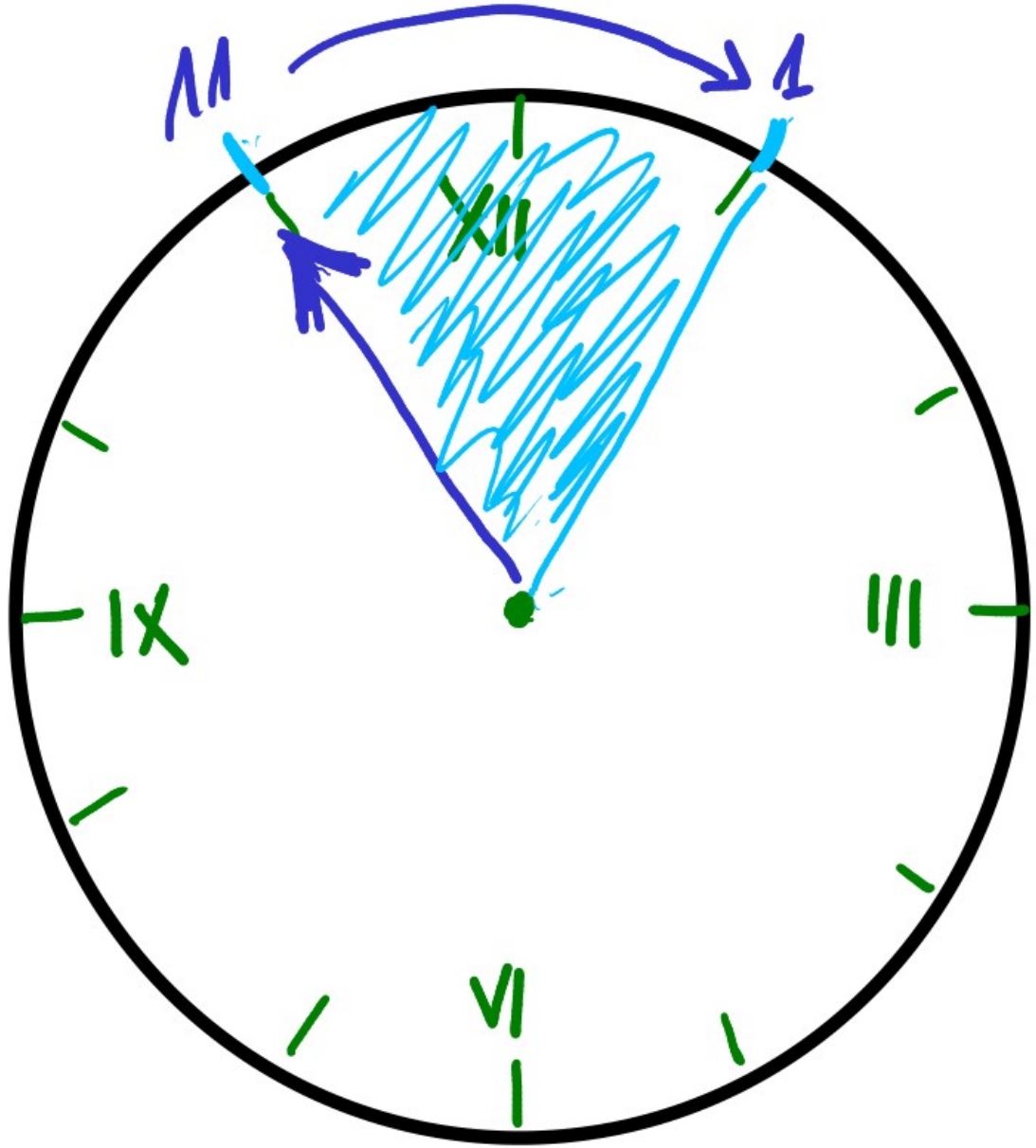
At the Pub

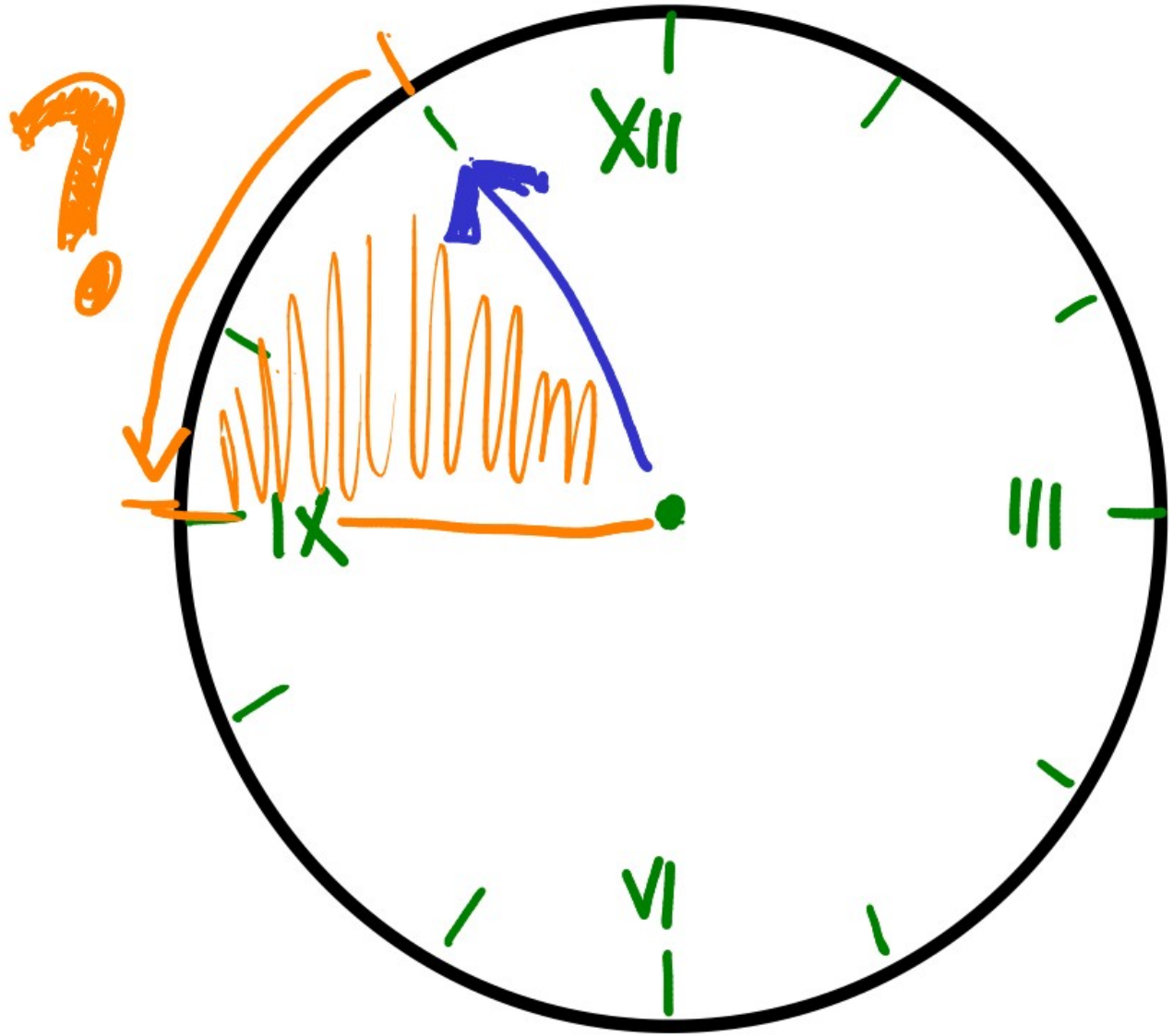
Freezing

Transactions are 4 byte integers

Counter wraps every 4 billion xids


11
10
XII
IX
III
VI


11
1
XII
IX
III
VI


XII
III
VI
IX

Freezing

Transactions are 4 byte integers

Counter wraps every 4 billion xids

Visibility of 2 billion xids to the past

Very old rows get frozen

Table pg_catalog.pg_database

```
datname        | name
datdba         | oid
encoding       | integer
datcollate     | name
datctype       | name
datistemplate  | boolean
datallowconn   | boolean
datconnlimit   | integer
datlastsysoid  | oid
datfrozenxid   | xid
datminmxid     | xid
dattablespace  | oid
datacl         | aclitem[]
```

Table pg_catalog.pg_database

```
datname       | name
datdba        | oid
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datallowconn  | boolean
datconnlimit  | integer
datlastsysoid | oid
datfrozenxid  | xid
datminmxid    | xid
dattablespace | oid
datacl        | aclitem[]
```

Table pg_catalog.pg_database

```
SELECT datname
     , datfrozenxid
     , age(datfrozenxid)
FROM pg_database;
```

Closing Words

Multi-Version Concurrency Control and VACUUM

Multi-Version Concurrency Control is crucial for ACID

Dead rows are created → Maintenance

VACUUM removes dead rows

Autovacuum does it for you

Plenty of data exposed at the catalog

Thank You

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