

Introduction to SQL PostgreSQL





Somkiat Puisungnoen

Somkiat Puisungnoen

Update Info 1 View Activity Log 10+ ...

Timeline About Friends 3,138 Photos More

When did you work at Opendream? X

... 22 Pending Items

Intro

Software Craftsmanship

Software Practitioner at สยามชัมนาณกิจ พ.ศ. 2556

Agile Practitioner and Technical at SPRINT3r

Post Photo/Video Live Video Life Event

What's on your mind?

Public Post

Somkiat Puisungnoen 15 mins · Bangkok · ⚙️

Java and Bigdata



Page

Messages

Notifications 3

Insights

Publishing Tools

Settings

Help ▾



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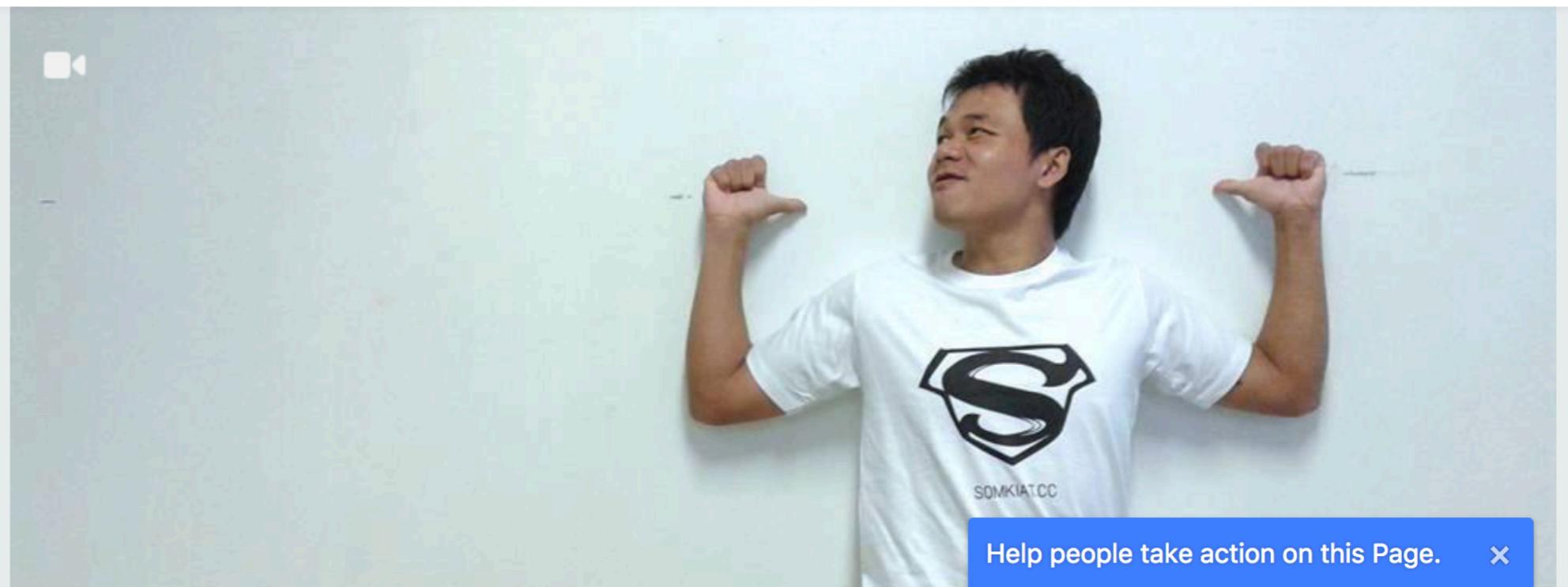
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Home

Posts

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Photos



SQL

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<https://github.com/up1/course-sql>



Topics

Overview of Database

SQL

SQL vs NoSQL

Relationship and JOINs

Database design

Normalization and De-normalization

Workshop



Topics

Read vs Write operation with Database
Improve performance of SQL query
Benchmark and performance testing with
Database (PostgreSQL)



Overview of Database



What is a Database ?

Any **collection** of related **information**

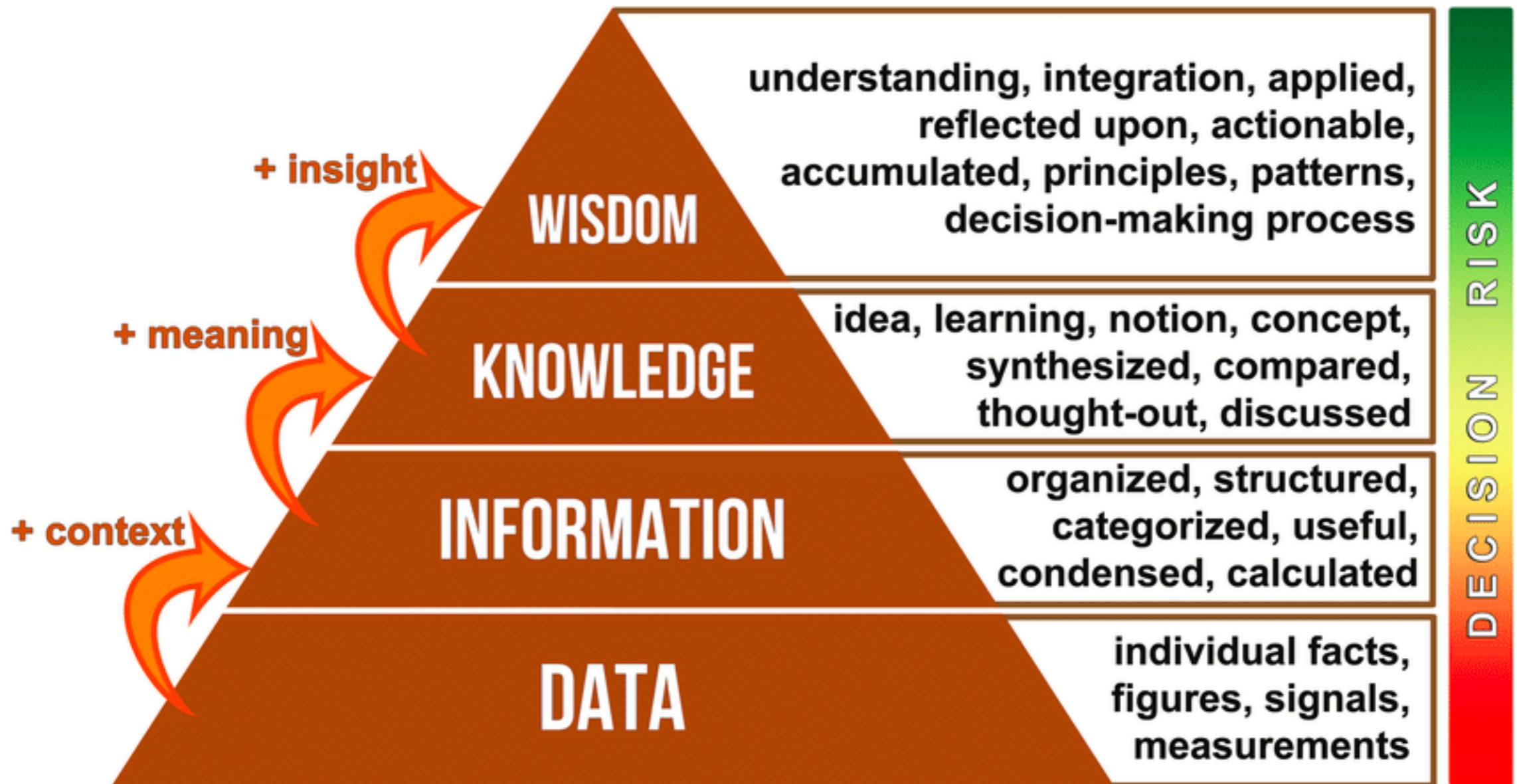
Phone numbers

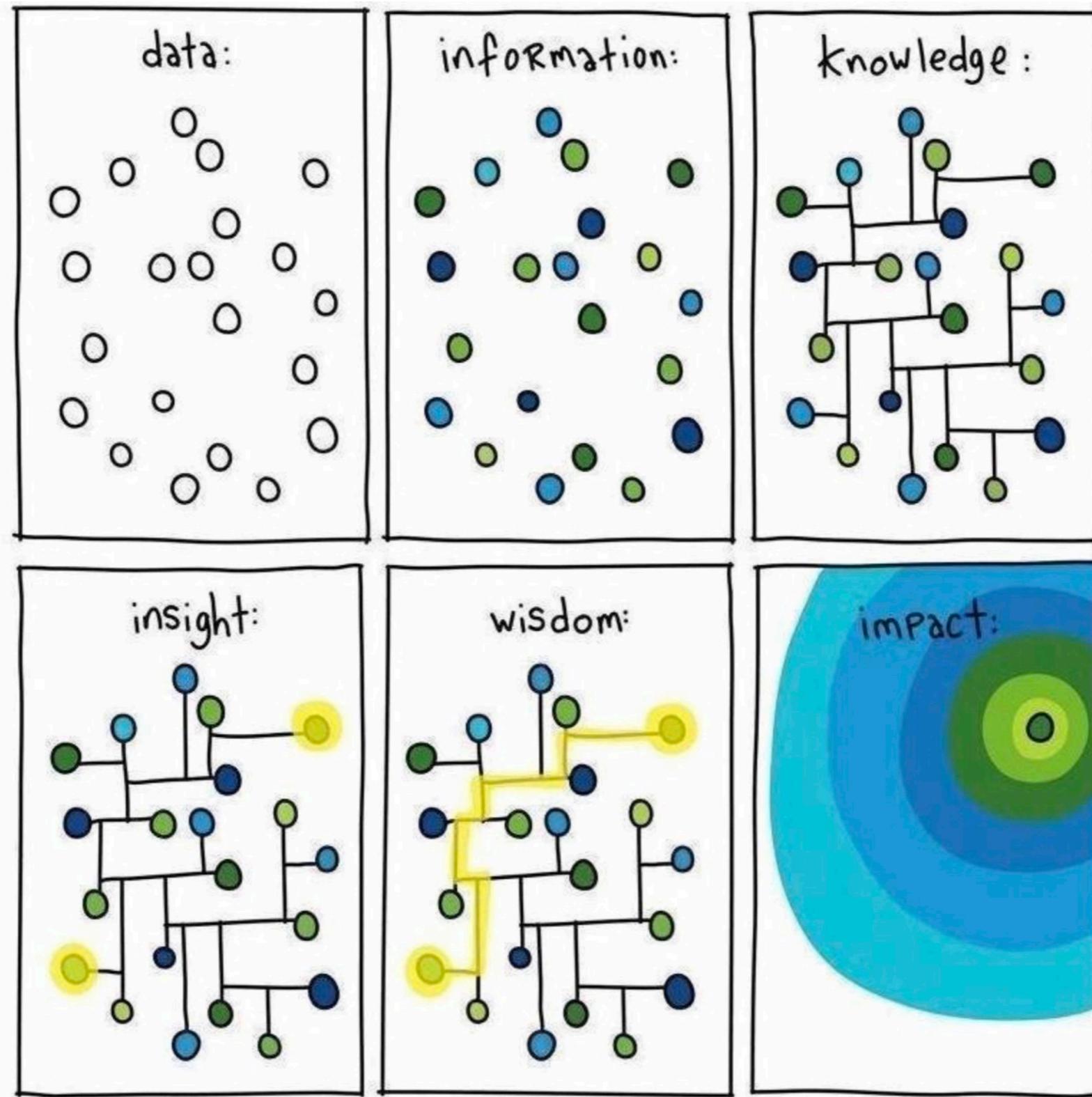
Shopping list

Todo list

LINE group and friends







What is a Database ?

Database can be stored in different ways

On paper

In your mind

On computer

Slide



E-commerce



E-commerce

Keep track of products/reviews/orders/users

Trillions of information need to be stored

Information is extremely valuable

Security is essential

Information is stored on a computer



Computers are great at keeping track of large amounts of information



Database Management System (DBMS)



Database Management System

Special software program
Help users create and maintain a database



Database Management System

Easy to manage large amounts of information

Handles security

Backup

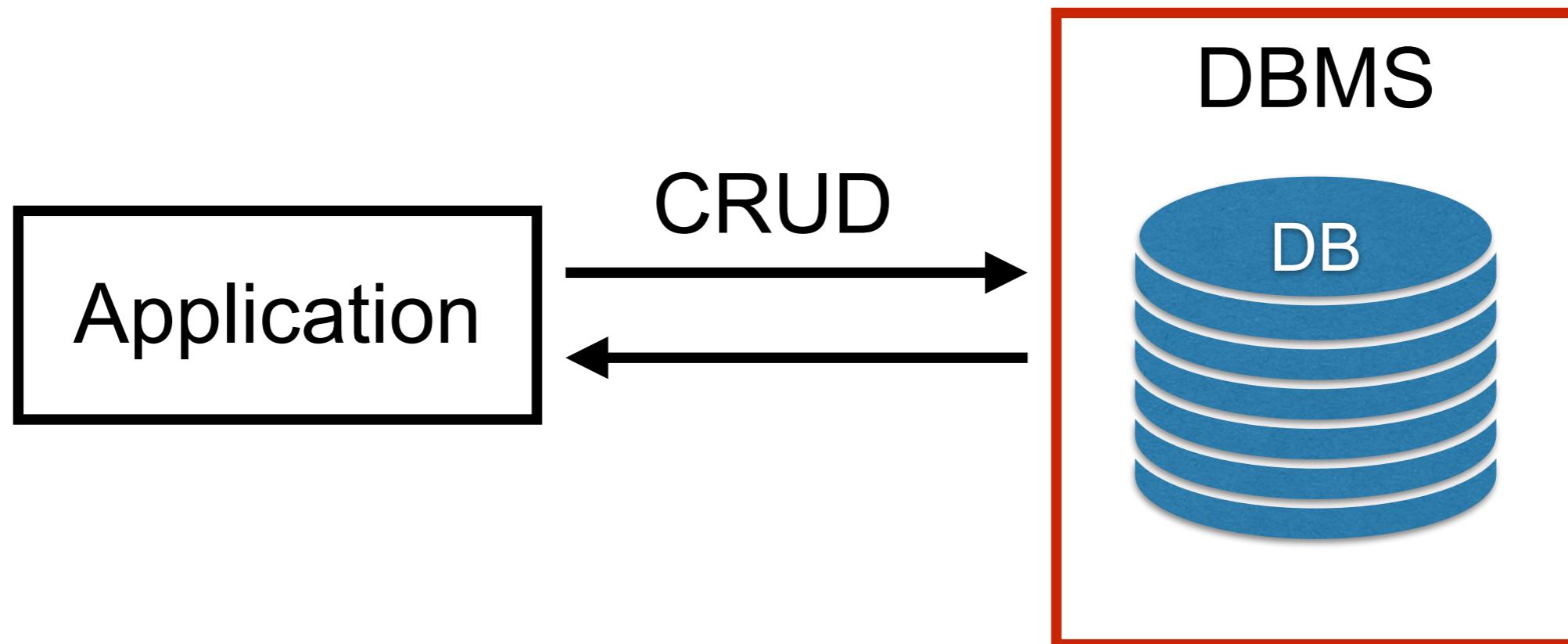
Import/export data

Concurrency

Interface with software applications



Database Management System



C.R.U.D

Create
Read
Update
Delete



Types of Databases



Types of Database

Relational Database (YesSQL)

Non-Relational Database (NoSQL)



1. Relational Database

Organize data into one or more tables

Each table has columns and rows

A unique key identified each row



Table customer

Column or attribute

Customer ID	Firstname	Lastname	Birthdate



Table customer

Row or tuple

Customer ID	Firstname	Lastname	Birthdate
1	Somkiat	Pui	April 18, 2000



Table customer

Unique key of Primary key for each row

Customer ID	Firstname	Lastname	Birthdate
1			
2			
3			
4			



2. Non-Relational Database

Organize data is anything

Key-value store

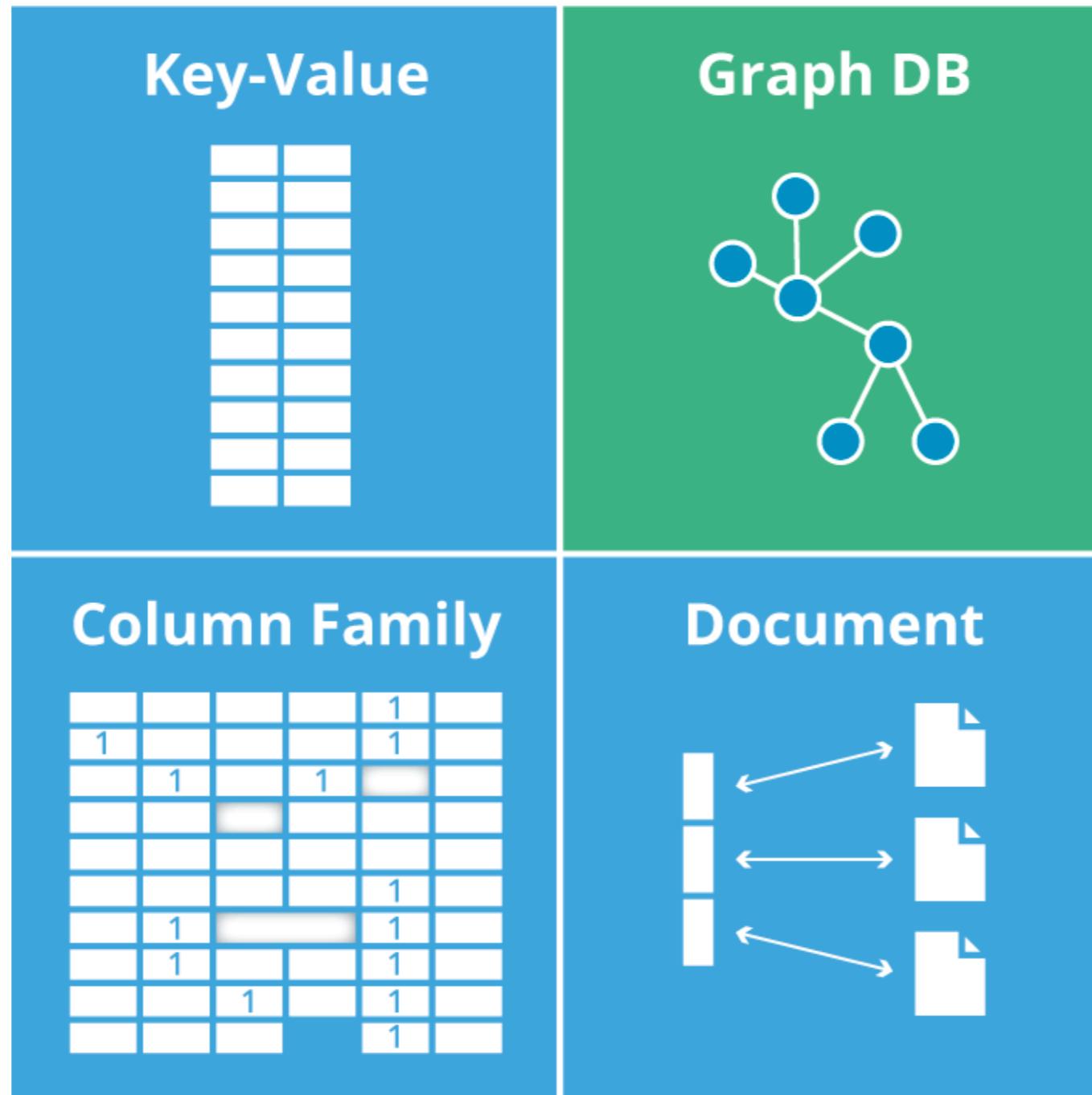
Document-based (JSON, XML)

Graph

Flexible table (Column-based)



NoSQL



Database ranking



Database ranking

358 systems in ranking, September 2020

Rank			DBMS	Database Model	Score		
Sep 2020	Aug 2020	Sep 2019			Sep 2020	Aug 2020	Sep 2019
1.	1.	1.	Oracle 	Relational, Multi-model 	1369.36	+14.21	+22.71
2.	2.	2.	MySQL 	Relational, Multi-model 	1264.25	+2.67	-14.83
3.	3.	3.	Microsoft SQL Server 	Relational, Multi-model 	1062.76	-13.12	-22.30
4.	4.	4.	PostgreSQL 	Relational, Multi-model 	542.29	+5.52	+60.04
5.	5.	5.	MongoDB 	Document, Multi-model 	446.48	+2.92	+36.42
6.	6.	6.	IBM Db2 	Relational, Multi-model 	161.24	-1.21	-10.32
7.	7.	↑ 8.	Redis 	Key-value, Multi-model 	151.86	-1.02	+9.95
8.	8.	↓ 7.	Elasticsearch 	Search engine, Multi-model 	150.50	-1.82	+1.23
9.	9.	↑ 11.	SQLite 	Relational	126.68	-0.14	+3.31
10.	↑ 11.	10.	Cassandra 	Wide column	119.18	-0.66	-4.22

<https://db-engines.com/en/ranking>



SQL

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Relational Database

358 systems in ranking, September 2020

Rank			DBMS	Database Model	Score		
Sep 2020	Aug 2020	Sep 2019			Sep 2020	Aug 2020	Sep 2019
1.	1.	1.	Oracle 	Relational, Multi-model 	1369.36	+14.21	+22.71
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9.	9.	↑ 11.	SQLite 	Relational	126.68	-0.14	+3.31
10.	↑ 11.	10.	Cassandra 	Wide column	119.18	-0.66	-4.22

<https://db-engines.com/en/ranking>



SQL

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Non-Relational Database

358 systems in ranking, September 2020

Rank			DBMS	Database Model	Score		
Sep 2020	Aug 2020	Sep 2019			Sep 2020	Aug 2020	Sep 2019
1.	1.	1.	Oracle 	Relational, Multi-model 	1369.36	+14.21	+22.71
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<https://db-engines.com/en/ranking>



SQL

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Structured Query Language (SQL)



Structured Query Language

Standard language for interacting with RDBMS

Use to perform **C.R.U.D** operations

Use to perform admin tasks (user, role, backup)



Structured Query Language

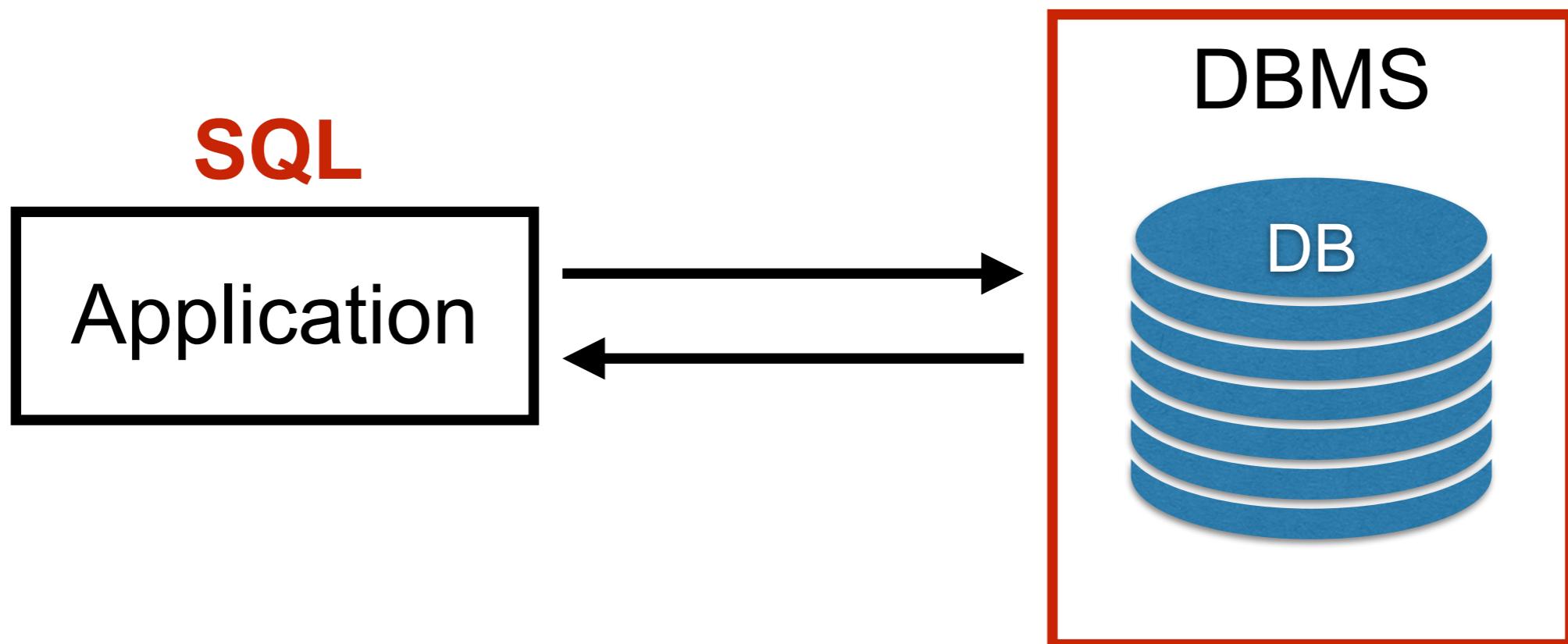
Data Definition Language (DDL)

Data Manipulation Language (DML)

Data Query Language (DQL)



SQL



Data Definition Language (DDL)

Define the structure of database/table/constraint

Create, Alter, Drop, Truncate



Data Manipulation Language (DML)

Used to manipulate data
Insert, Update, Delete



Data Query Language (DQL)

Used to performing queries on the data

Select ...

From <table>

Where <condition>

Group by ...

Having ...

Order by ...



Summary of Database

Database is any collection of information
Computer are great for storing database
DBMS make it easy to manage database



Summary of Database

2 types of database (relation and non-relation)

Relational database use SQL

Relational database store data in tables with
rows and columns



Workshop

Create/Alter/Drop table
C.R.U.D operations



Table customer

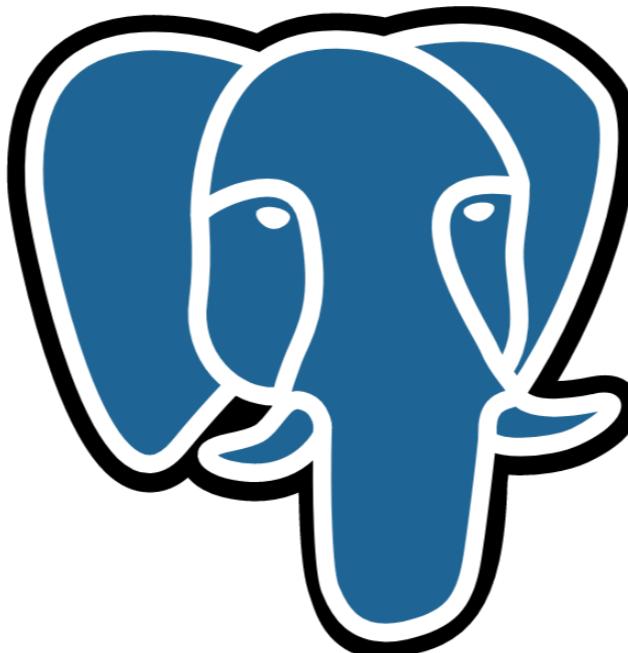
Unique key of Primary key for each row

Customer ID	Firstname	Lastname	Birthdate
1			
2			
3			
4			



Create table customer

Define data type of each column
Working with PostgreSQL



Types of column in table

Consistency
Validation
Compactness
Performance



Data types

Numerics
Monetary
Character
Binary data
Data/Time

<https://www.postgresql.org/docs/current/datatype.html>



Data types

Enumerated

Geometric

Network address

XML

JSON

Text search

Array

Custom/composite

Range

<https://www.postgresql.org/docs/current/datatype.html>



Define data type of columns

Table customer

Customer ID	Firstname	Lastname	Birthdate
1			
2			
3			
4			



Define data type of columns

Table customer

Column name	Type	Unique	Nullable
Customer_id	Int	Yes	No
Firstname	varchar(100)	No	No
Lastname	varchar(100)	No	No
Birthdate	Date	No	Yes



1. Create table

```
CREATE TABLE customer_1 (
    customer_id INT PRIMARY KEY,
    firstname VARCHAR(100) Not Null,
    lastname VARCHAR(100) Not Null,
    birthdate DATE
);
```



1. Create table

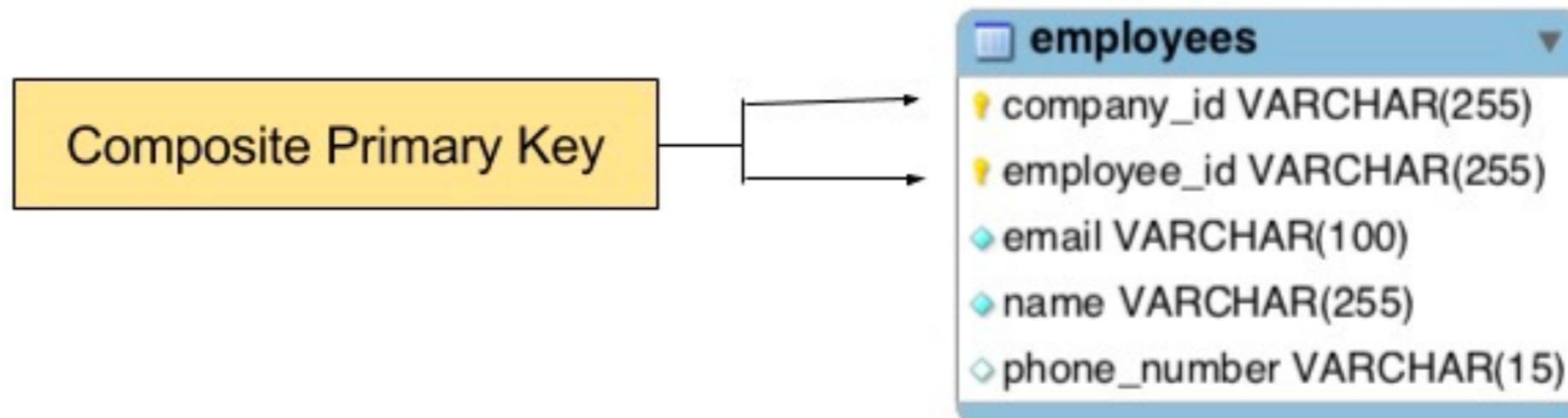
```
CREATE TABLE customer_1 (
    customer_id INT PRIMARY KEY,
    firstname VARCHAR(100) Not Null,
    lastname VARCHAR(100) Not Null,
    birthdate DATE
);
```

```
CREATE TABLE customer_2 (
    customer_id INT Not Null,
    firstname VARCHAR(100) Not Null,
    lastname VARCHAR(100) Not Null,
    birthdate DATE,
    PRIMARY KEY(customer_id)
);
```

Composite Primary Key



Composite Primary Key



Constraints in SQL



Constraints in SQL

Key and reference integrity

Restrictions on column and NULL

Constraints on each row within a relation



Key and Referential Integrity

PRIMARY KEY (PK)
UNIQUE
FOREIGN KEY (FK)



Foreign Key (FK)

Default operation: reject update in violation

Attach referential trigger action

On Delete

On Update

Cascade option for relationship



Constraints in SQL

NULL / NOT NULL

DEFAULT <value>

CHECK <condition>

<https://docs.microsoft.com/en-us/sql/relational-databases/tables/create-check-constraints>



SQL

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CHECK Constraints

```
CREATE TABLE employees(  
    employee_id INT NOT NULL,  
    last_name VARCHAR(50) NOT NULL,  
    first_name VARCHAR(50),  
    salary MONEY,  
  
    CONSTRAINT check_employee_id  
        CHECK (employee_id BETWEEN 1 and 10000)  
);
```



CHECK Constraints

```
CREATE TABLE employees(  
    employee_id INT NOT NULL,  
    last_name VARCHAR(50) NOT NULL,  
    first_name VARCHAR(50),  
    salary MONEY,  
  
    CONSTRAINT check_salary  
        CHECK (salary > 0)  
);
```



Default value of column

```
CREATE TABLE Orders (
    ID int NOT NULL,
    OrderNumber int NOT NULL,
    OrderDate date DEFAULT GETDATE()
);
```



2. Alter table

Add new column

```
ALTER TABLE customer_1 ADD score DECIMAL;
```

Delete existing column

```
ALTER TABLE customer_2 DROP COLUMN birthdate;
```



2. Alter table

Add new column with default value

```
ALTER TABLE Persons  
ADD CONSTRAINT city  
DEFAULT 'Bangkok' FOR City;
```



3. Drop table

Delete data and structure of table from database

```
Drop table customer_1;
```



4. Truncate table

Delete all data from table

```
Truncate table customer_2;
```



C.R.U.D operations



C.R.U.D operations

Operation	Command
Create	INSERT
Read	SELECT
Update	UPDATE
Delete	DELETE



INSERT

INSERT INTO <table> VALUES (values);

**INSERT INTO <table>(columns) VALUES
(values);**

INSERT INTO <table> SELECT <condition>;



SELECT

SELECT * FROM <table>

SELECT count(1) FROM <table>;

SELECT * FROM <table> WHERE <condition>;



UPDATE

UPDATE <table> SET <column>=<value>

UPDATE <table> SET <column>=<value>
WHERE <condition>



DELETE

DELETE FROM <table>;

DELETE FROM <table> WHERE <condition>;



Delete vs Truncate ?



Delete vs Truncate

	Delete	Truncate
Command Type	DML	DDL
Where condition	Support	Not support
Reset identify column	No	Yes
Acquired lock	Row lock	Table lock
Performance	Slow	Faster than delete



Workshop C.R.U.D 01



Relationships



Relationship

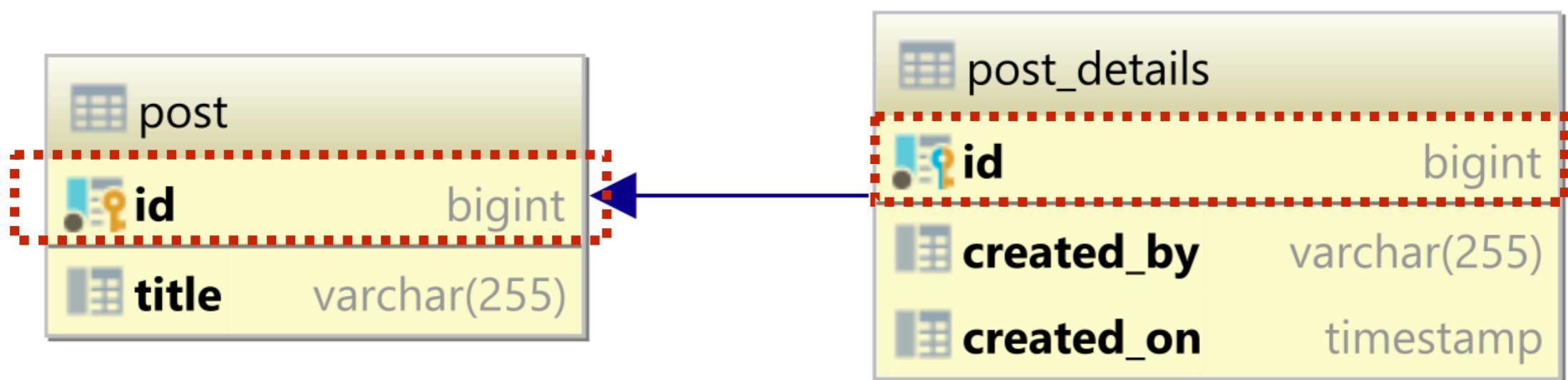


Types of Relationship

One-to-One
One-to-Many
Many-to-Many



One-to-One



One-to-One

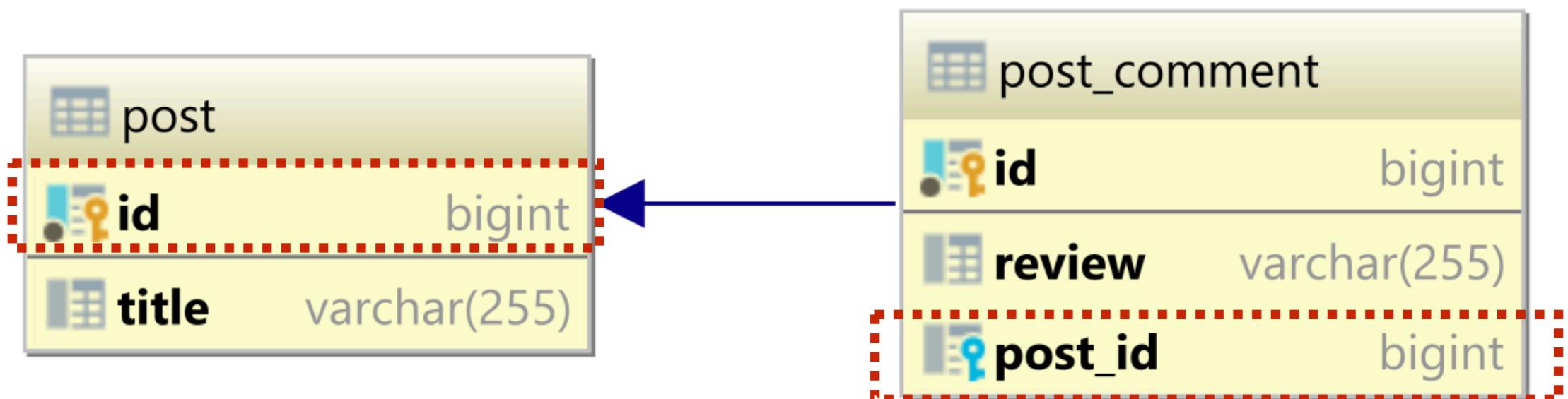
Primary key (PK)



Foreign key (FK)



One-to-Many



One-to-Many

Primary key (PK)

post
id
title

Foreign key (FK)

post_comment
id
review
post_id



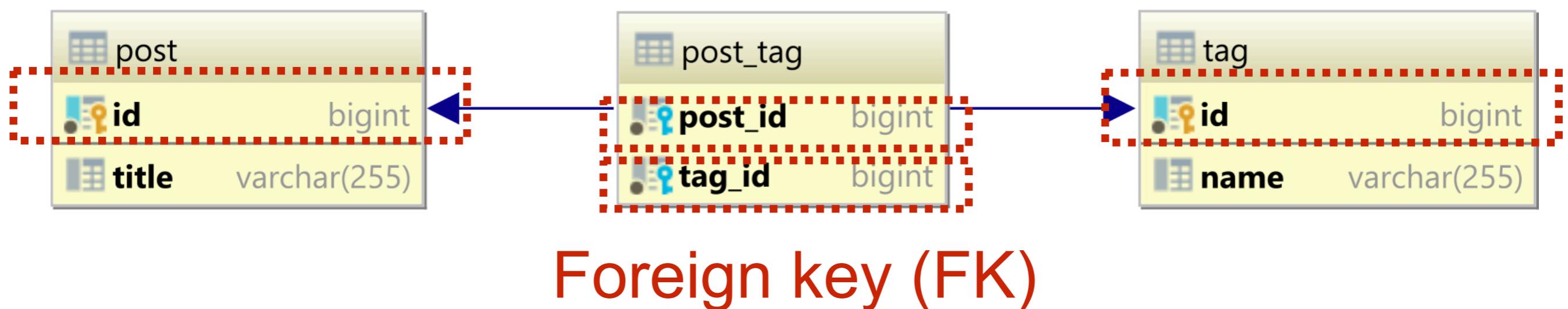
Many-to-Many



Many-to-Many

Primary key (PK)

Primary key (PK)



Many-to-Many

Primary key (PK)

post	
	id bigint
	title varchar(255)

Primary key (PK)

post_tag	
	post_id bigint
	tag_id bigint

tag	
	id bigint
	name varchar(255)

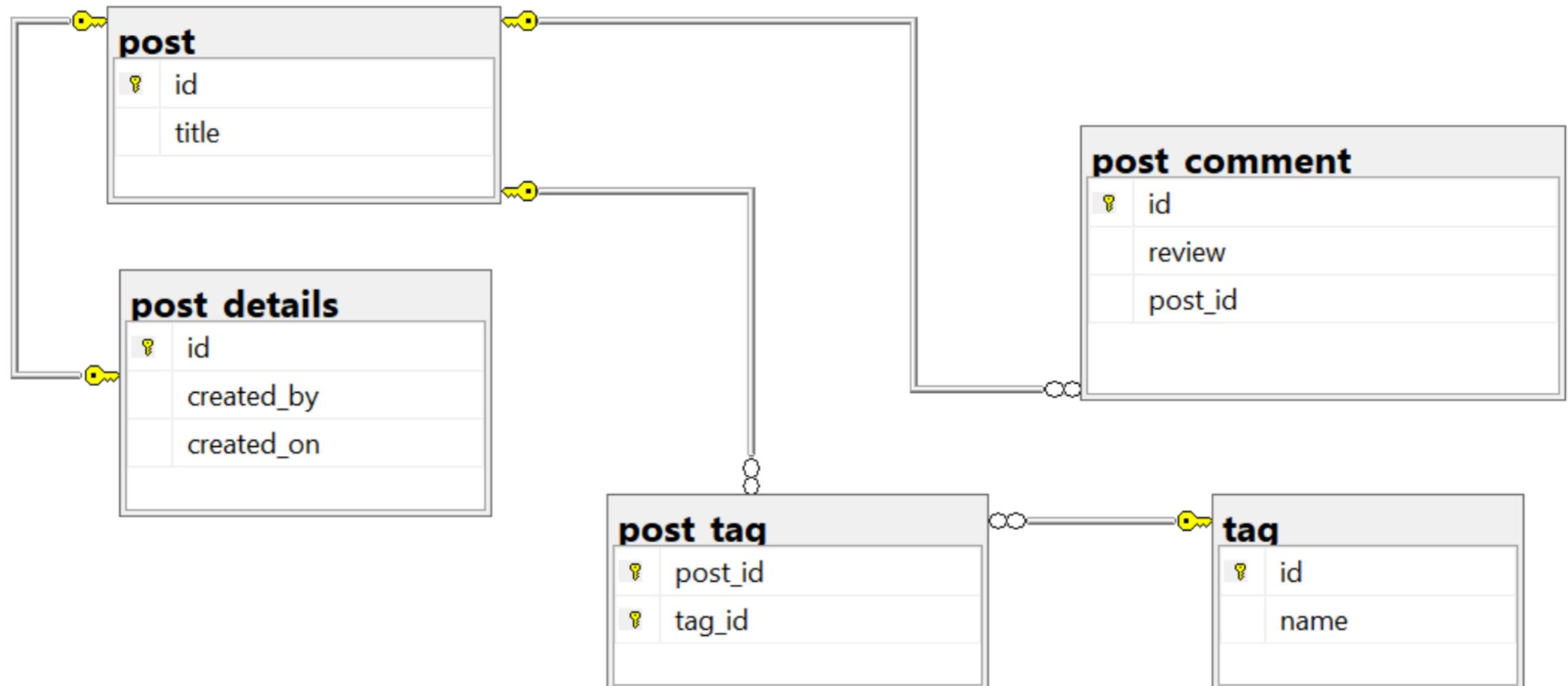
Composite Primary key (FK)



Workshop with relationship



Create Database Diagram



Workshop

Insert data into all tables



Data Query Language (DQL)



Data Query Language (DQL)

Used to performing queries on the data

Select ...

From <table>

Where <condition>

Group by ...

Having ...

Order by ...



Basic of SELECT statement

Select <column list>

From <table list>

Where <condition> AND/OR <condition>



Condition in Where clause

Logical comparison operators

=, <, <=, >, >=, <>

LIKE comparison operator

Use string pattern matching

% = zero or more characters

_ = one character

BETWEEN comparison operator



Example

Table customer

Customer_id	Firstname	Lastname	Age
1	Ant	Wallace	1
2	Bat	Dune	5
3	Cat	Puisu	3
4	Dog	Morad	10



List of customer

Age less than 5

```
Select *  
From customer  
Where age < 5
```



List of customer

Firstname start with A character

```
Select *  
From customer  
Where first name like 'A%'
```



List of customer

Age more than 3 and less than 20

Select *

From customer

Where age between 3 and 20



List of customer

Age more than 3 and less than 20

Select *

From customer

Where ~~age between 3 and 20~~

≥ 3 and ≤ 20 !!



List of customer

Age more than 3 and less than 20

Select *

From customer

Where age > 3 and age < 20



Use ORDER BY clause

Select <column list>
From <table list>
Where <condition>
Order by <column list>



Use ORDER BY clause

Keyword **DESC** to see result in a descending order of values

Keyword **ASC** to see result in a ascending order of values

“Order By name DESC, age ASC”

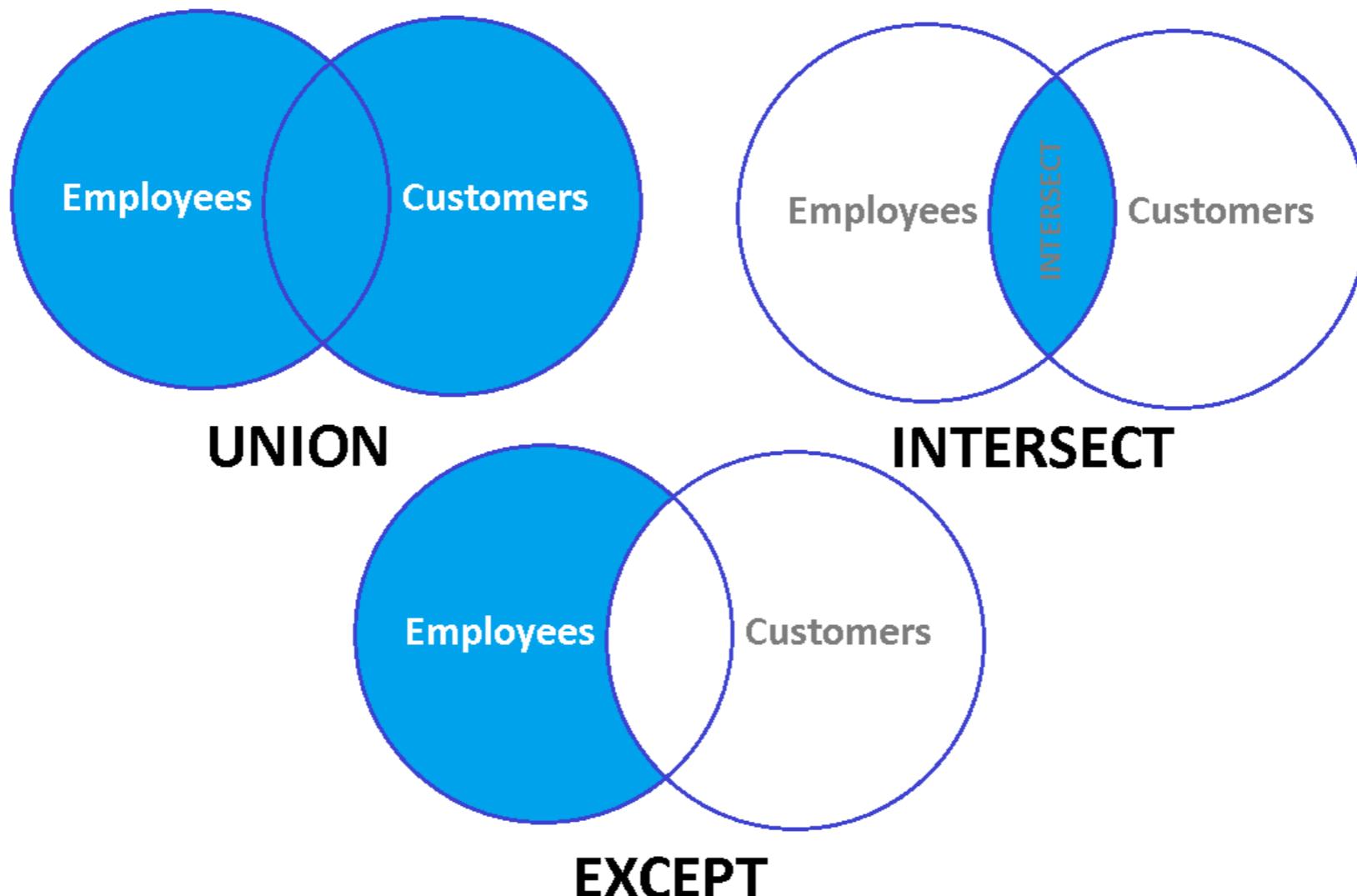


Set operations

Union/ Union All
Except
Intersect

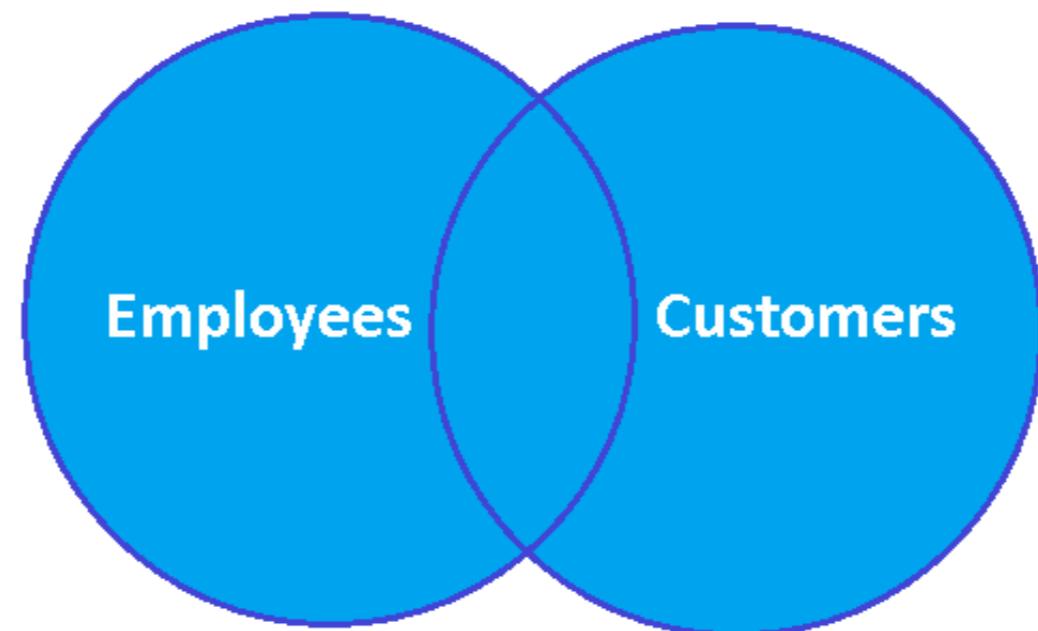


Set operations



Union

Combine multiple inputs into a single result



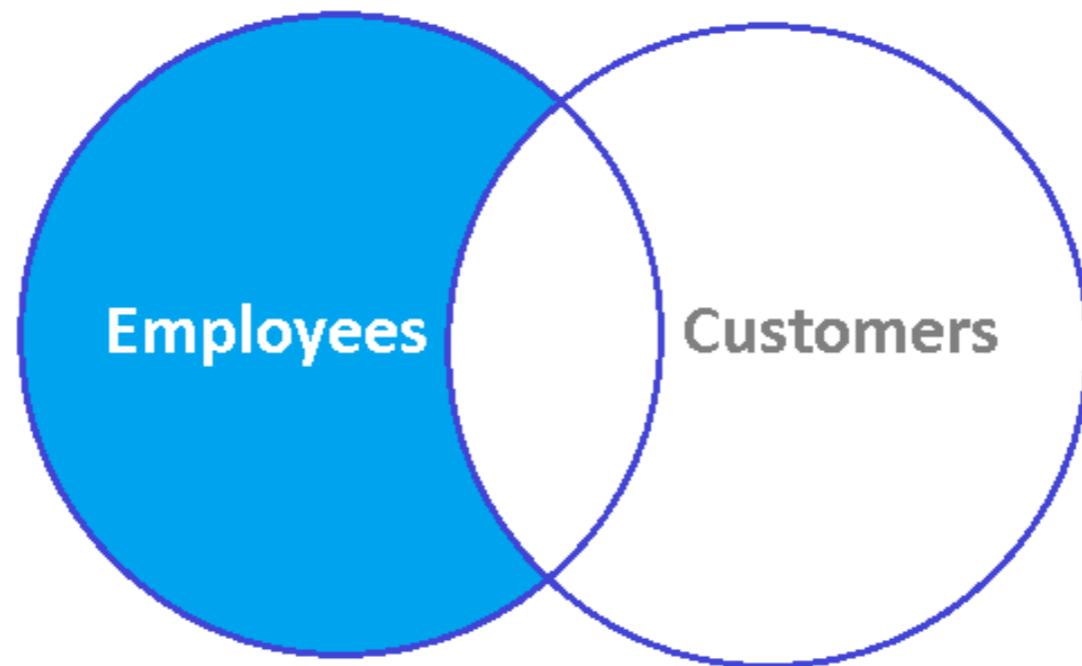
Union All

Like Union operator **but not filter out
duplicated rows**



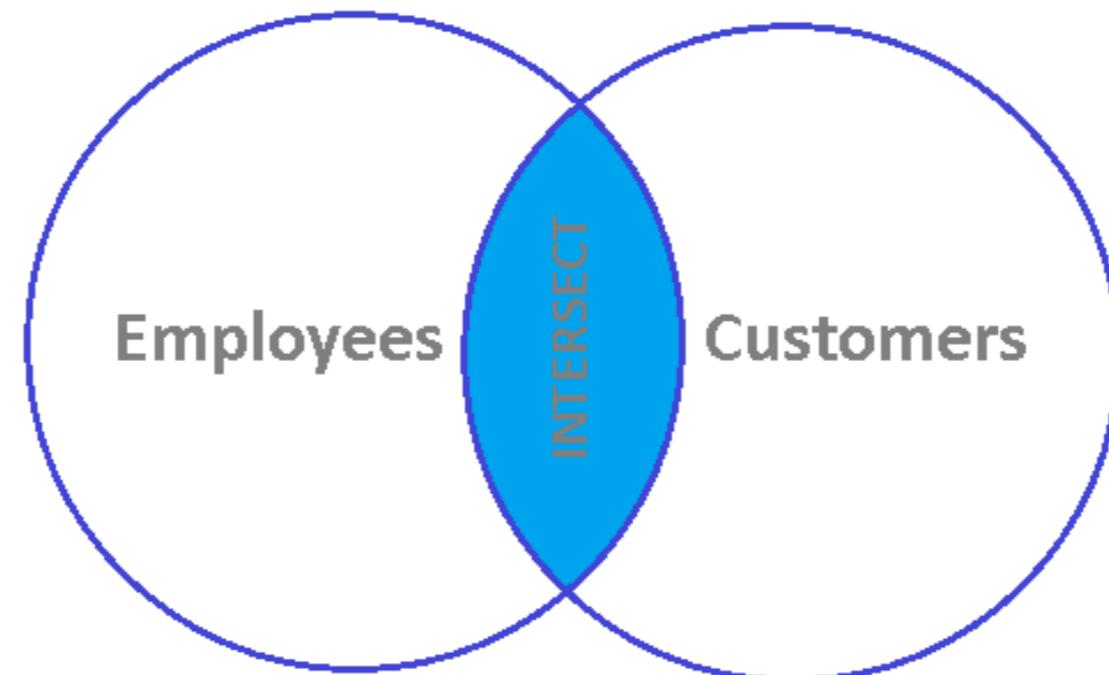
Except

Return distinct rows that only in first input



Intersect

Return only distinct rows that are present in both input

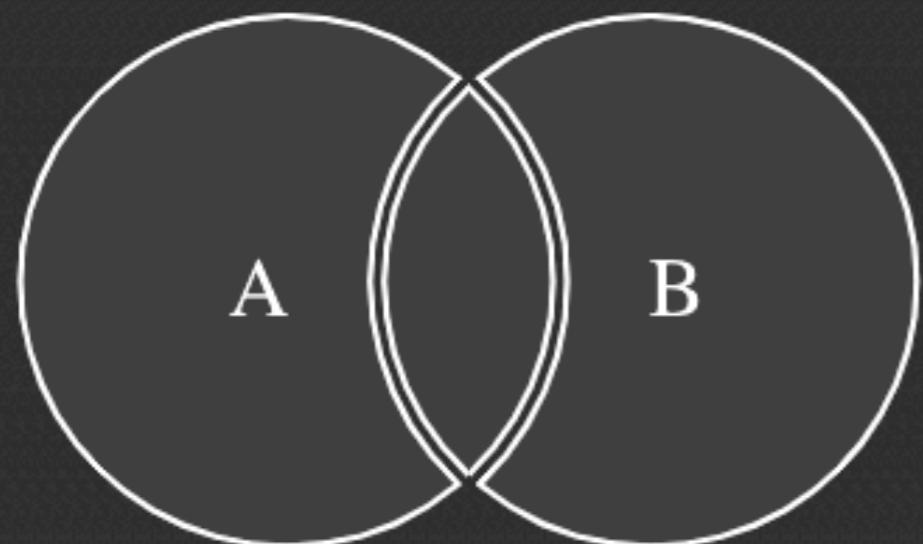


Joining



SQL Joins Visualizer

SQL Joins Visualizer help to you build SQL JOIN between two tables by using of Venn diagrams.
Working offline and as mobile app.

A large, empty rectangular input field with a dashed border, representing the SQL query input area.

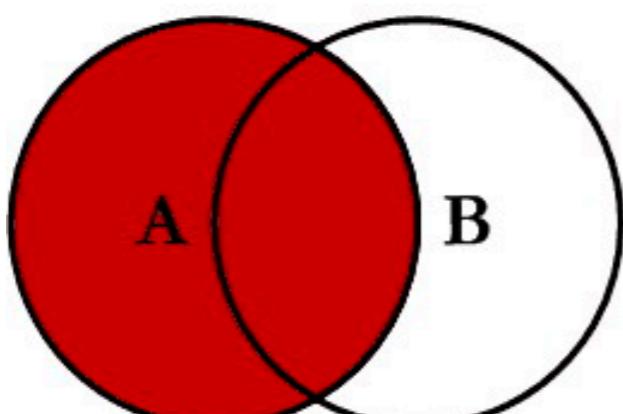
Copy SQL

Please select how do you want to do SQL JOIN
between two table

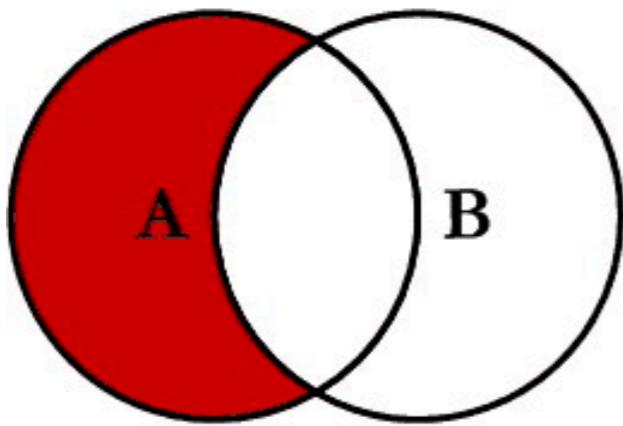
<https://sql-joins.leopard.in.ua/>



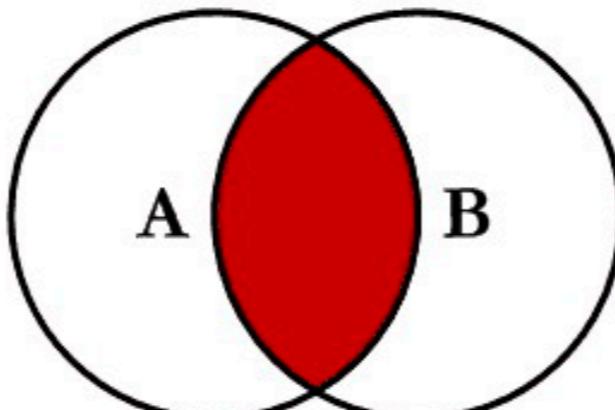
SQL JOINS



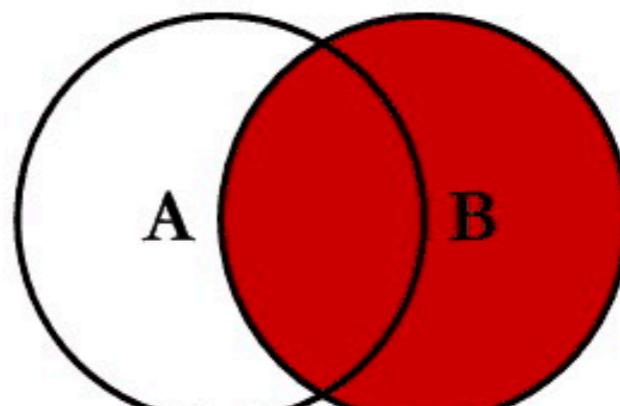
```
SELECT <select_list>
FROM TableA A
LEFT JOIN TableB B
ON A.Key = B.Key
```



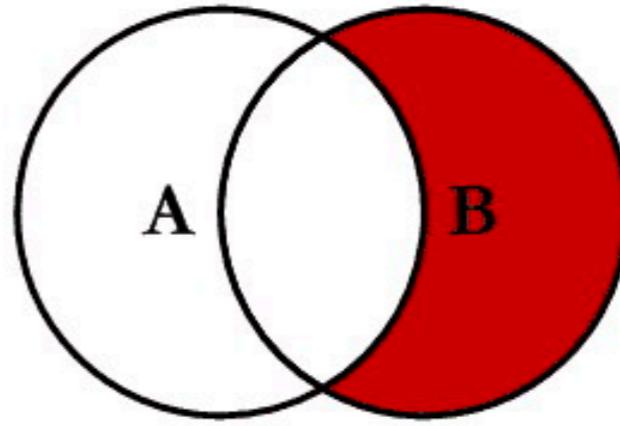
```
SELECT <select_list>
FROM TableA A
LEFT JOIN TableB B
ON A.Key = B.Key
WHERE B.Key IS NULL
```



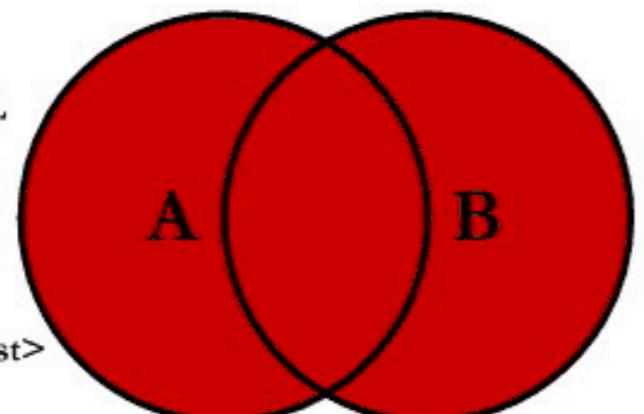
```
SELECT <select_list>
FROM TableA A
INNER JOIN TableB B
ON A.Key = B.Key
```



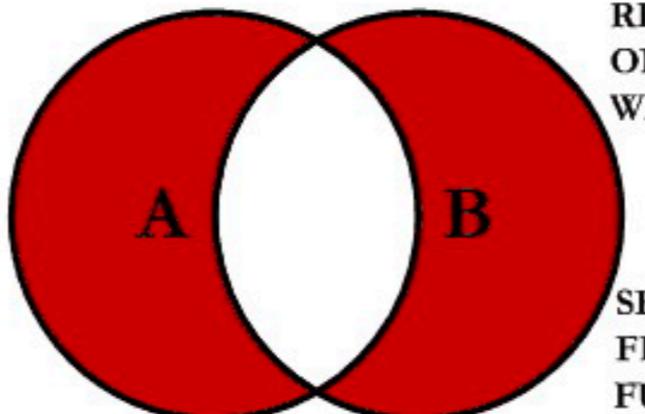
```
SELECT <select_list>
FROM TableA A
RIGHT JOIN TableB B
ON A.Key = B.Key
```



```
SELECT <select_list>
FROM TableA A
RIGHT JOIN TableB B
ON A.Key = B.Key
WHERE A.Key IS NULL
```



```
SELECT <select_list>
FROM TableA A
FULL OUTER JOIN TableB B
ON A.Key = B.Key
```



```
SELECT <select_list>
FROM TableA A
FULL OUTER JOIN TableB B
ON A.Key = B.Key
WHERE A.Key IS NULL
OR B.Key IS NULL
```

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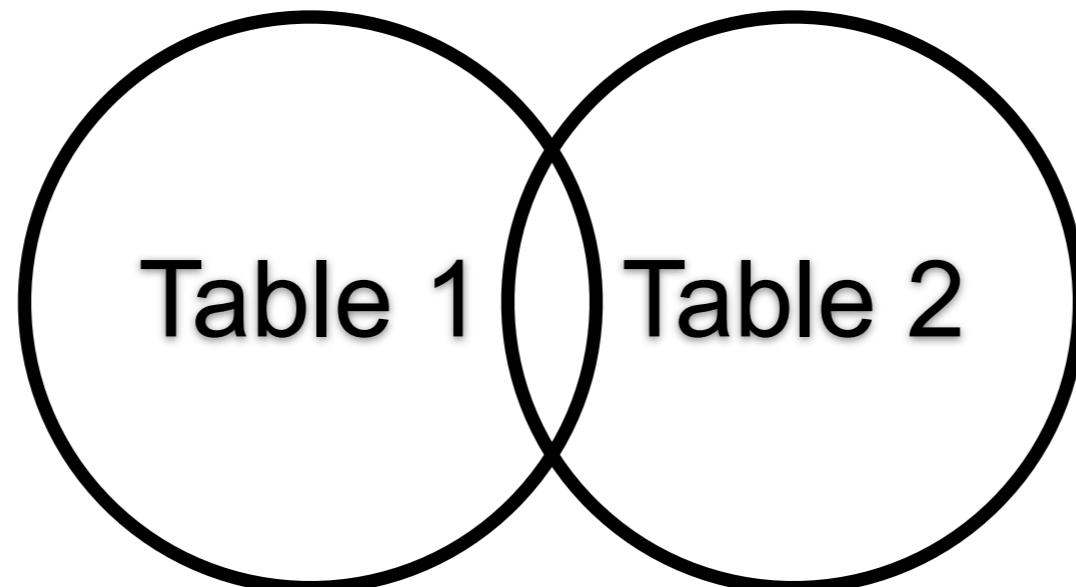


SQL

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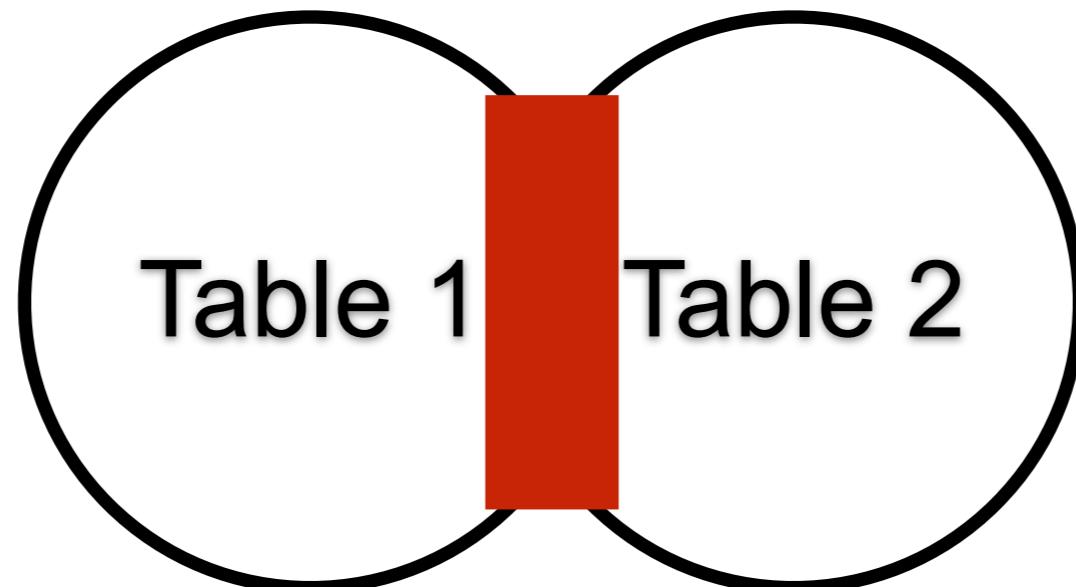
(Inner) Join

Returns rows that have matching values in both tables



(Inner) Join

Returns rows that have matching values in both tables



(Inner) Join

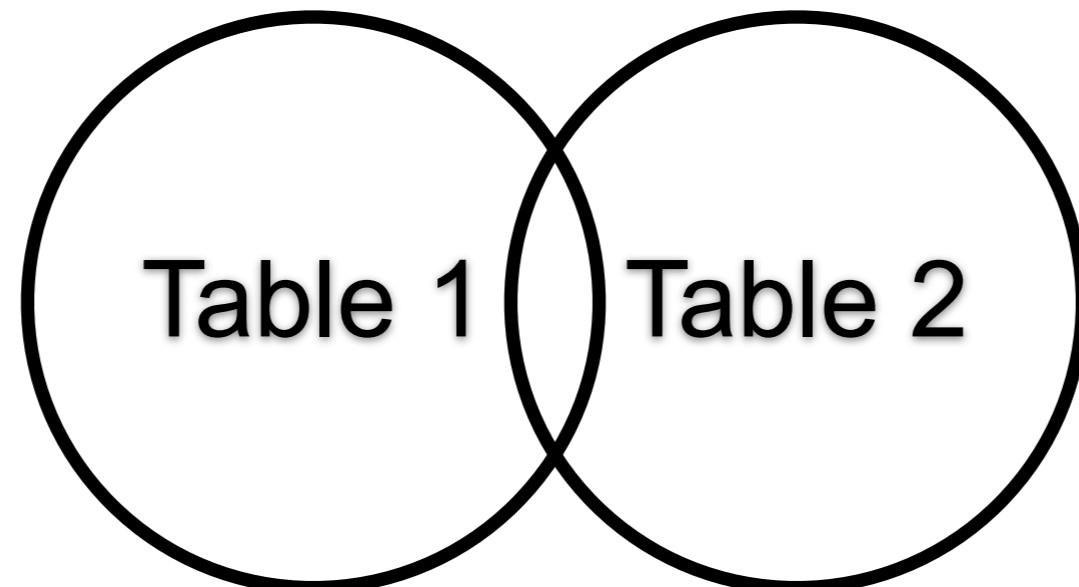
```
SELECT *
FROM Table1
INNER JOIN Table2 ON Table1.id = Table2.id
```

```
SELECT *
FROM Table1, Table2
WHERE Table1.id = Table2.id
```



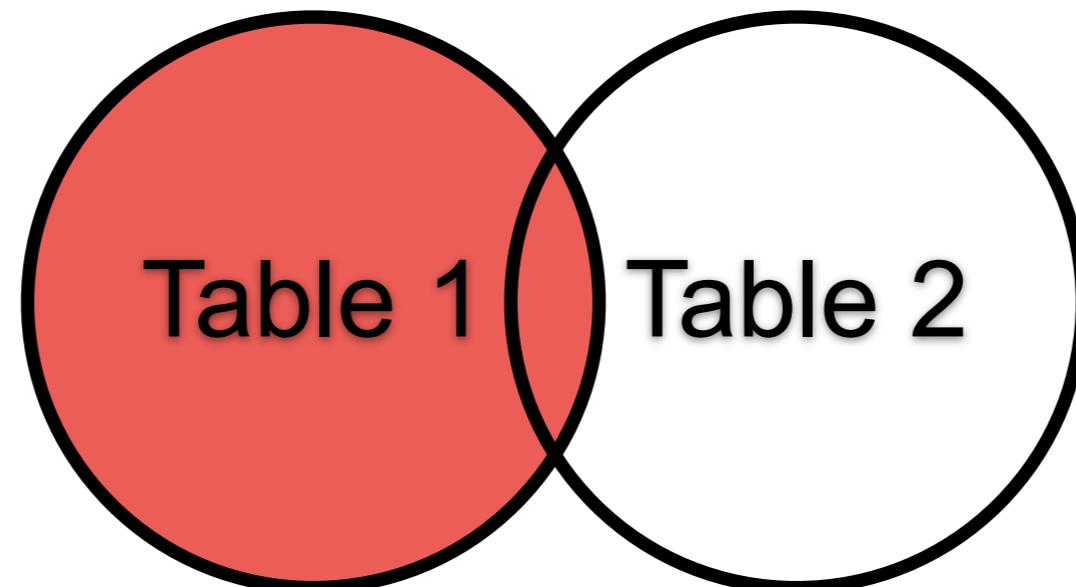
Left (outer) Join

Returns all rows from the left table and matched rows from the right table



Left (outer) Join

Returns all rows from the left table and matched rows from the right table



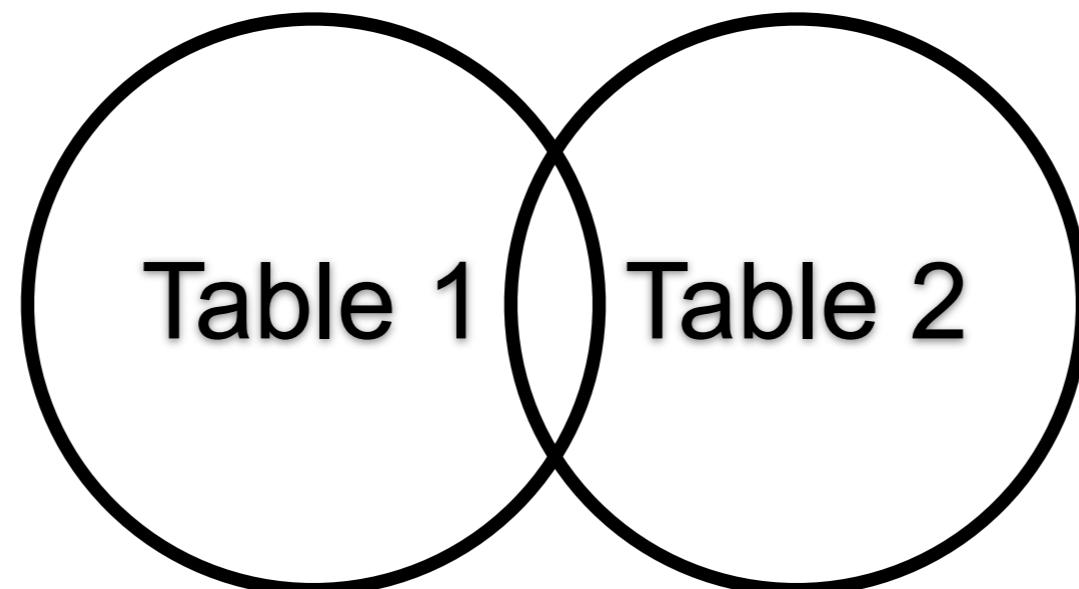
Left (outer) Join

```
SELECT *
FROM table1
LEFT JOIN table2
ON table1.column_name = table2.column_name;
```



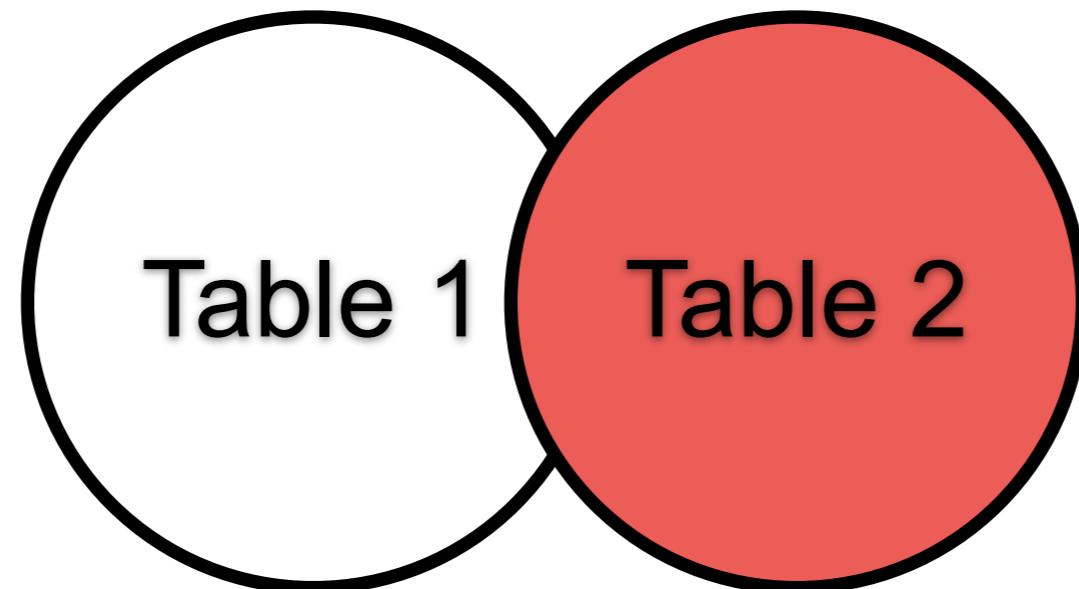
Right (outer) Join

Returns all rows from the right table and matched rows from the left table



Right (outer) Join

Returns all rows from the right table and matched rows from the left table



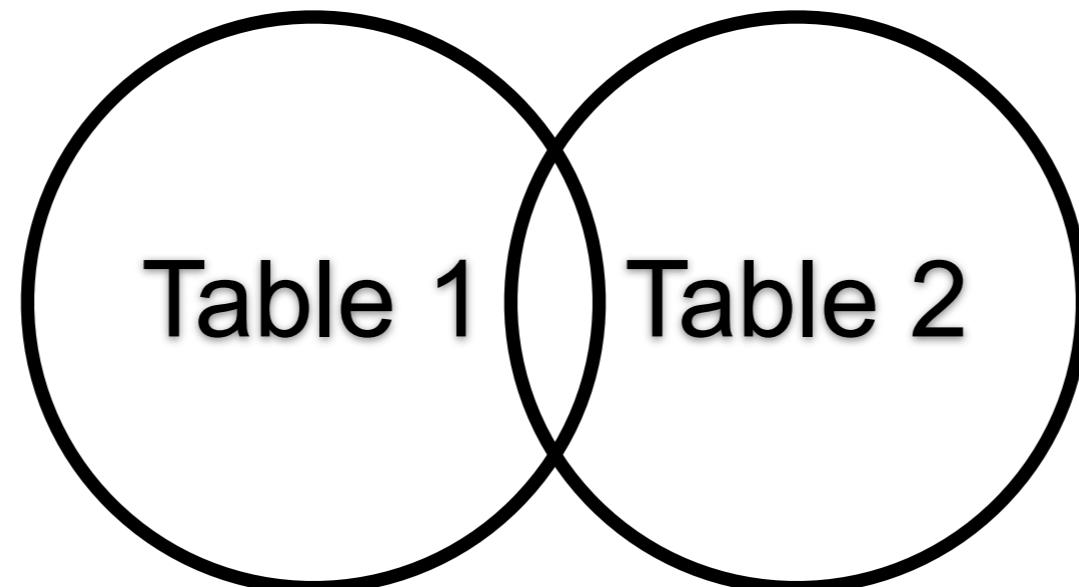
Right (outer) Join

```
SELECT *
FROM table1
RIGHT JOIN table2
ON table1.column_name = table2.column_name;
```



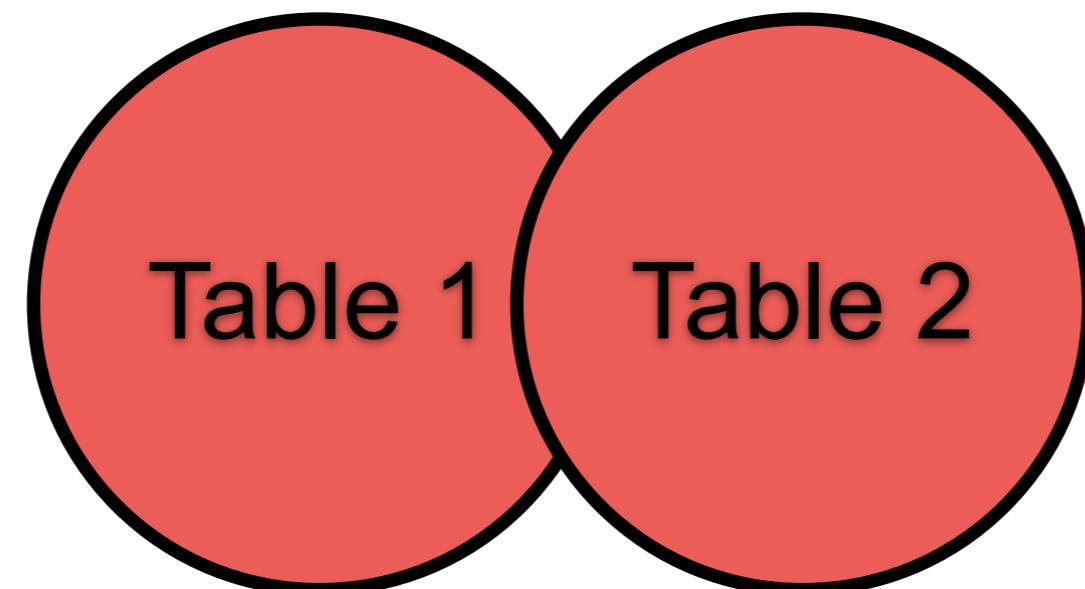
Full (outer) Join

Returns all rows when there a match in either left or right table



Full (outer) Join

Returns all rows when there a match in either left or right table



Full (outer) Join

```
SELECT *
FROM table1
FULL OUTER JOIN table2
ON table1.column_name = table2.column_name;
```



Aggregation in SQL

Use to summarize information from multiple rows into single

Try to grouping data with **GROUPY BY**

Build-in aggregation function ?



Aggregation functions

Count
Sum
Max
Min
Avg



Modifier in Aggregation

ALL (not remove duplicate)

DISTINCT (remove duplicate)

Max

Min

Avg



C.R.U.D with more tables



Workshop with post data



Workshop as a Team Company database



Company Database

Employee

<u>emp_id</u>	first_name	last_name	birth_date	sex	salary	super_id	branch_id
100	David	Wallace	1967-11-17	M	250,000	NULL	1
101	Jan	Levinson	1961-05-11	F	110,000	100	1
102	Michael	Scott	1964-03-15	M	75,000	100	2
103	Angela	Martin	1971-06-25	F	63,000	102	2
104	Kelly	Kapoor	1980-02-05	F	55,000	102	2
105	Stanley	Hudson	1958-02-19	M	69,000	102	2
106	Josh	Porter	1969-09-05	M	78,000	100	3
107	Andy	Bernard	1973-07-22	M	65,000	106	3
108	Jim	Halpert	1978-10-01	M	71,000	106	3

Branch

<u>branch_id</u>	branch_name	<u>mgr_id</u>	mgr_start_date
1	Corporate	100	2006-02-09
2	Scranton	102	1992-04-06
3	Stamford	106	1998-02-13

Works_With

<u>emp_id</u>	<u>client_id</u>	total_sales
105	400	55,000
102	401	267,000
108	402	22,500
107	403	5,000
108	403	12,000
105	404	33,000
107	405	26,000
102	406	15,000
105	406	130,000

Client

<u>client_id</u>	client_name	<u>branch_id</u>
400	Dunmore Highschool	2
401	Lackawana Country	2
402	FedEx	3
403	John Daly Law, LLC	3
404	Scranton Whitepages	2
405	Times Newspaper	3
406	FedEx	2

Branch Supplier

<u>branch_id</u>	<u>supplier_name</u>	supply_type
2	Hammer Mill	Paper
2	Uni-ball	Writing Utensils
3	Patriot Paper	Paper
2	J.T. Forms & Labels	Custom Forms
3	Uni-ball	Writing Utensils
3	Hammer Mill	Paper
3	Stamford Lables	Custom Forms

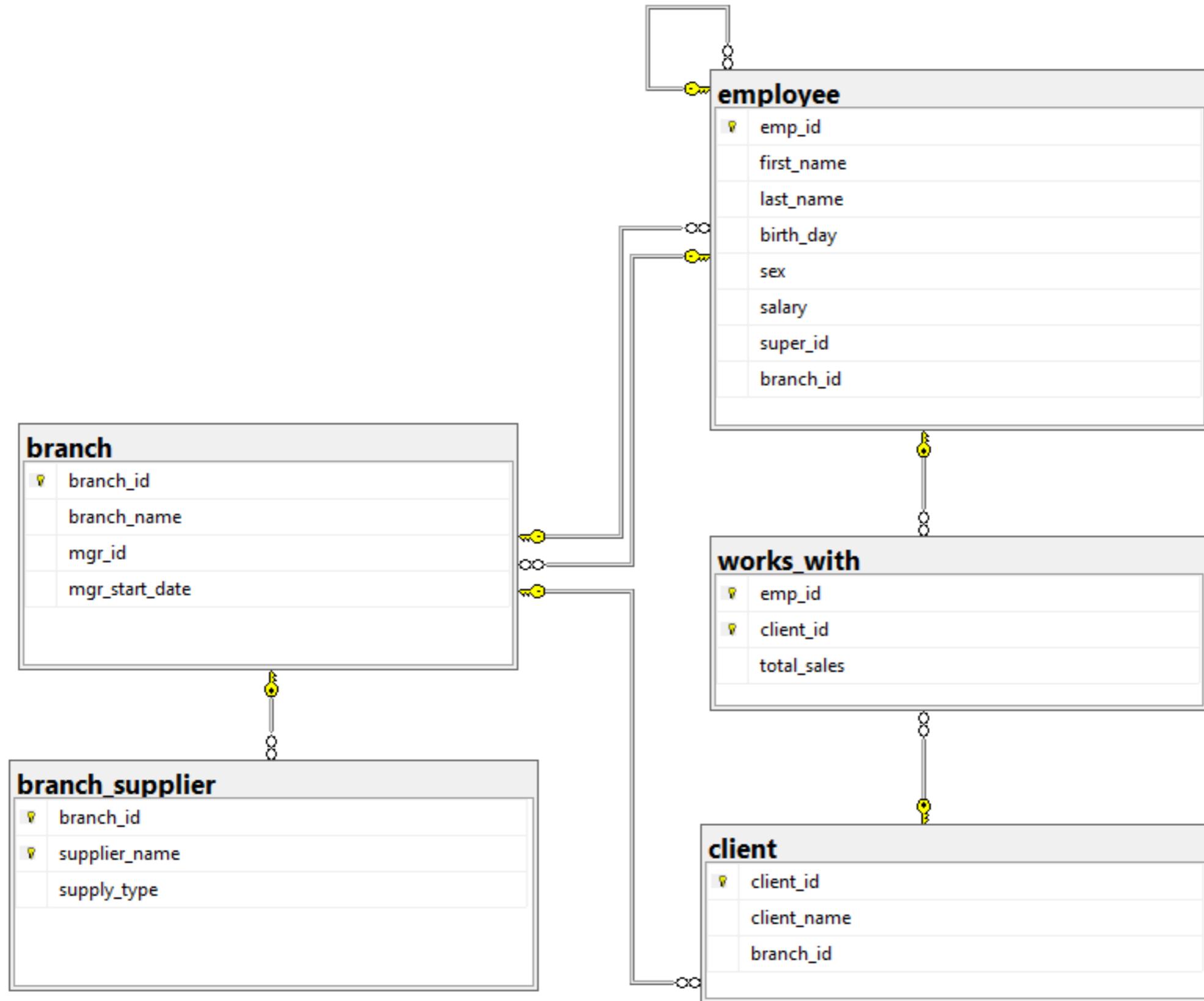
Labels

	<u>Primary Key</u>
	Foreign Key
	Attribute



SQL

126



Database design



Normalization Form



What is Normalization ?

Process to organize data with efficiency



What is Normalization ?

Process to organize data with **efficiency**

- Eliminate redundancy

- Ensure data is stored in the right table

- Eliminate need for restructure database when data is added



Benefits

Data deduplication
Consistency
Data Integrity



Drawbacks

Divide data into many tables

Complex JOINs

Hard to change the structure of data

Impedance mismatch with modern applications



5 levels of Normal form

Third normal form is sufficient for most typical database applications



First Normal Form (1NF)

No repeat or duplicate columns

Each column contains only a single value

Each row is unique



Example

Item	Colors	Price	Tax
T-shirt	Red, blue	12.00	0.60
Polo	Red, yellow	12.00	0.60
T-shirt	Red, blue	12.00	0.60
Other	Blue, black	25.00	1.25



Duplication rows

Item	Colors	Price	Tax
T-shirt	Red, blue	12.00	0.60
Polo	Red, yellow	12.00	0.60
T-shirt	Red, blue	12.00	0.60
Other	Blue, black	25.00	1.25



No Primary Key

Item	Colors	Price	Tax
T-shirt	Red, blue	12.00	0.60
Polo	Red, yellow	12.00	0.60
T-shirt	Red, blue	12.00	0.60
Other	Blue, black	25.00	1.25



Multiple-value in colors

Item	Colors	Price	Tax
T-shirt	Red, blue	12.00	0.60
Polo	Red, yellow	12.00	0.60
T-shirt	Red, blue	12.00	0.60
Other	Blue, black	25.00	1.25



Improvement with 1NF

Item	Colors	Price	Tax
T-shirt	Red	12.00	0.60
T-shirt	Blue	12.00	0.60
Polo	Red	12.00	0.60
Polo	Yellow	12.00	0.60
Other	Blue	25.00	1.25
Other	Black	25.00	1.25



Second Normal Form (2NF)

All non-key columns depend on all components
of the primary key



Price and Tax depend on Item

Item	Colors	Price	Tax
T-shirt	Red	12.00	0.60
T-shirt	Blue	12.00	0.60
Polo	Red	12.00	0.60
Polo	Yellow	12.00	0.60
Other	Blue	25.00	1.25
Other	Black	25.00	1.25



Improvement with 2NF

Item	Colors
T-shirt	Red
T-shirt	Blue
Polo	Red
Polo	Yellow
Other	Blue
Other	Black

Item	Price	Tax
T-shirt	12.00	0.60
Polo	12.00	0.60
Other	25.00	1.25



Third Normal Form (3NF)

No non-key columns depend upon another of
the primary key



Tax depend on price, not item

Item	Colors
T-shirt	Red
T-shirt	Blue
Polo	Red
Polo	Yellow
Other	Blue
Other	Black

Item	Price	Tax
T-shirt	12.00	0.60
Polo	12.00	0.60
Other	25.00	1.25



Improvement with 3NF

Item	Colors
T-shirt	Red
T-shirt	Blue
Polo	Red
Polo	Yellow
Other	Blue
Other	Black

Item	Price
T-shirt	12.00
Polo	12.00
Other	25.00

Price	Tax
12.00	0.60
25.00	1.25



Add Relationship ?

Item	Colors
T-shirt	Red
T-shirt	Blue
Polo	Red
Polo	Yellow
Other	Blue
Other	Black

Item	Price
T-shirt	12.00
Polo	12.00
Other	25.00

Price	Tax
12.00	0.60
25.00	1.25



Workshop



Workshop with 3NF

Name	Assignment 1	Assignment 2
Somkiat Pui	Article summary	Paper prototype
John At	Article summary	Paper prototype
Jane Scott	Article summary	Paper prototype



Workshop with 3NF

ID	Firstname	Lastname
1	Somkiat	Pui
2	John	At
3	Jane	Scott

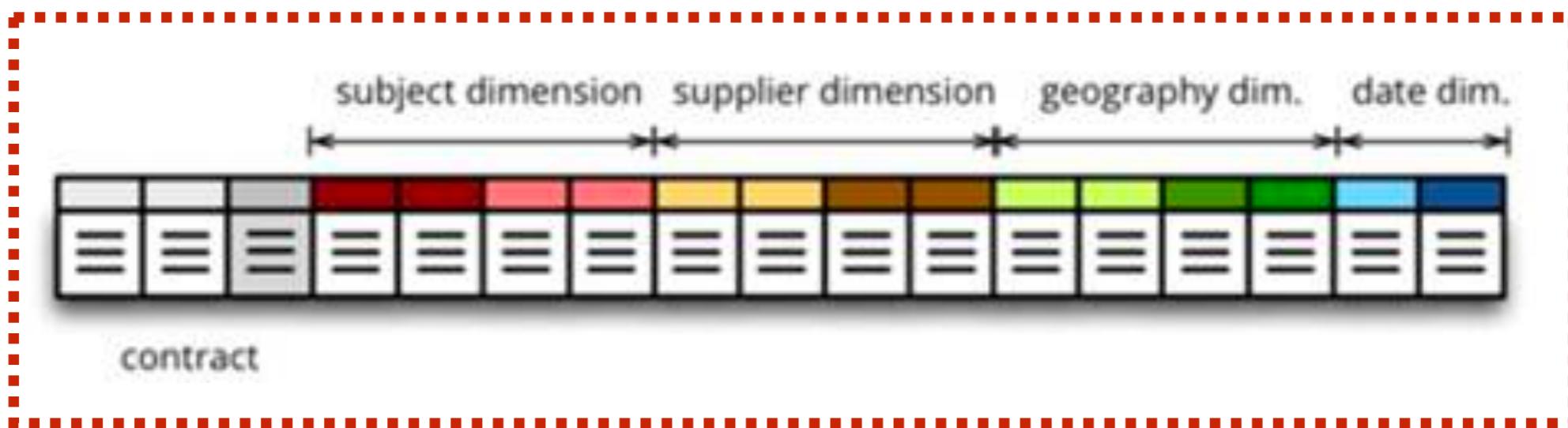
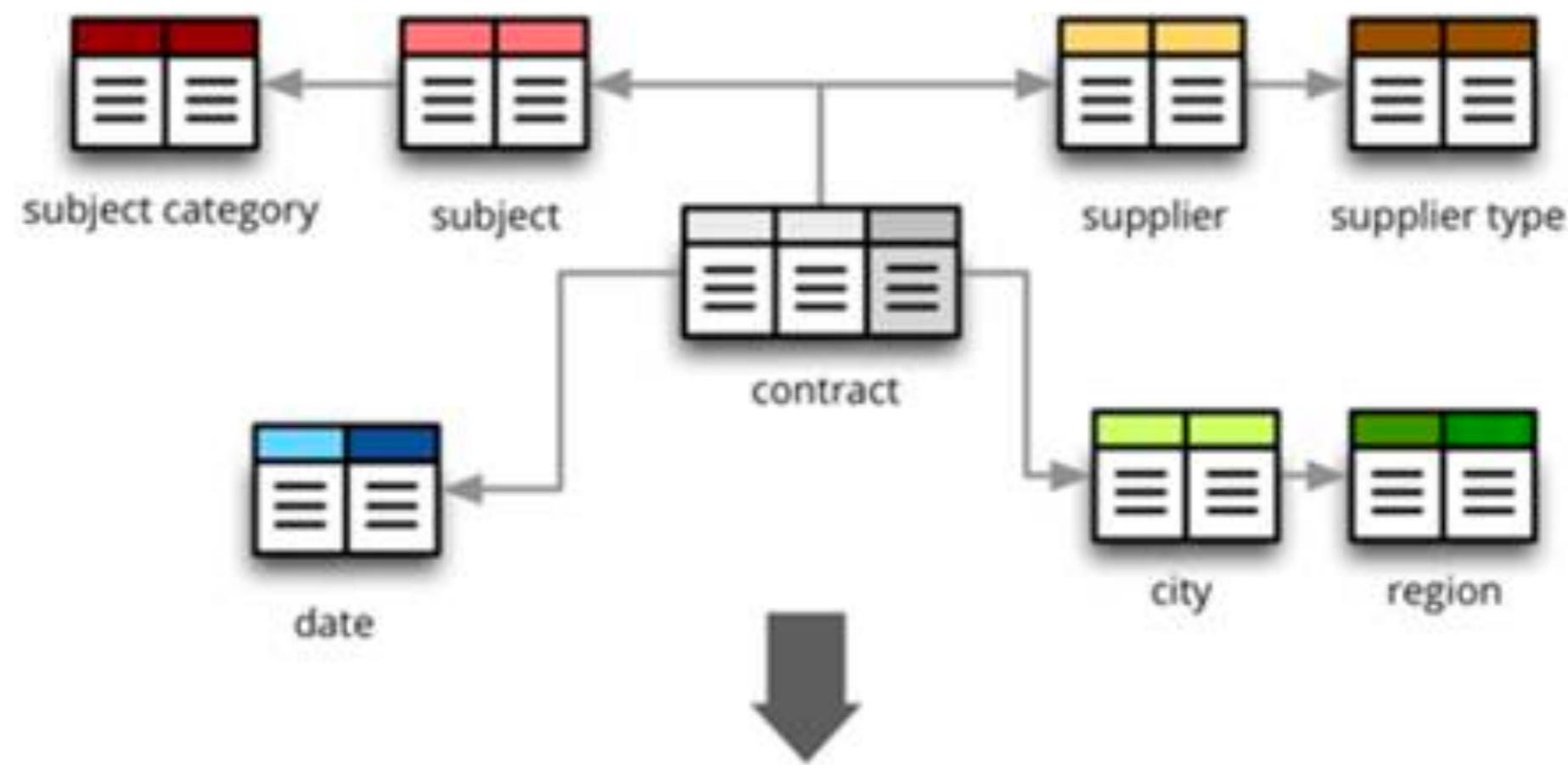
ID	Description
1	Article summary
2	Paper prototype

student_id	assignment_id
1	1
1	2
1	3
2	1
2	3
3	2



De-Normalization ?





Benefits

Reduce impedance mismatch

Improve performance

Remove/reduce JOINs

To facilitate and accelerate reporting



Drawbacks

Data duplication

Data inconsistency

Hard to model complex relationships



Impedance mismatch

John Smith

INVOICE

4490 Oak Drive
Albany, NY 12210

Bill To
Jessie M Horne
4312 Wood Road
New York, NY 10031

Ship To
Jessie M Horne
2019 Redbud Drive
New York, NY 10011

Invoice # INT-001
Invoice Date 11/02/2019
P.O.# 2412/2019
Due Date 26/02/2019

QTY	DESCRIPTION	UNIT PRICE	AMOUNT
1	Front and rear brake cables	100.00	100.00
2	New set of pedal arms	25.00	50.00
3	Labor 3hrs	15.00	45.00
		Subtotal	195.00
		Sales Tax 5.0%	9.75
		TOTAL	\$204.75



Common mistake in Database design !!



Mistakes

Poor preplanning
Failure to understand the purpose of data
Poor Normalization
Poor indexing
Redundant records
Inconsistent naming convention
Poor documentation
Inadequate testing



Improve query performance



Benchmark and performance testing with PostgreSQL

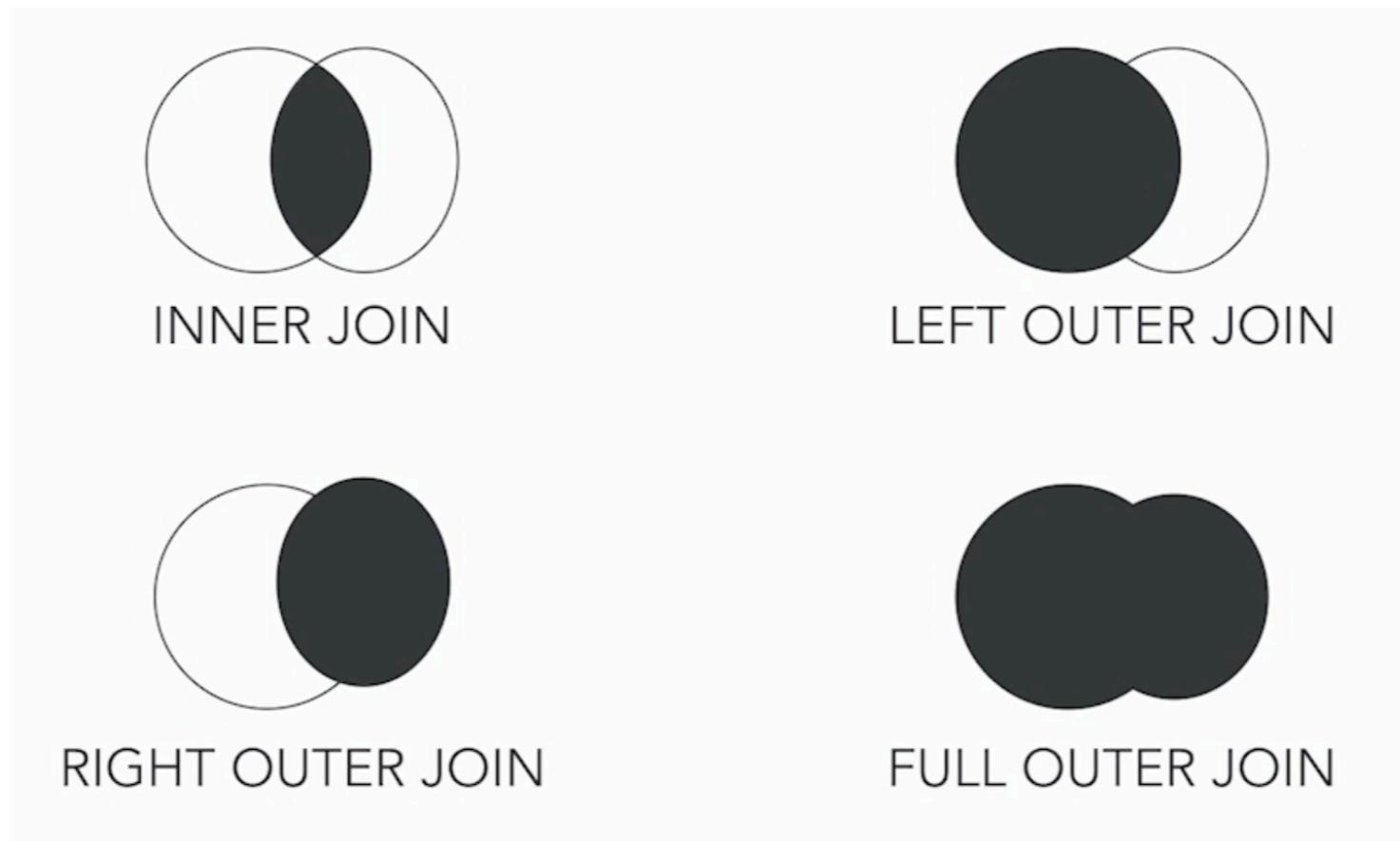


TODO



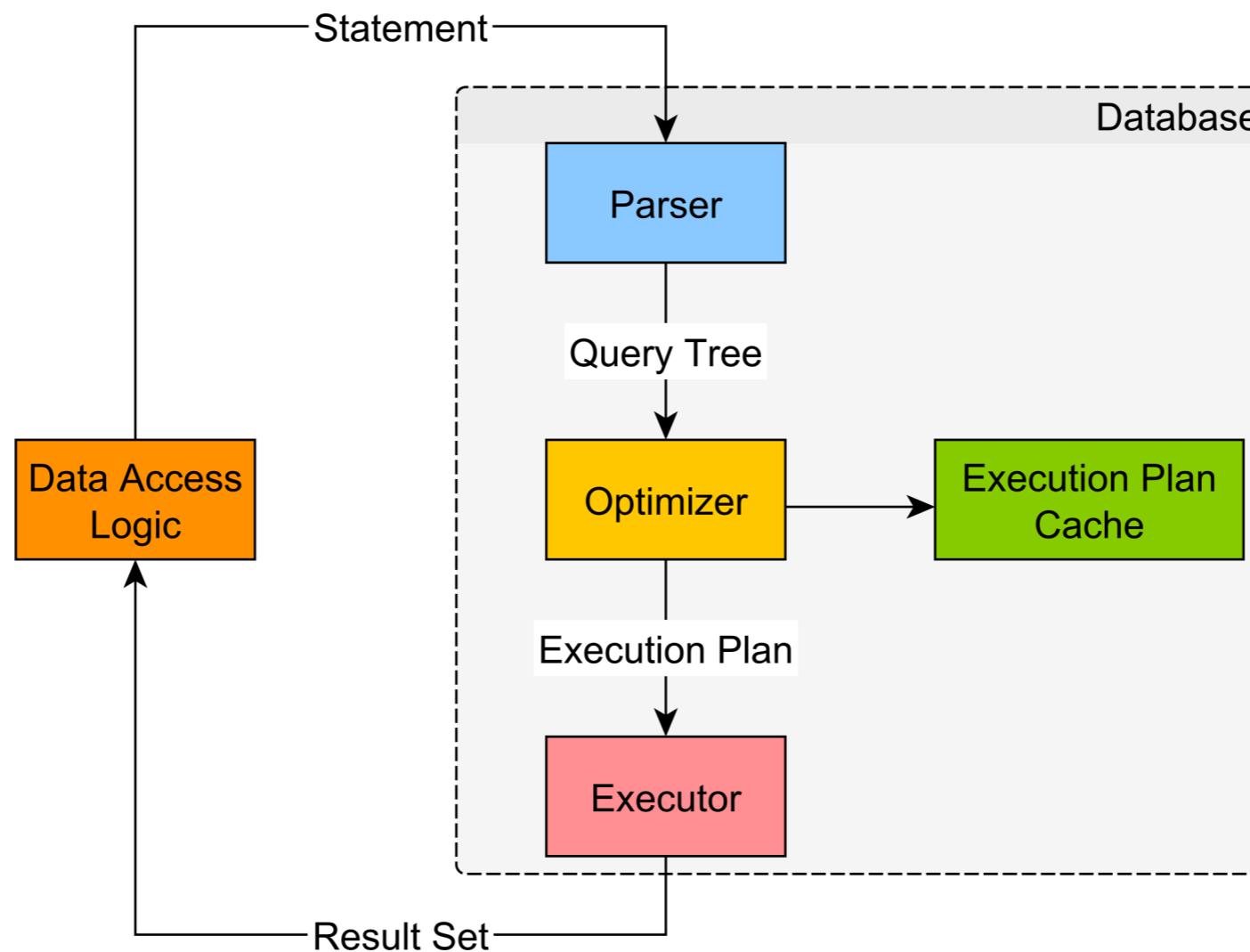
Tuning ?

Reduce query response time with query tuning
Explain query ?



SQL use execute plan

Set of step that scan, filter and join data



Efficient execution plan ?

Good or Bad ?

Good

Using index to find data

Bad

Scan 1M rows to find 100 rows



Step to learn

Understand query plan steps

Understand trade-offs in way to implement
query plan

Learn techniques that lead to efficient plans



Scanning tables



customer_id	fname	lname	last_purchase_date	status_level
1234	Alice	Smith	23-Jan-2016	silver
2345	Bob	Washington	14-July-2018	bronze
2352	Charlie	Johnson	20-Dec-2018	gold
2678	Chendong	Mao	19-Dec-2017	gold
3422	Javier	Valdez	23-Dec-2018	gold
3577	Avery	Winston	5-Jan-2019	silver
4240	Charles	Davis	15-Jan-2017	bronze
6235	Vihaan	Patel	12-Nov-2018	gold
2352	Katherine	Coltrane	04-Apr-2016	silver



Scanning tables

Scanning looks at each row

Fetch data block containing row

Apply filters or conditions

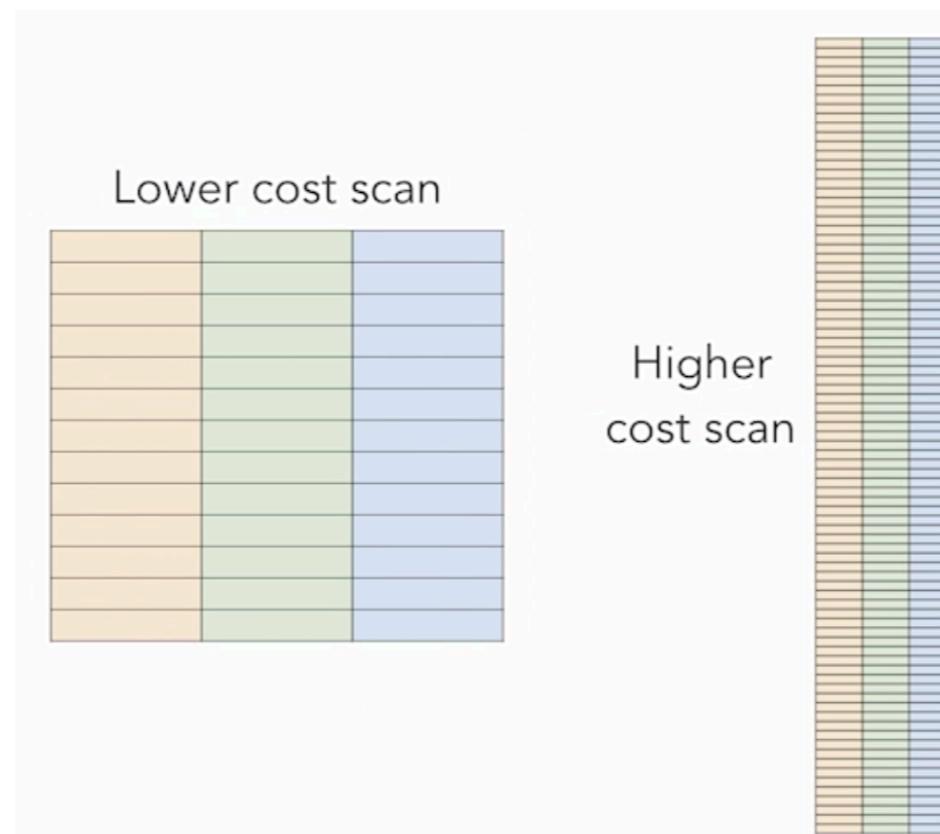
**Cost of query based on number of rows in
the table**



Cost based on number of rows

Scanning on small tables is efficient

Scanning on large tables can be efficient if
have few queries



Indexing reduce full table scan

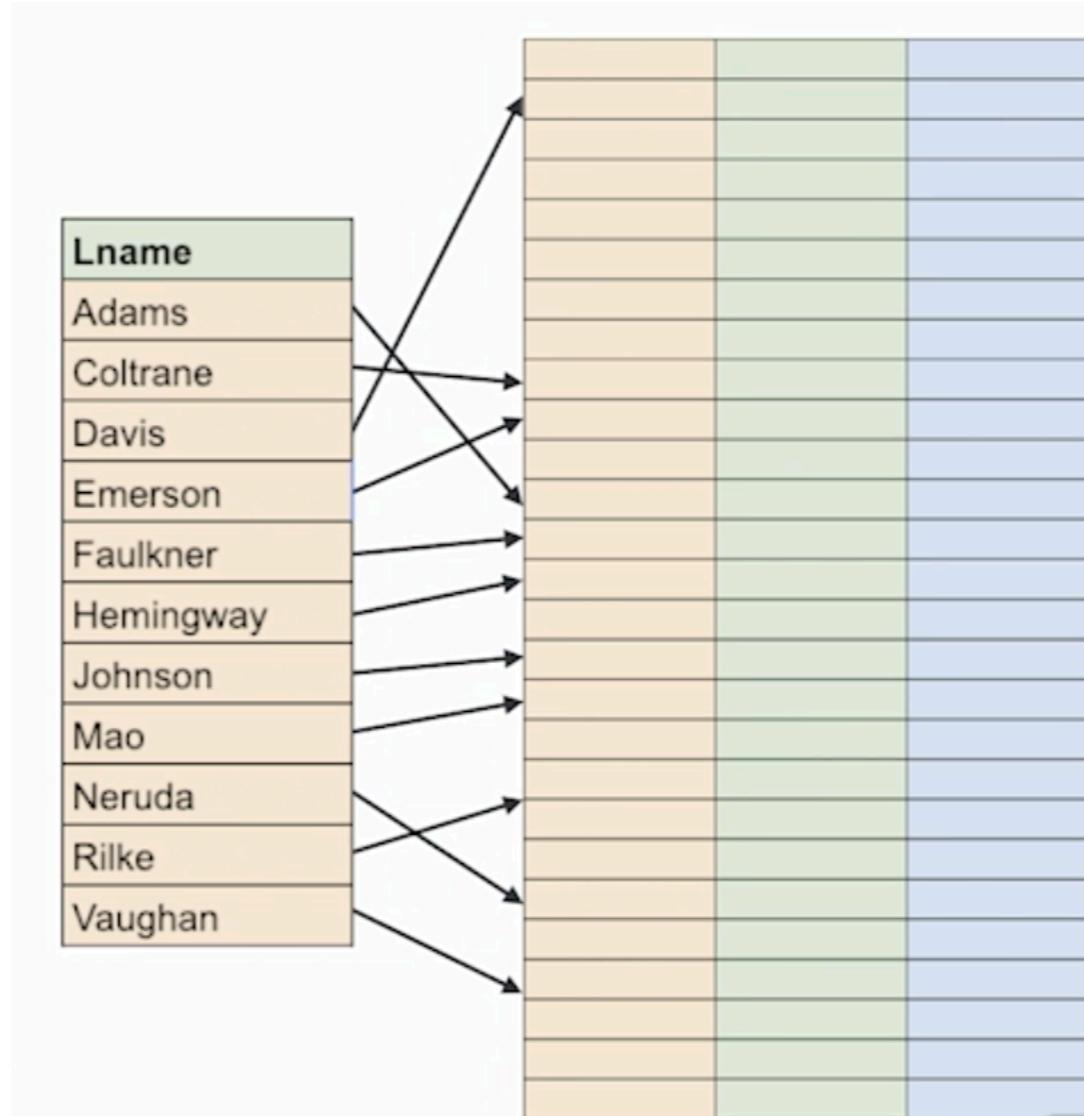
Indexes are **ordered**

Faster to search index for an attribute value

Point to location of row



Indexing reduce full table scan



Purposes of indexes

Speed up access to data

Help enforce constraints

Indexes are ordered

Typically smaller than tables

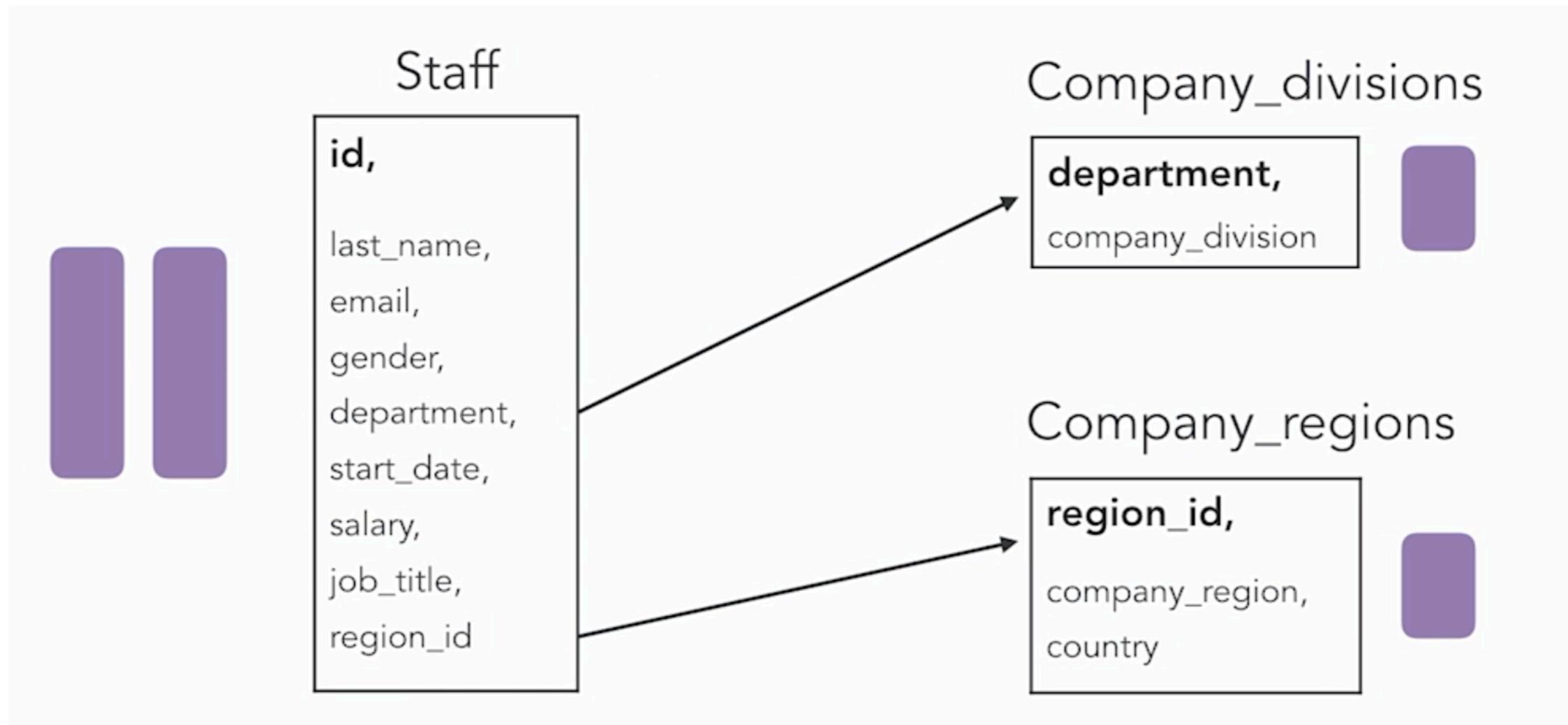


Implementation of indexes

Data structure separate from table
Sometime duplicate some data (e.g. key)
Organised differently than table data



Implementation of indexes



Types of indexes

B-tree for equality and range query

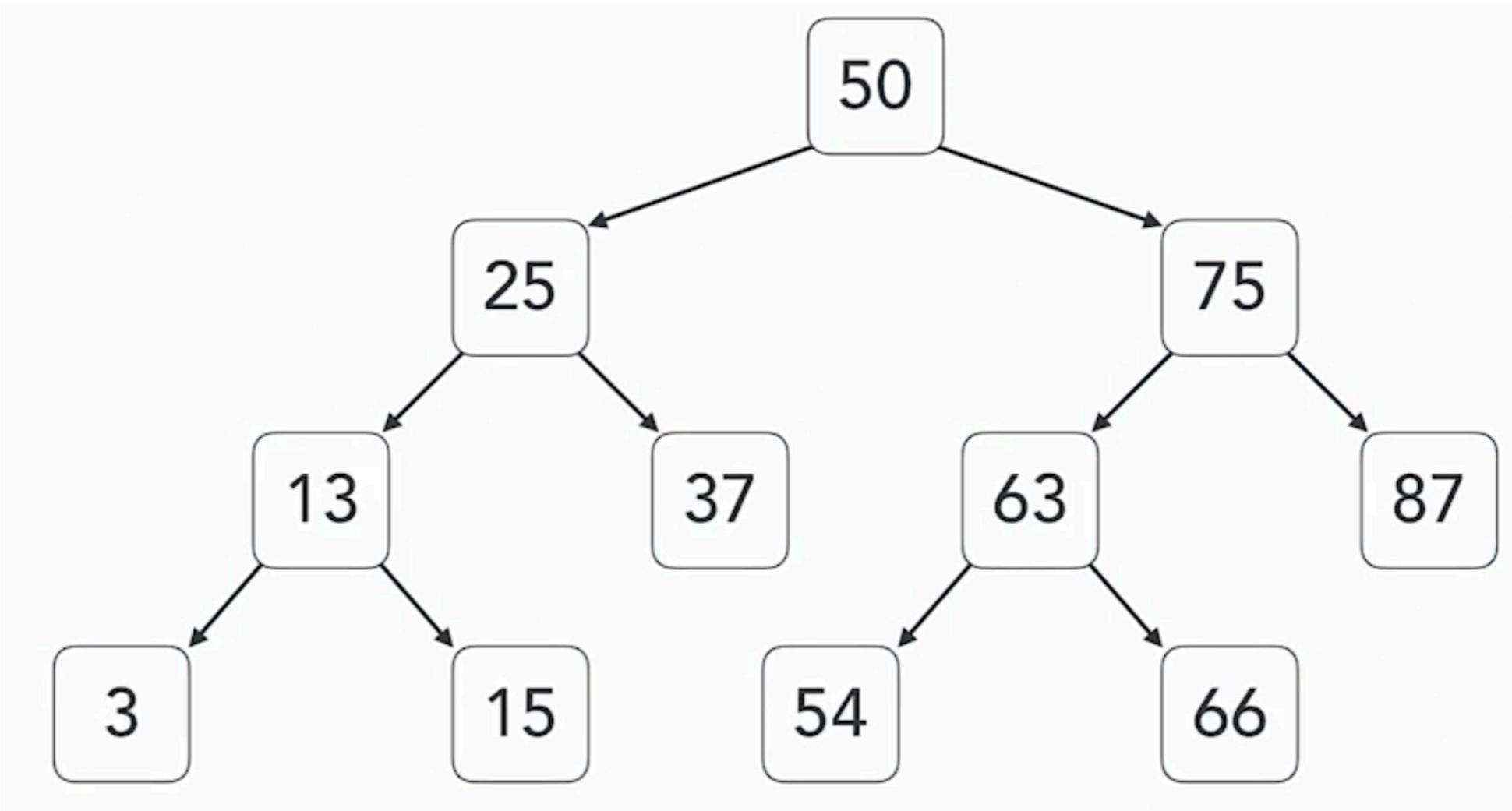
Hash for equality query

Bitmap for inclusion

Specialize for geo-spatial or user-defined



B-tree indexes



B-tree indexes

Most common type of index

Use when large number of possible values in a column

Rebalances as need

Time to access is based on **depth of tree**



Benchmark and performance testing with PostgreSQL



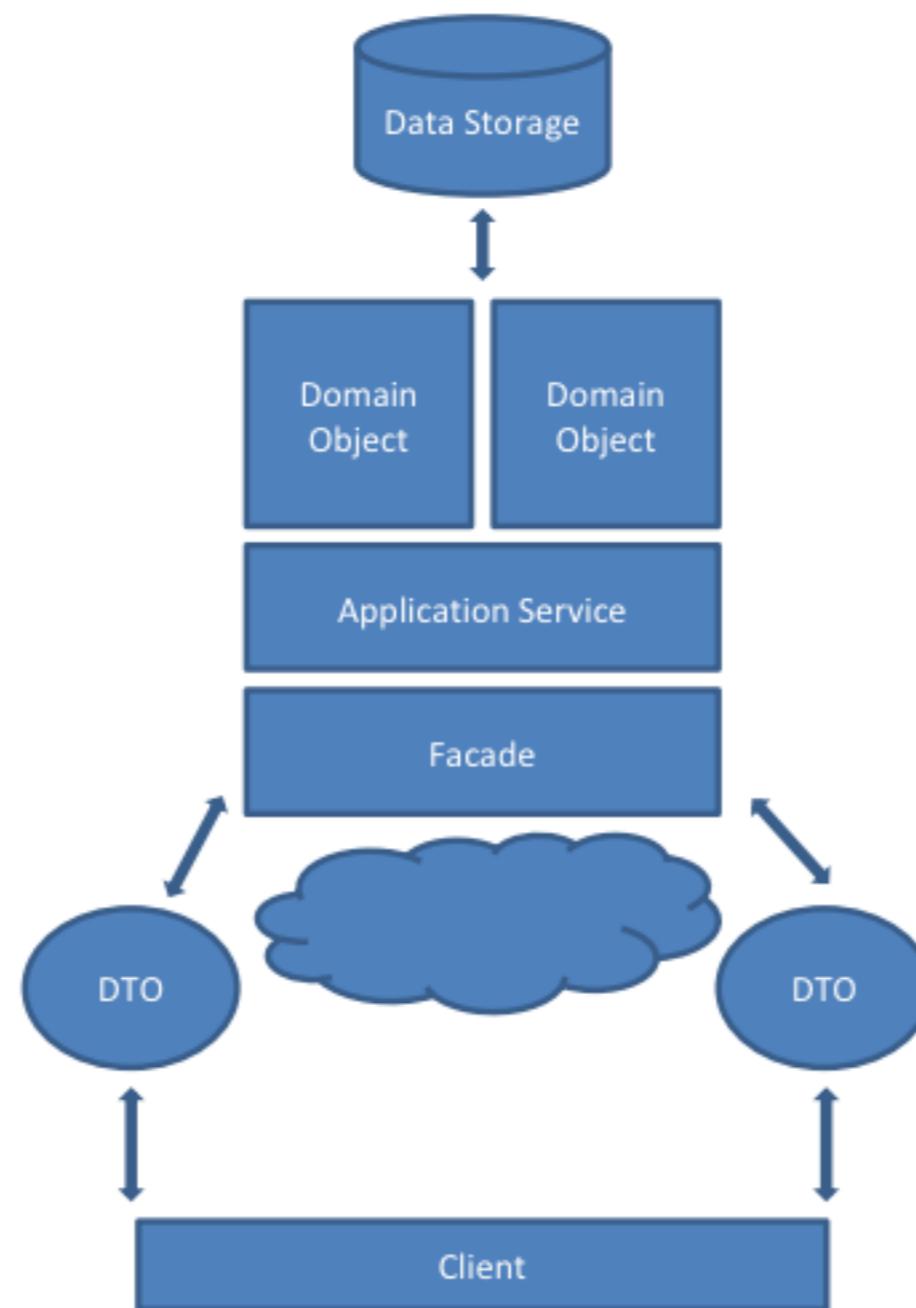
Reporting problem ?



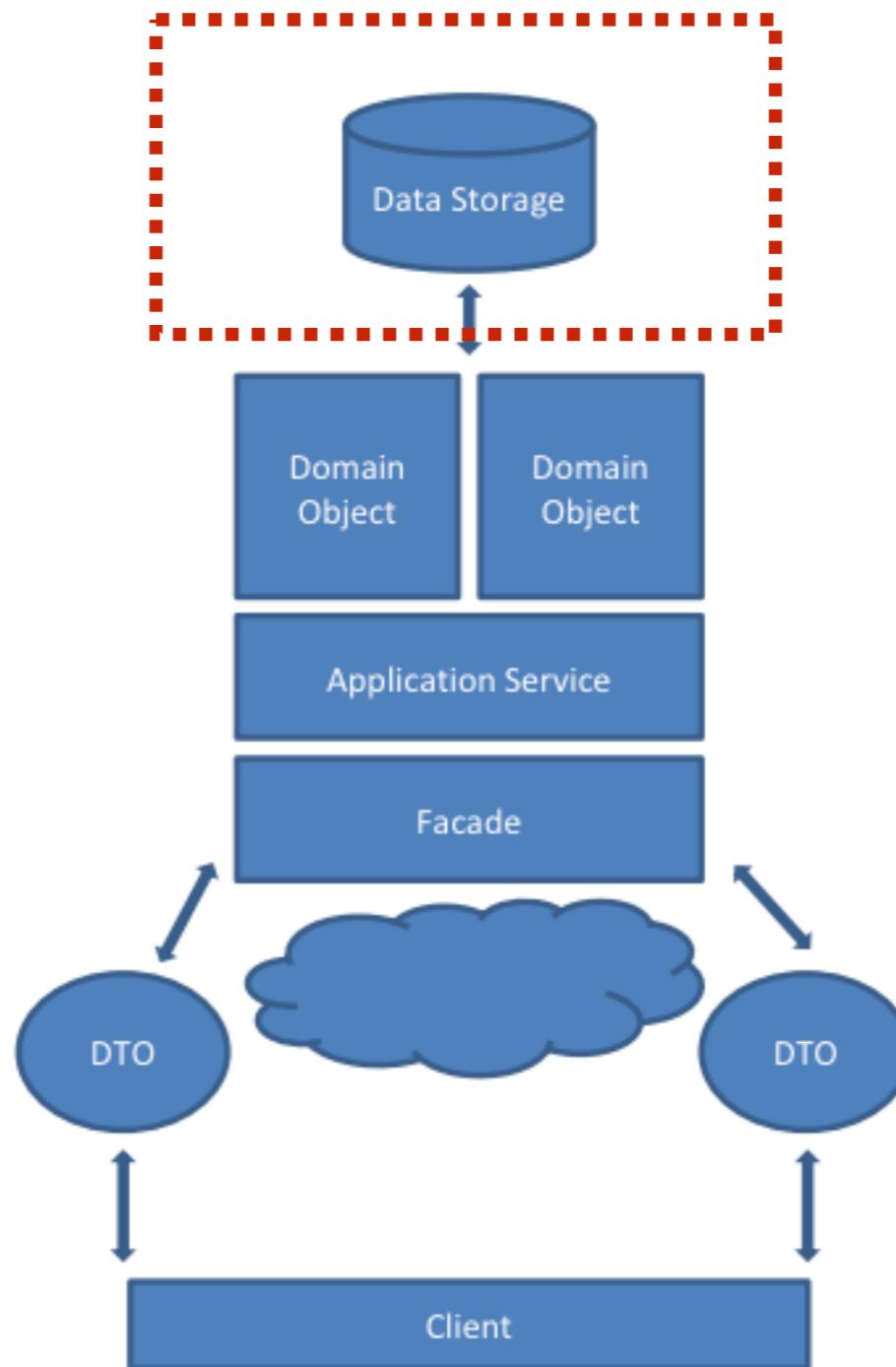
Read vs Write operation with Database



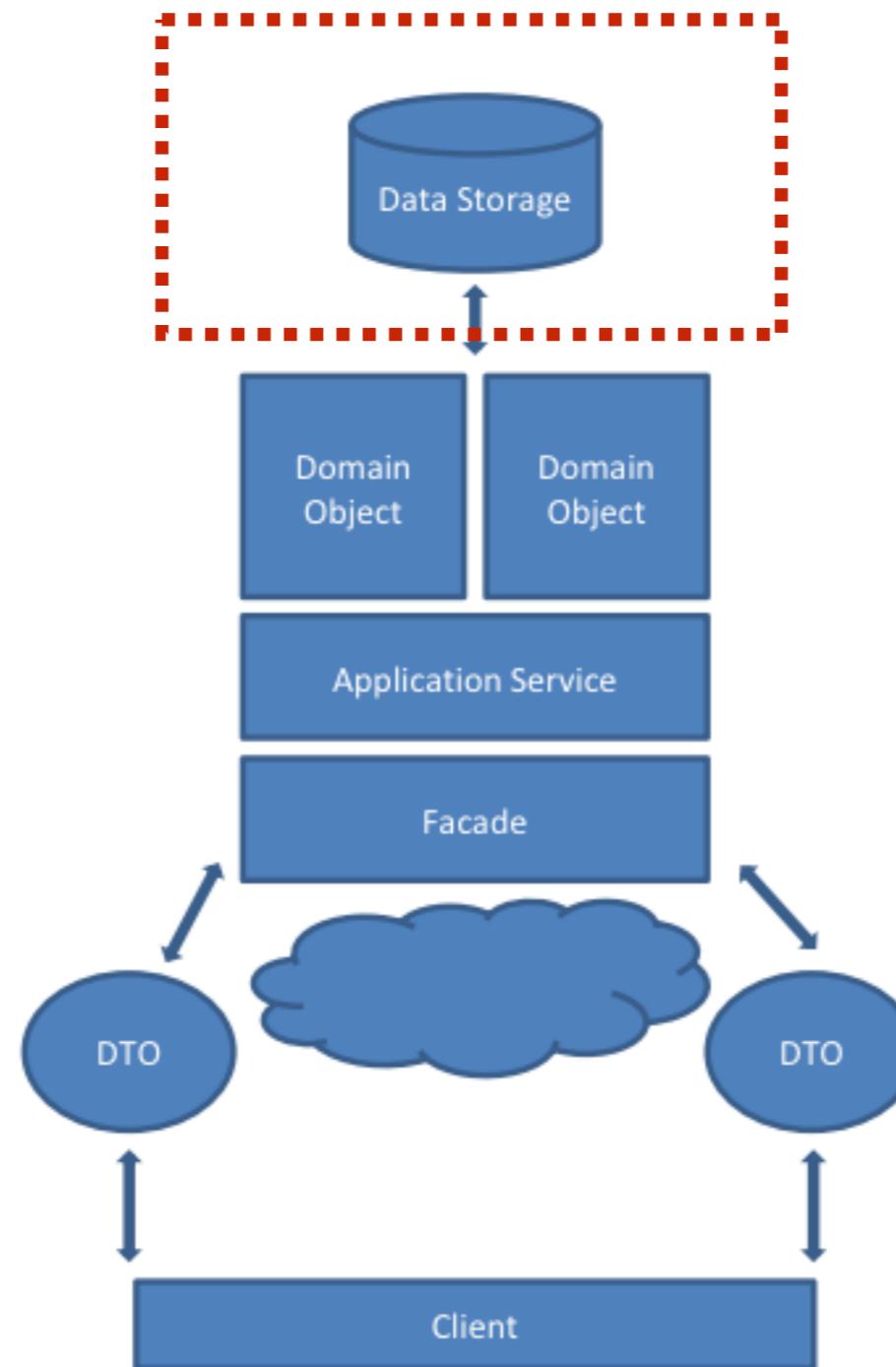
Simple Architecture



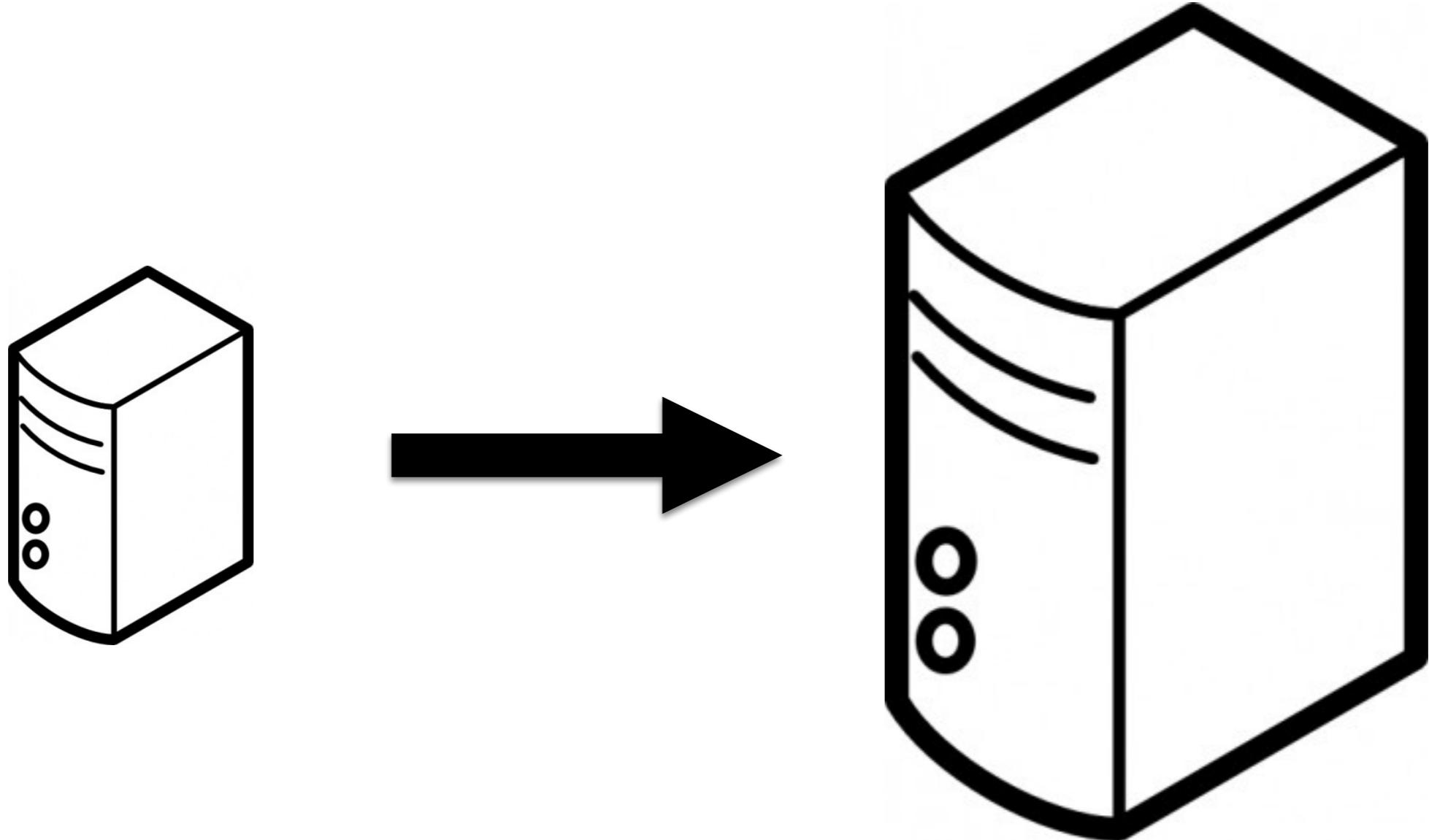
Read and Write



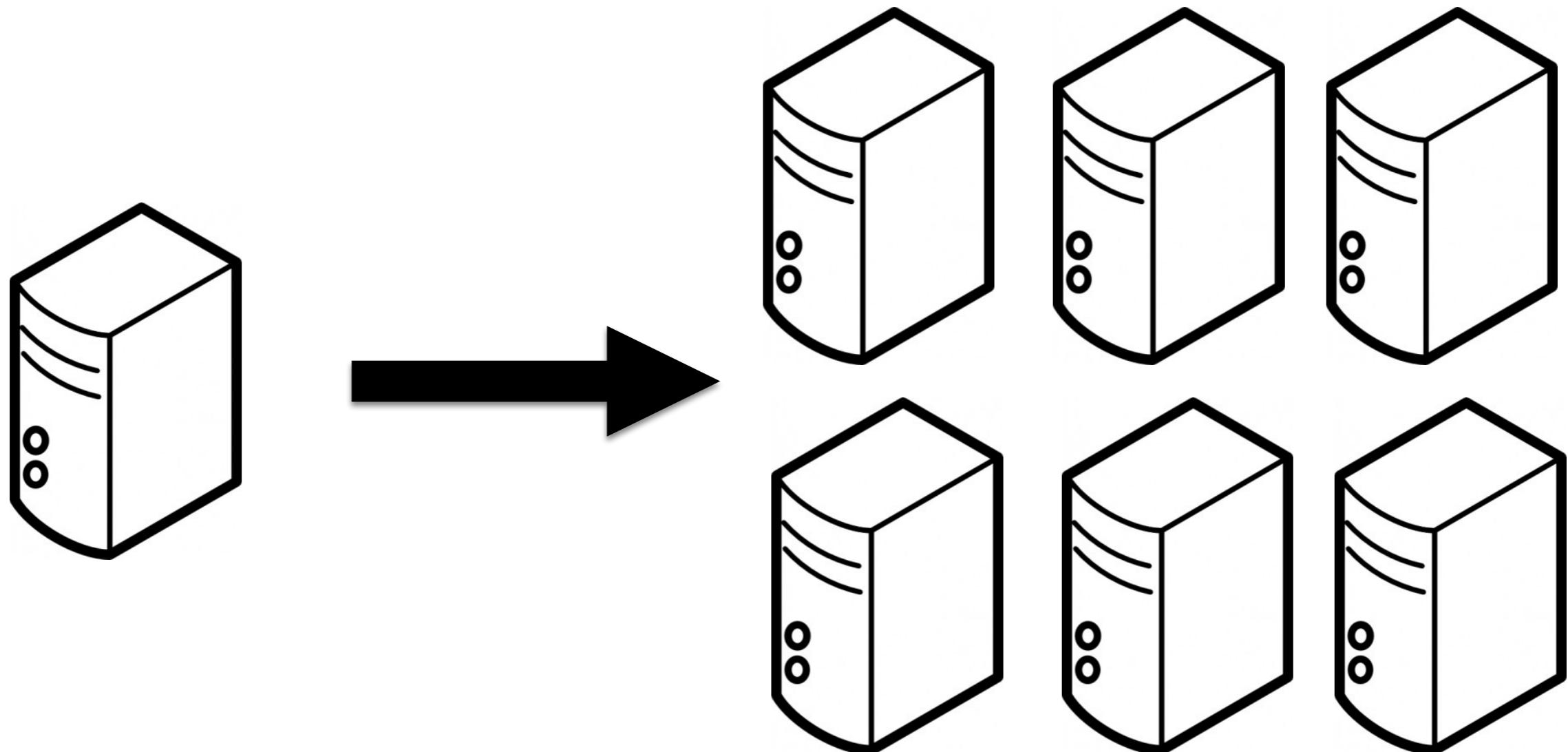
How to scale ?



Scale up (Vertical)

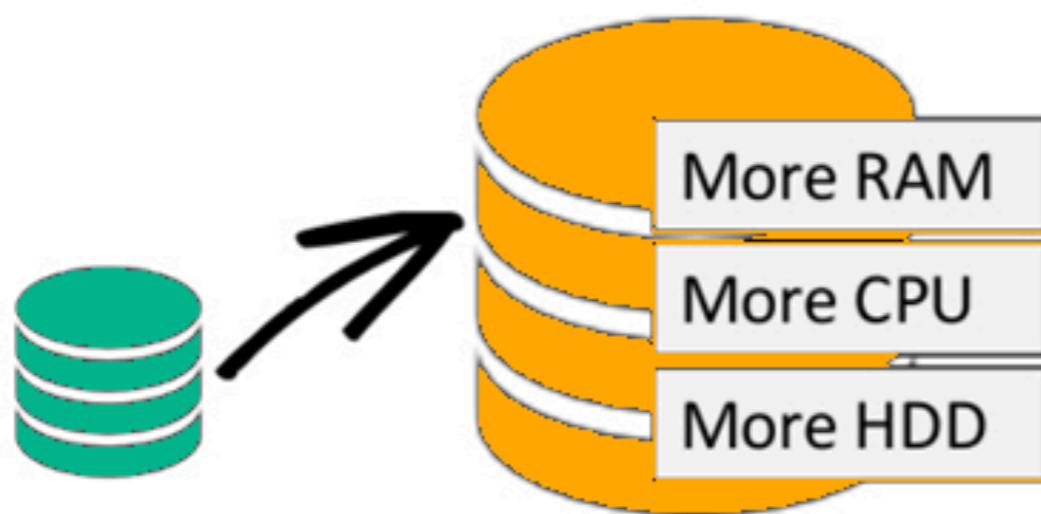


Scale out (Horizontal)

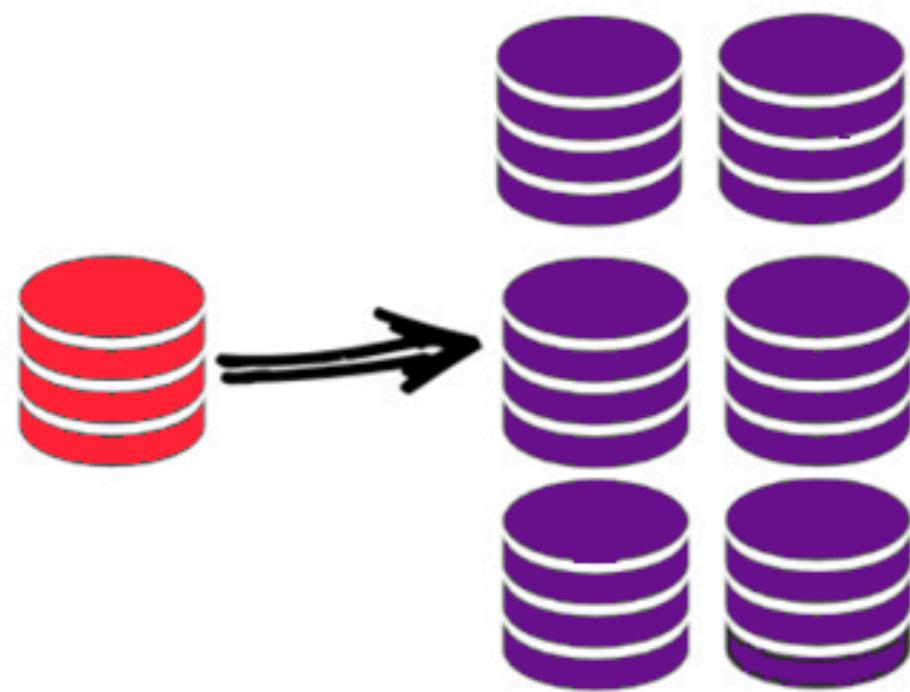


Scale up vs out ?

Scale-Up (*vertical* scaling):



Scale-Out (*horizontal* scaling):



Scale up

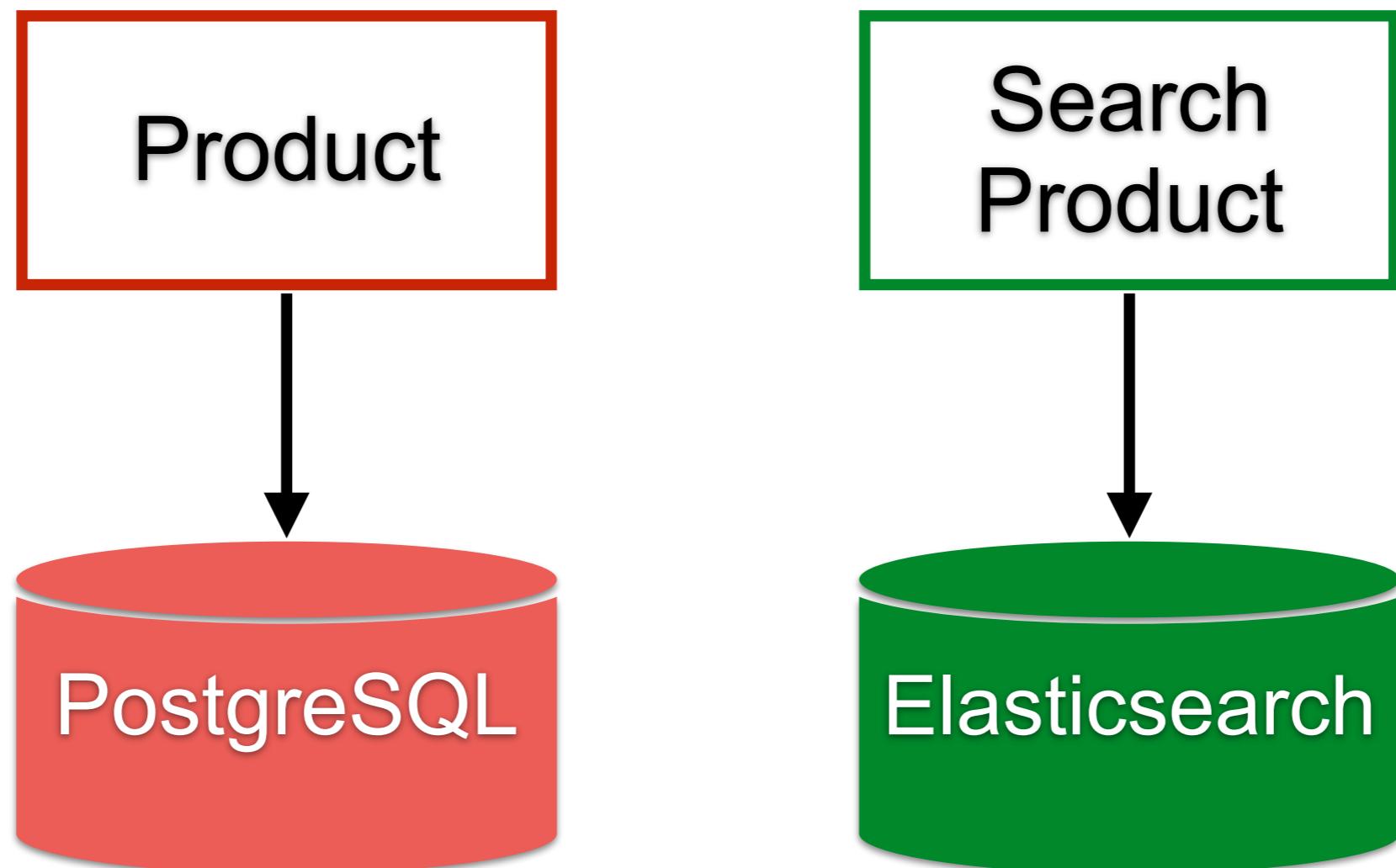
Command Query Responsibility Segregation



Design for read
Design for write



Separate DB for read and write



Command Query Separation

Every method should either be a **command** that performs an action,
or a **query** that returns data to the caller
but not both



Simple service

```
BankAccountService
{
    BankAccount CreateBankAccount(BankAccount);
    BankAccount GetBankAccount(AccountId);
    decimal UpdateBalance(AccountId, Balance);
    void UpdateBankAccount(BankAccount);
    decimal GetBankAccountBalance(AccountId);
}
```



CQS service

```
BankAccountReadService
```

```
{
```

```
    BankAccount GetBankAccount (AccountId) ;  
    decimal GetBankAccountBalance (AccountId) ;
```

```
}
```

```
BankAccountWriteService
```

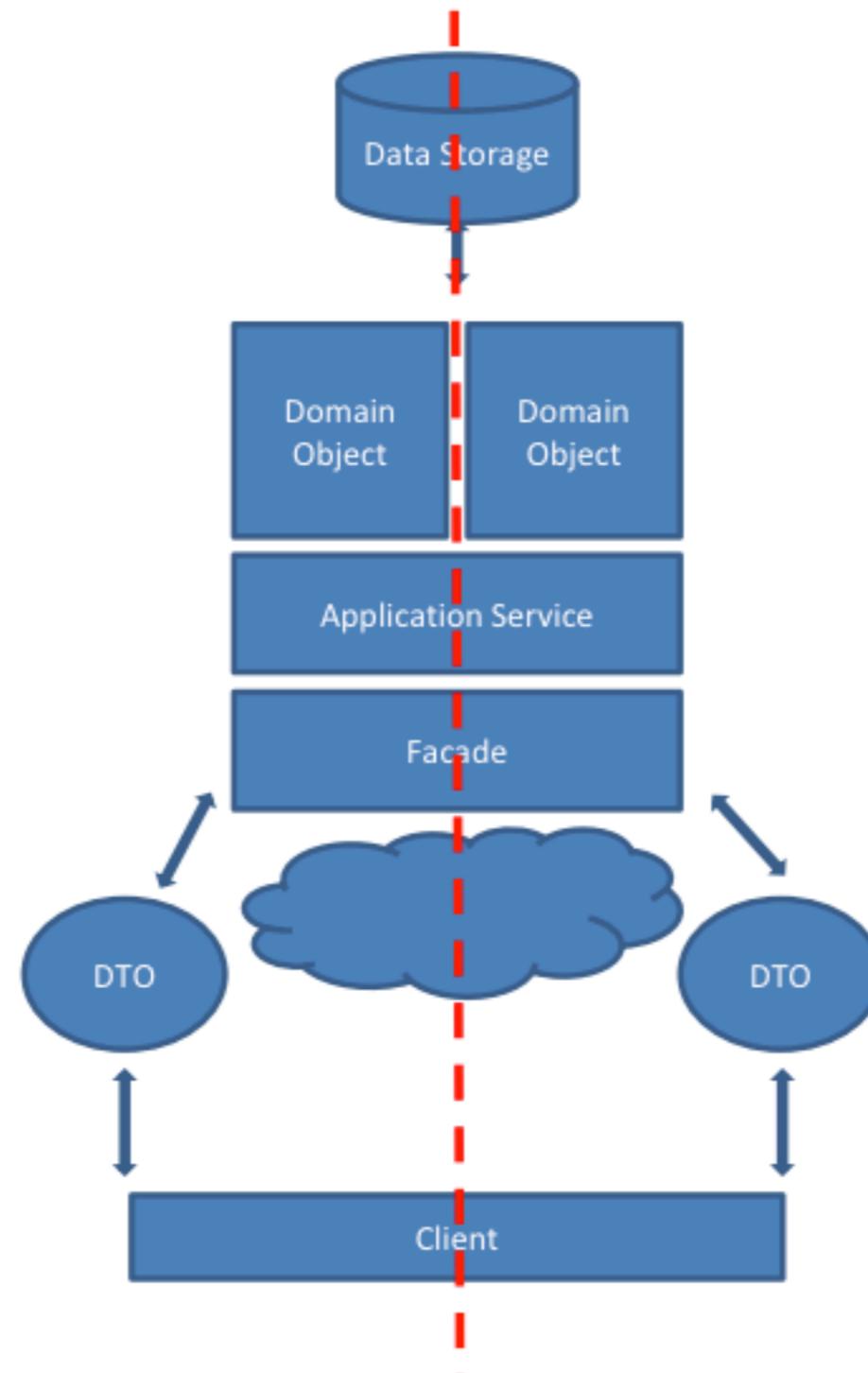
```
{
```

```
    BankAccount CreateBankAccount (BankAccount) ;  
    decimal UpdateBalance (AccountId, Balance) ;  
    void UpdateBankAccount (BankAccount) ;
```

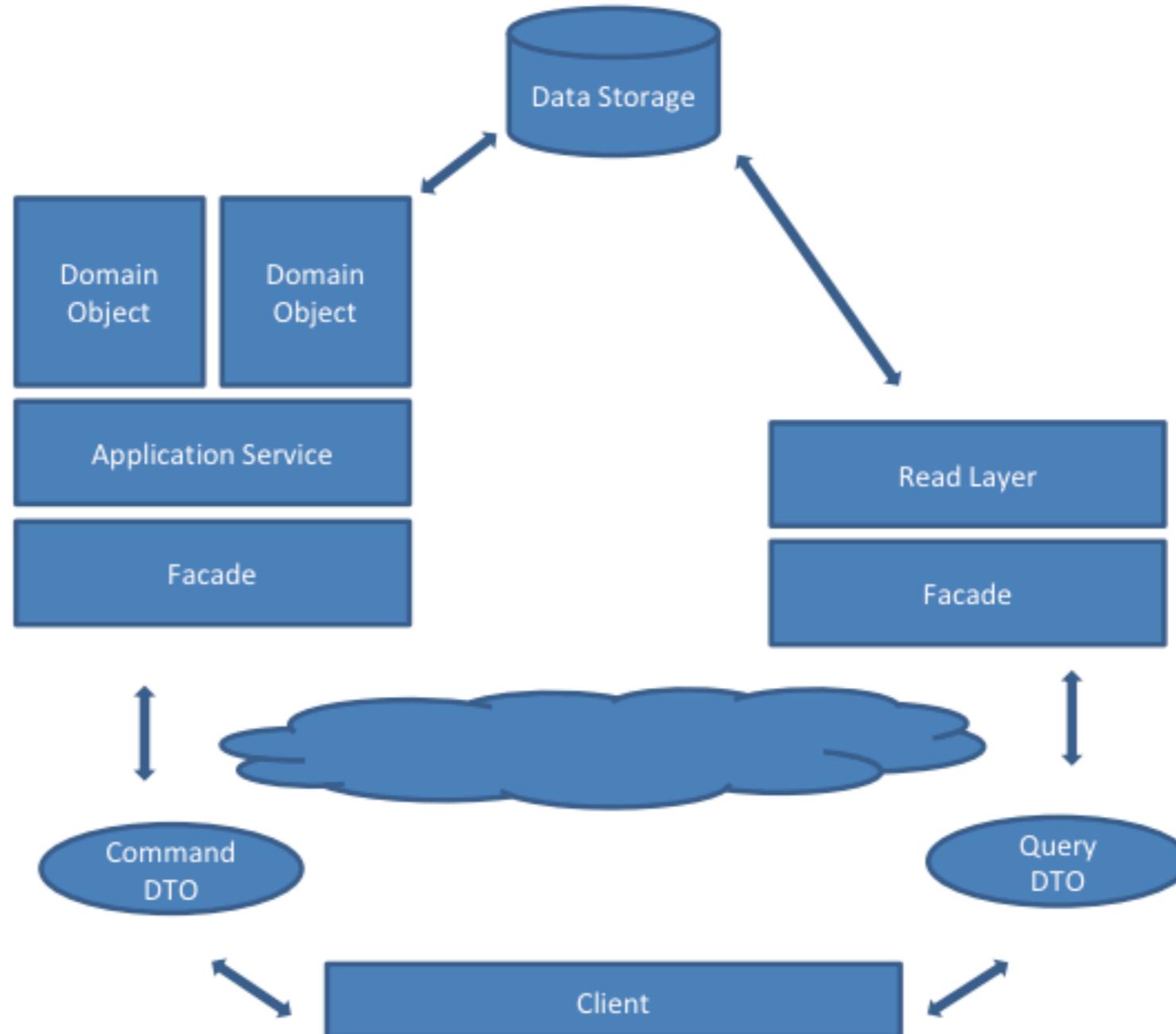
```
}
```



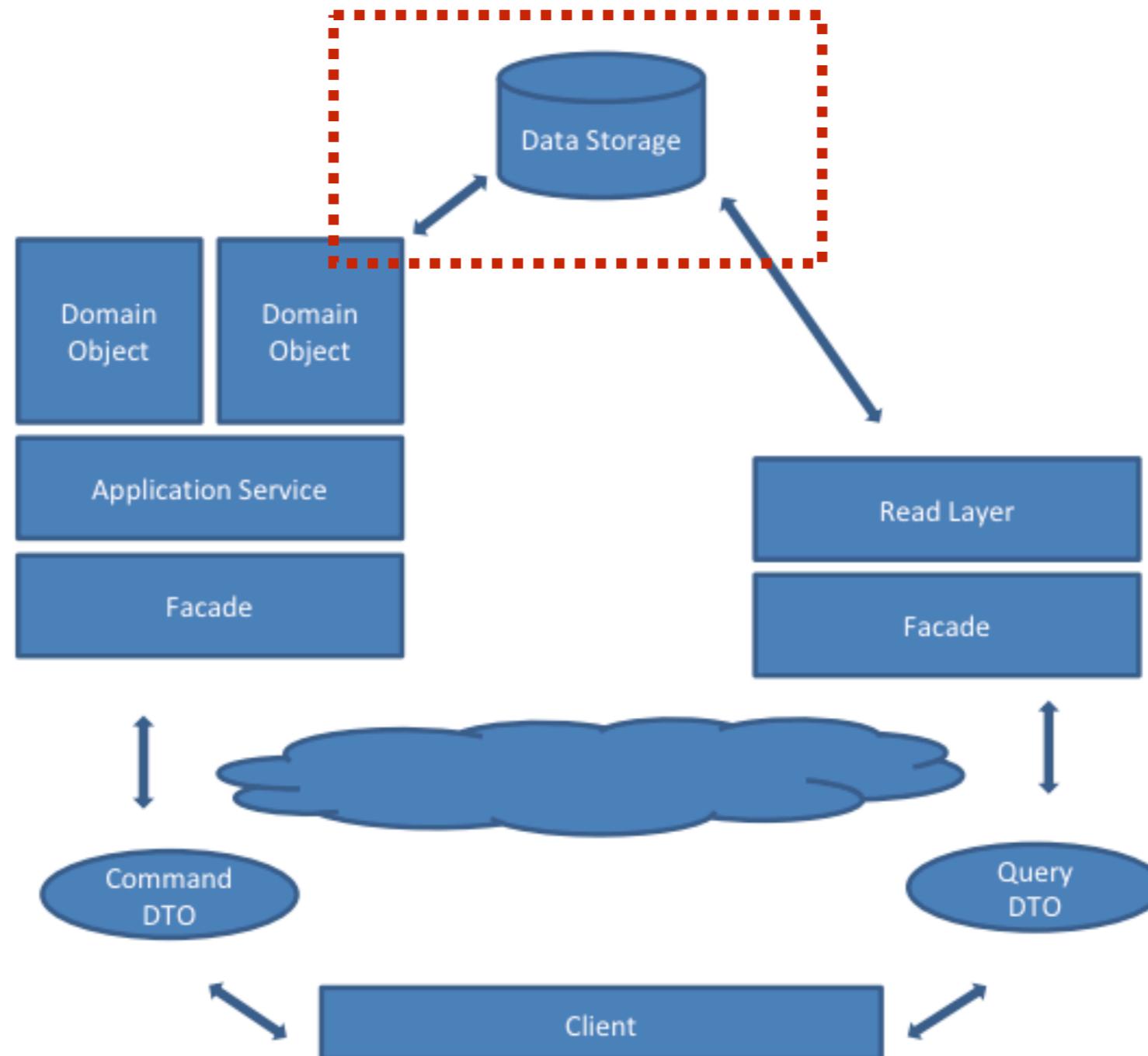
Separate responsibility



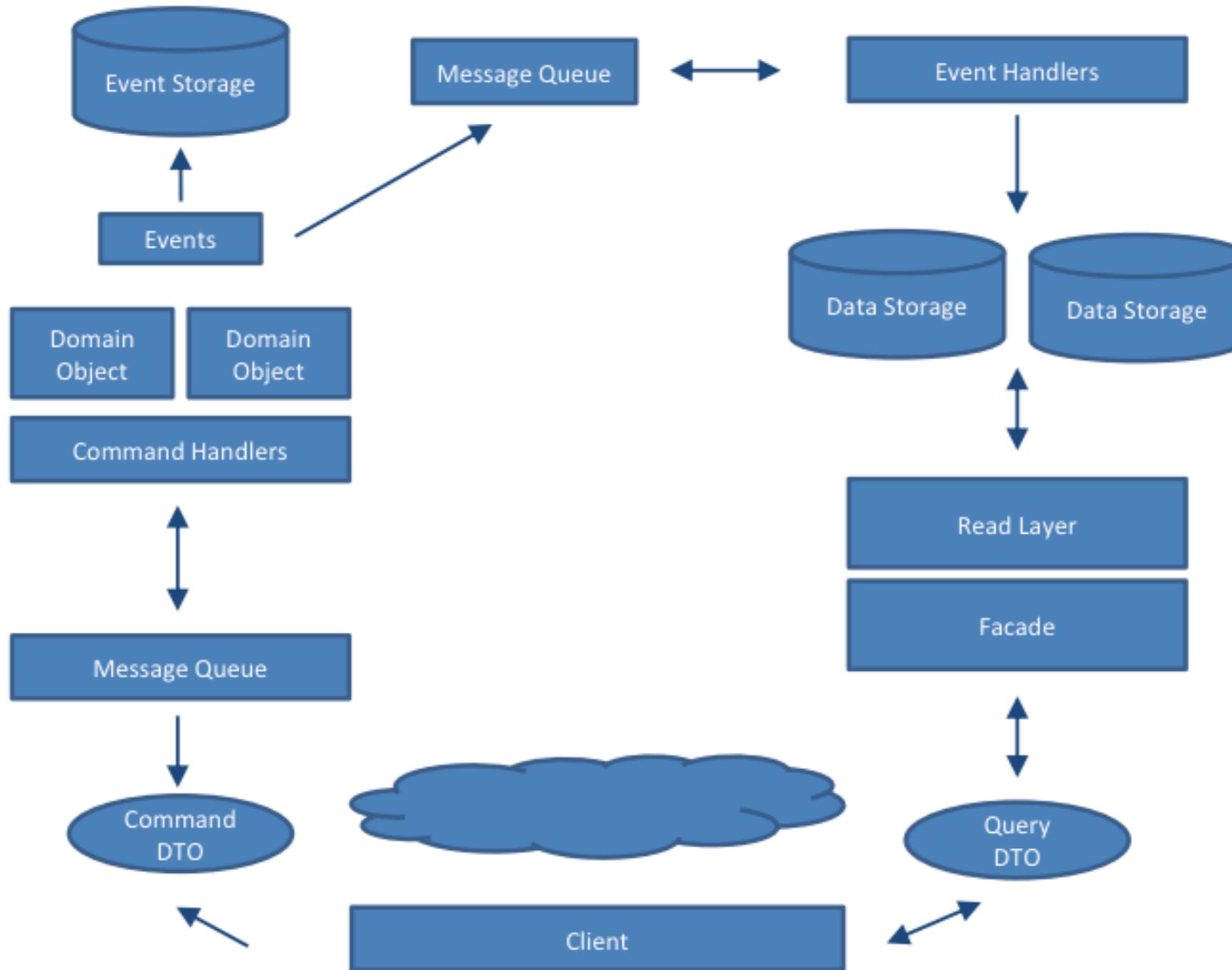
Separate Responsibility



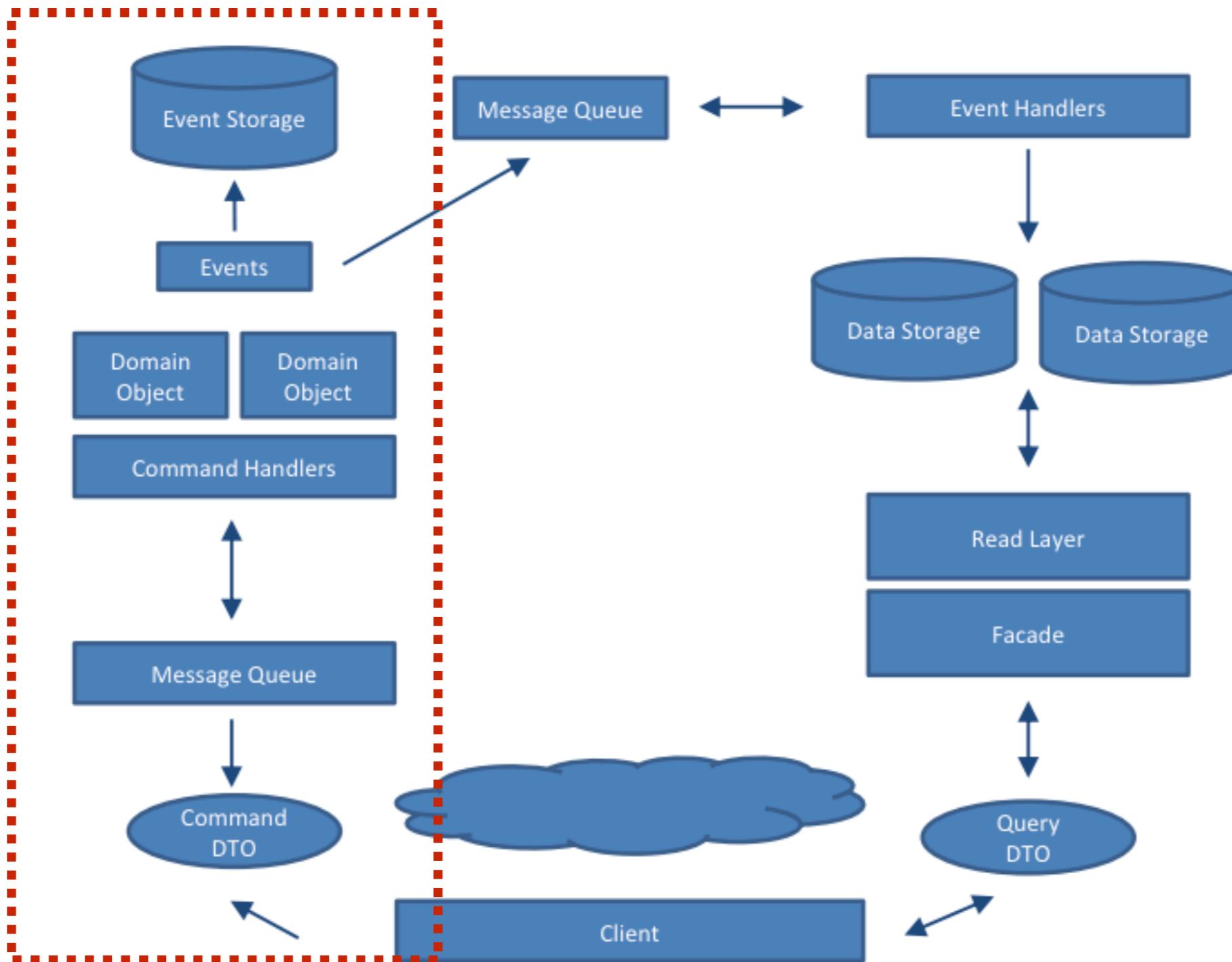
Separate responsibility



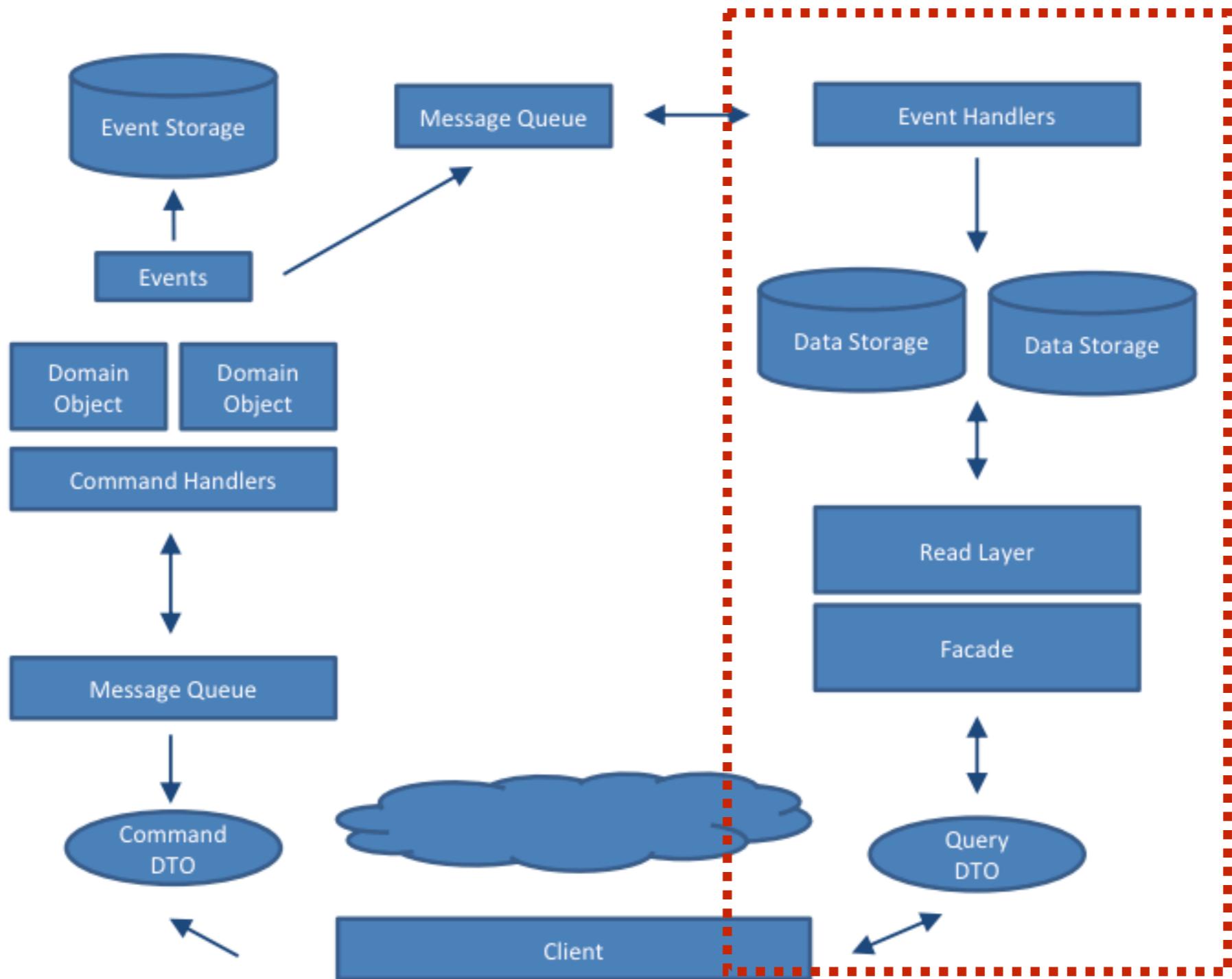
Scalability



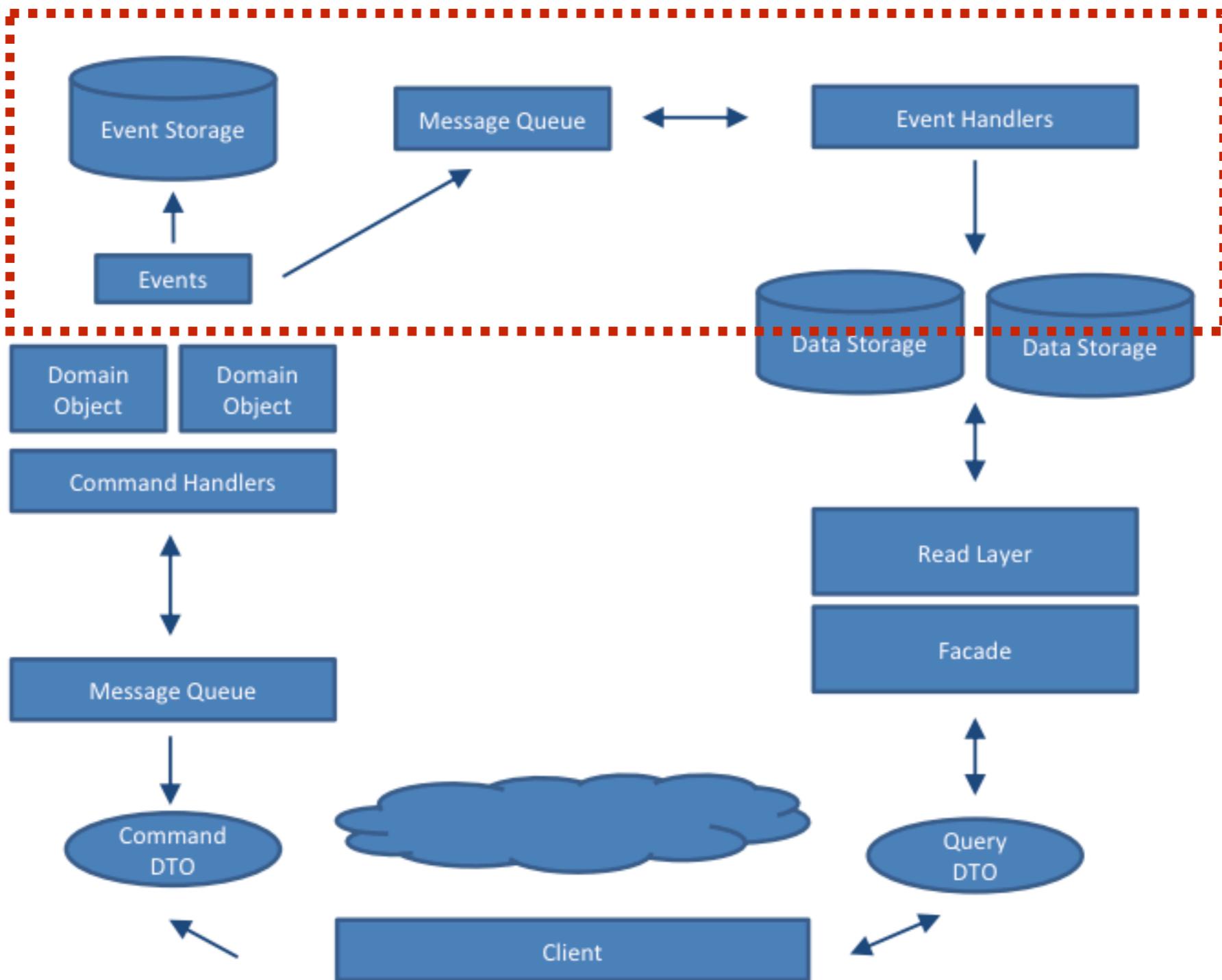
Command



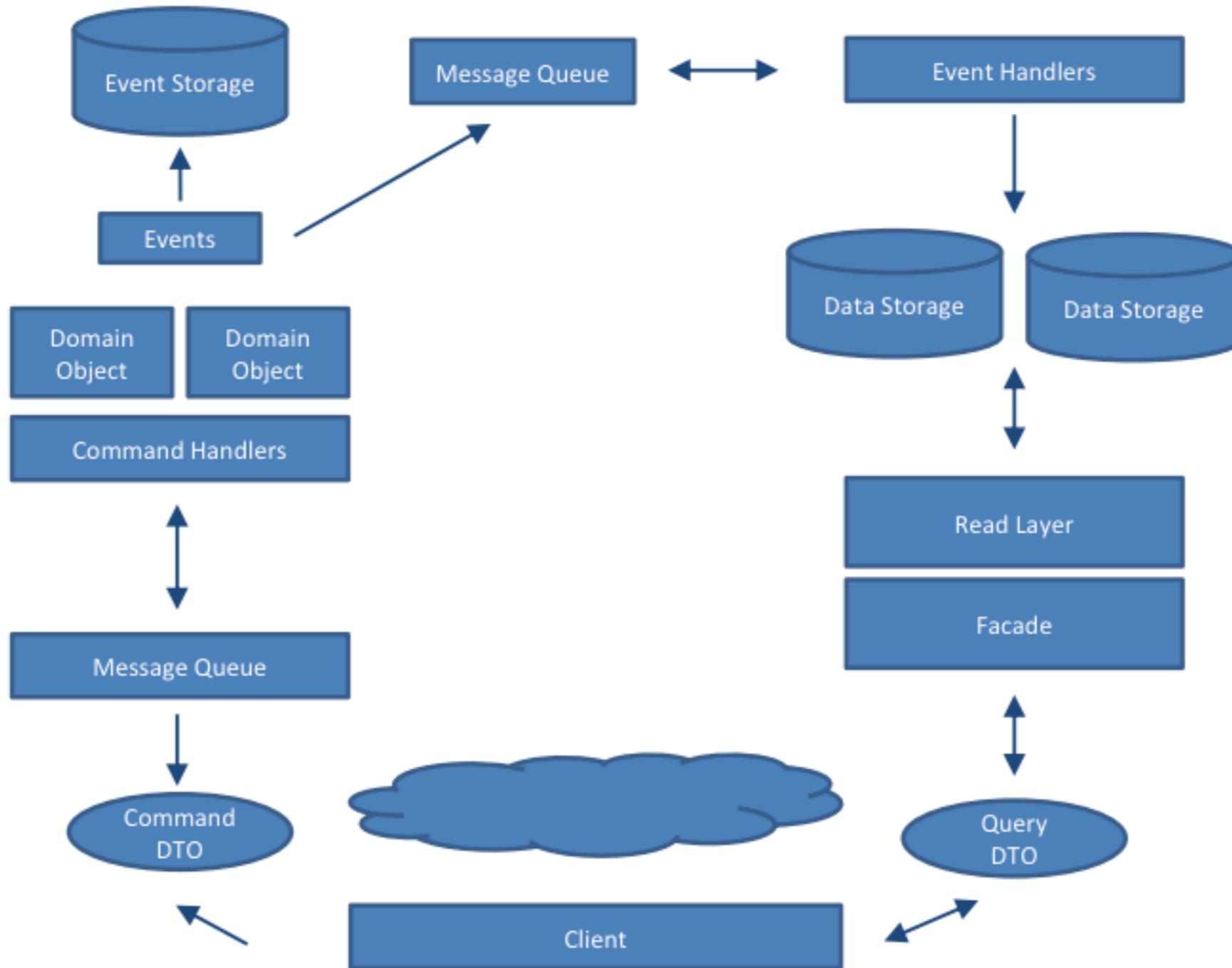
Query



Sync data



CQRS



CQRS

Command Query Responsibility Segregation



Scale with PostgreSQL

Partitioning
Replication
Clustering



Partitioning

Storing table data in multiple sub-tables
Called “Partition”



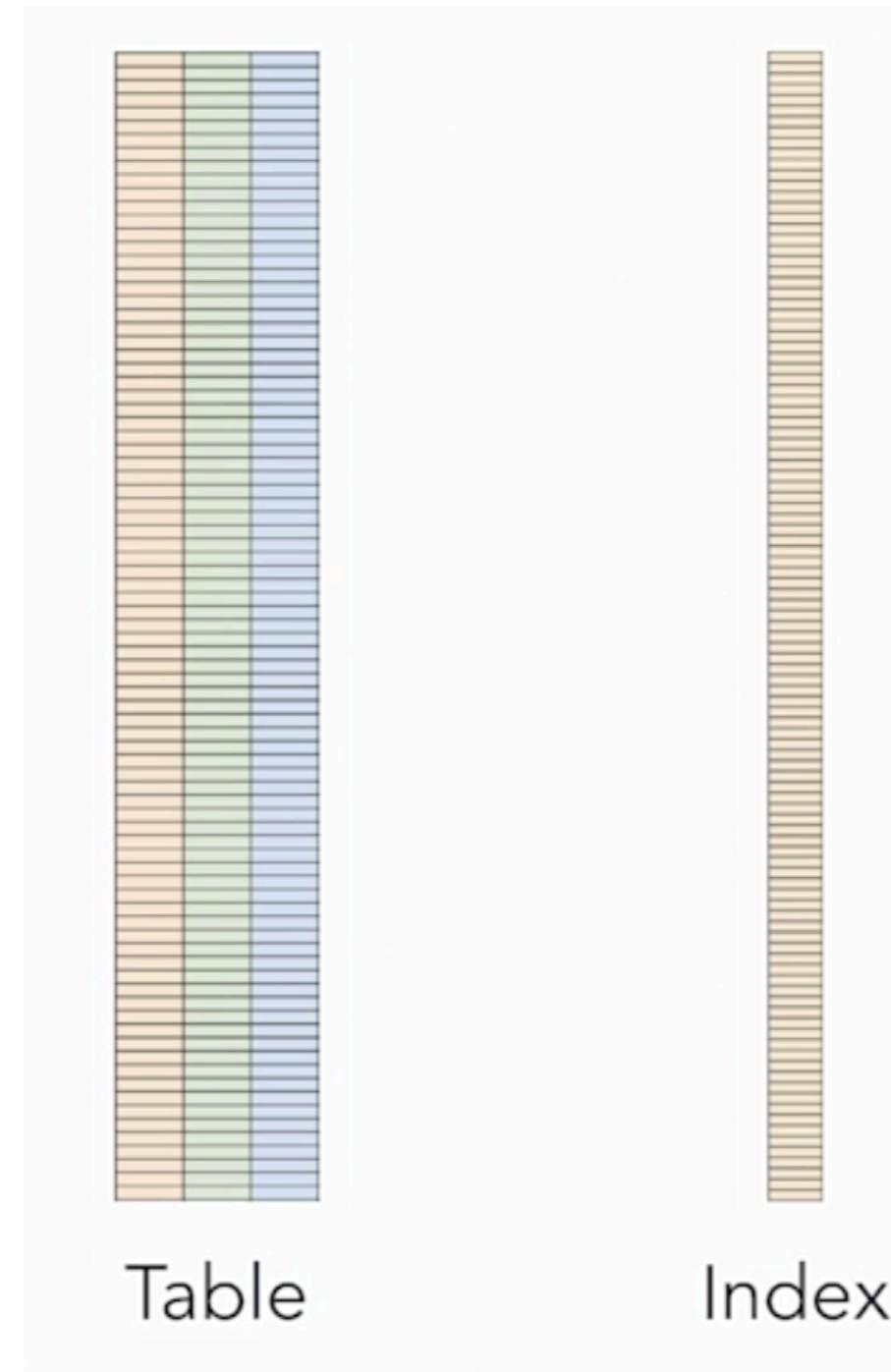
Partitioning

Used to improve query, load and delete operation

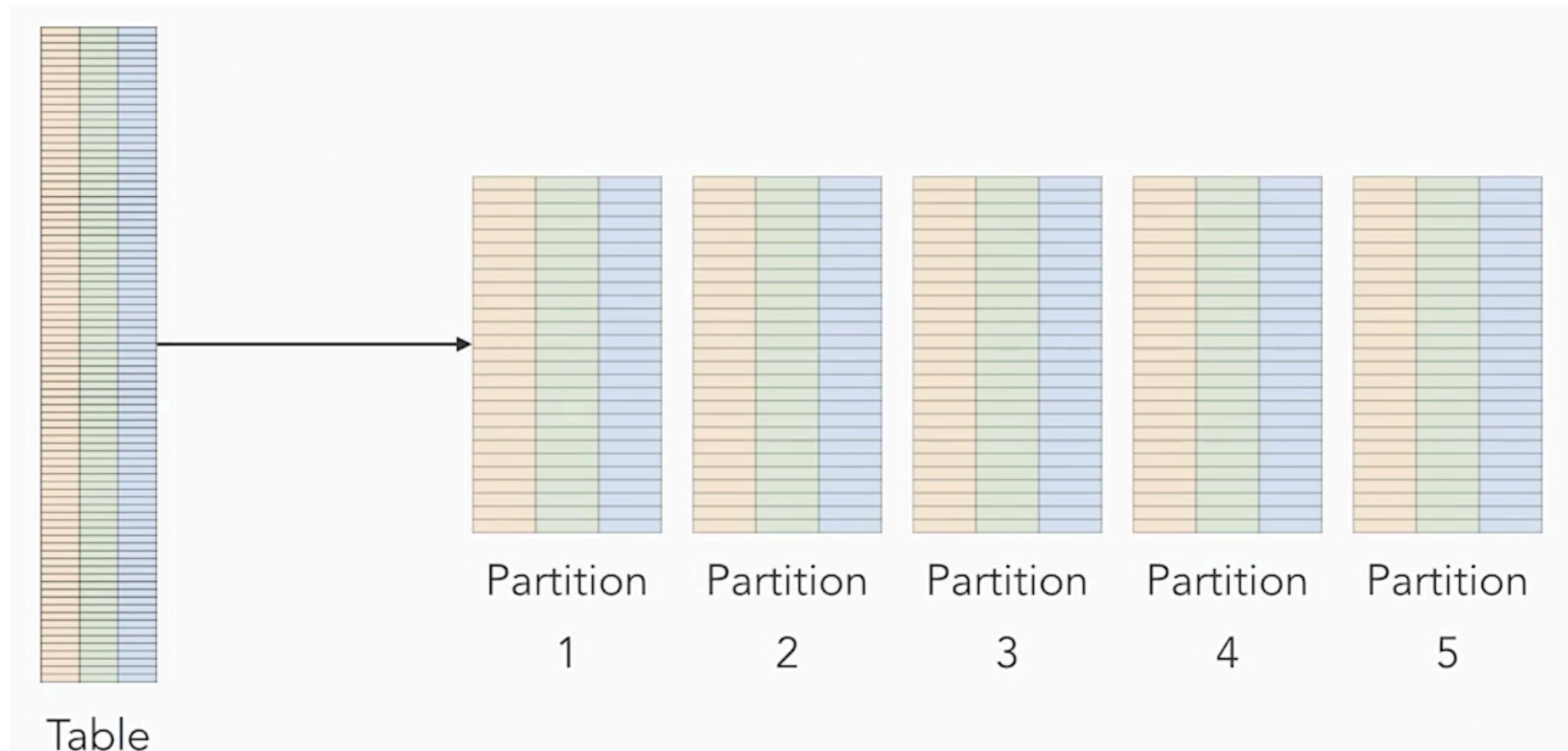
Used for **large tables**



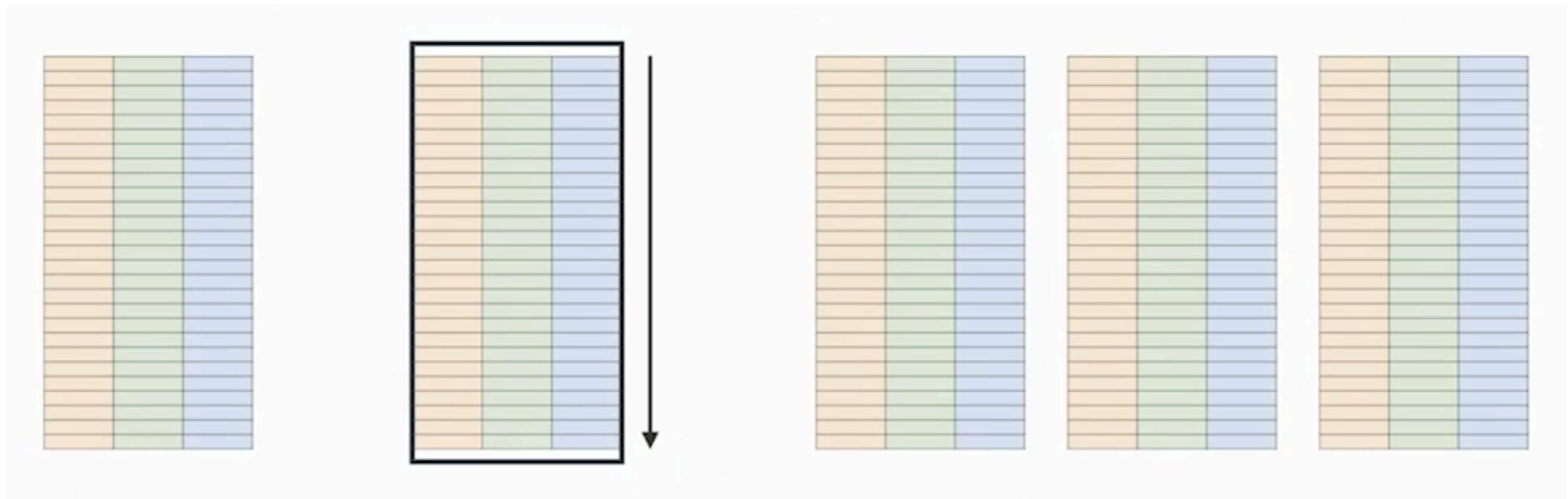
Large table == Large index



Partition data



Faster scan



Partitioning

Range of values

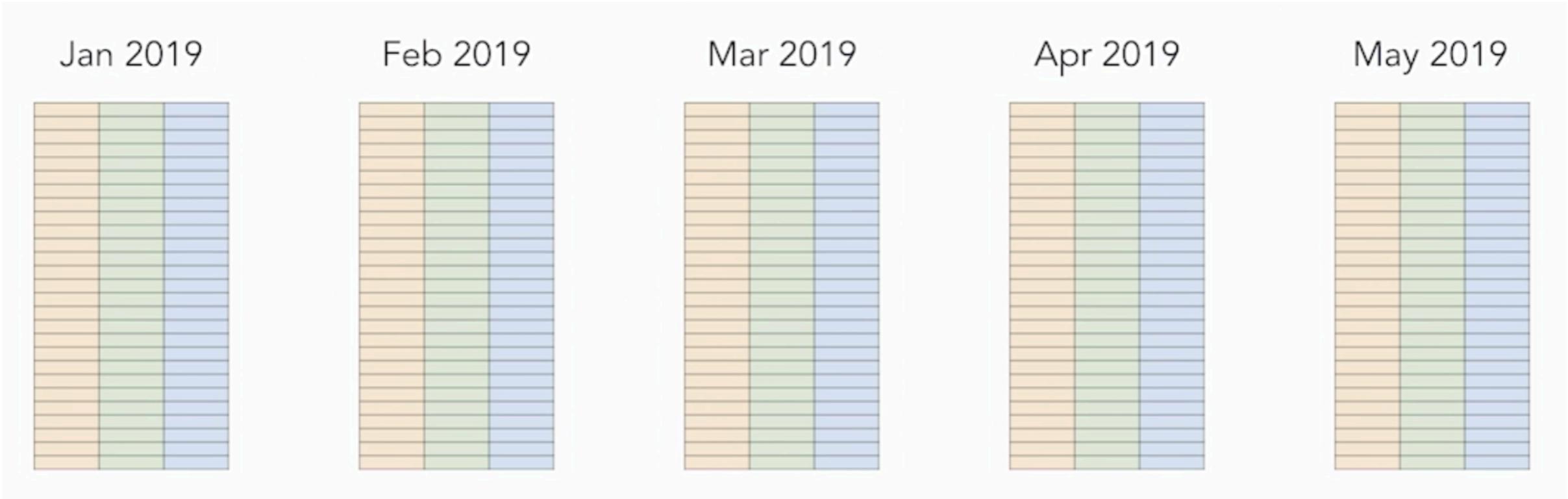
List of values

Hash of values

<https://github.com/up1/course-sql/blob/master/workshop-postgresql/partition.md>



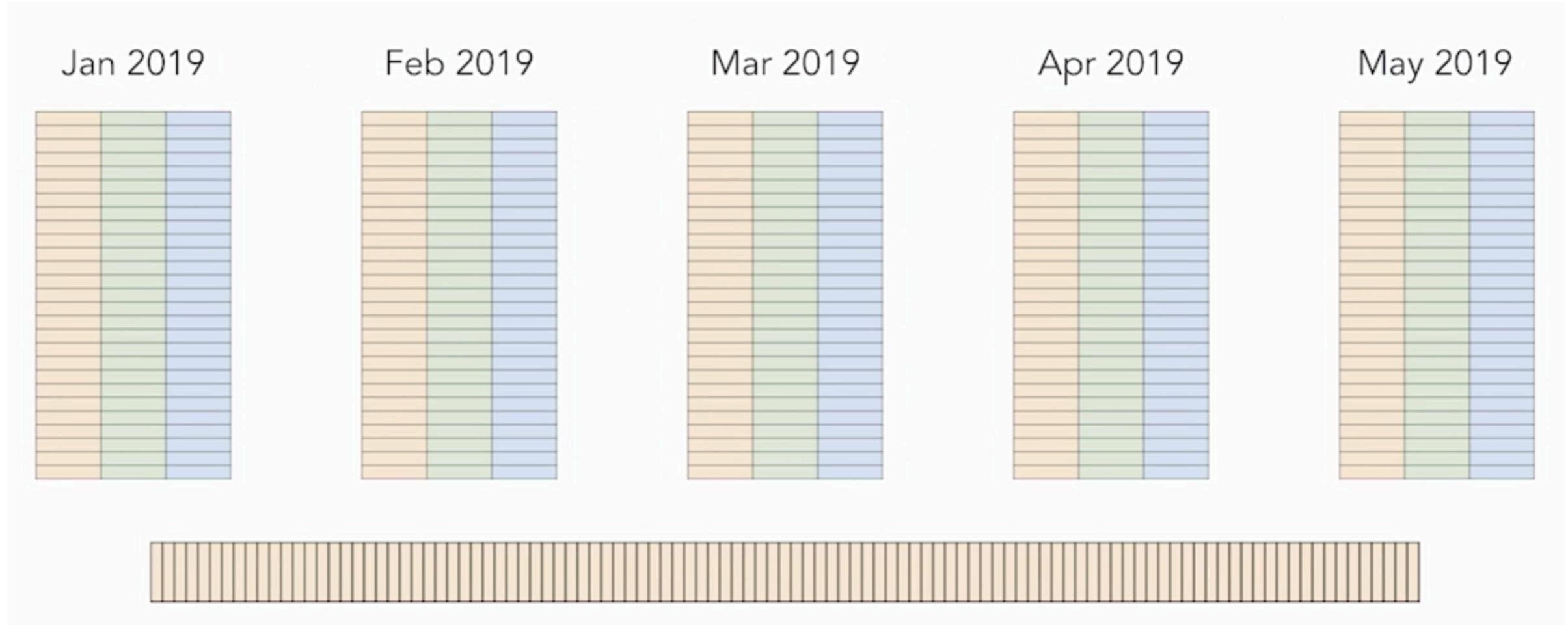
Partition by range



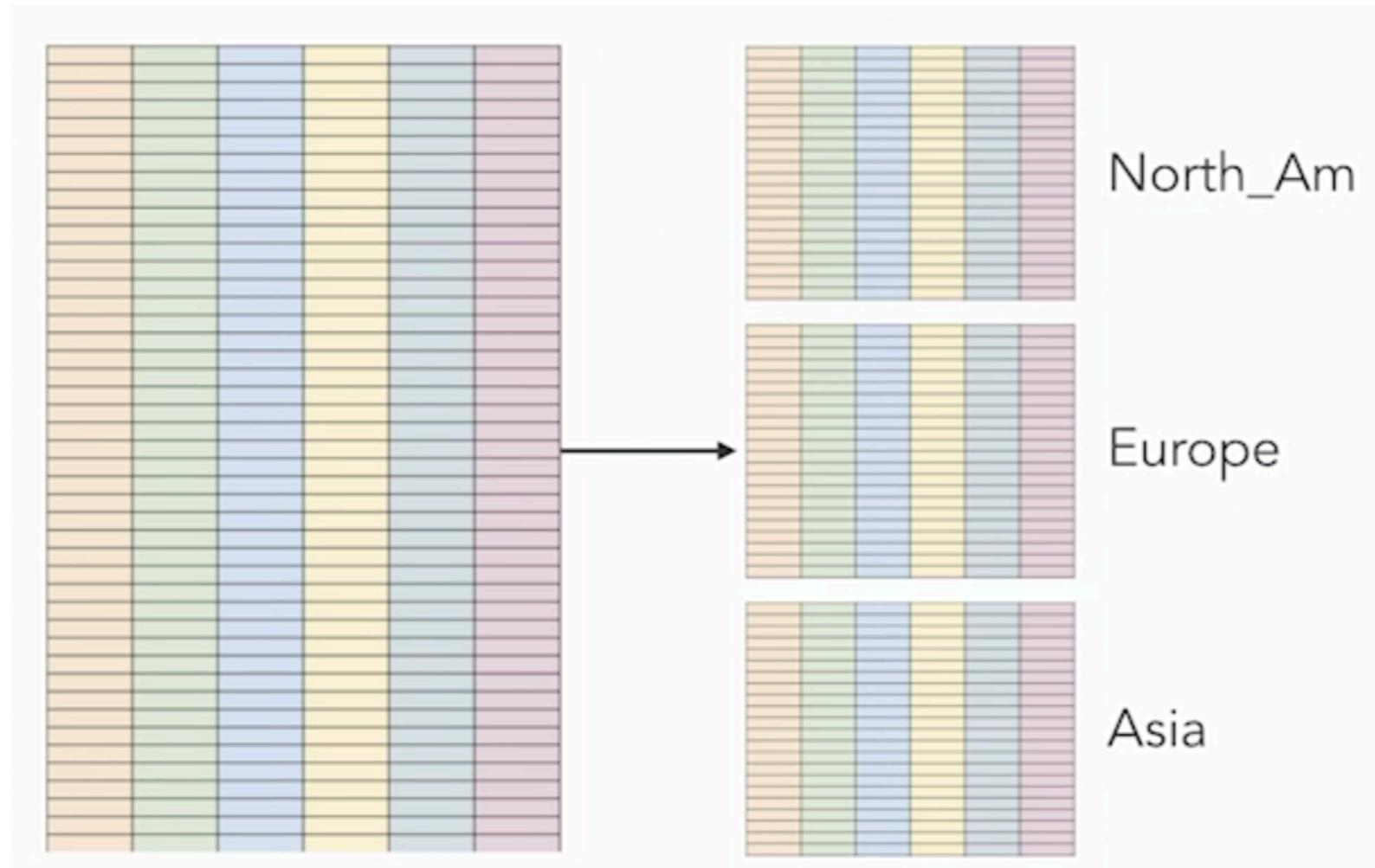
Local index in each partition



Global index for all partitions



Partition by list of values



Example

Partition by list of product catalog

```
CREATE TABLE products
  (prod_id    int not null,
   prod_name  text not null,
   prod_short_descr text not null,
   prod_long_descr text not null,
   prod_category varchar)
PARTITION BY LIST (prod_category);
```



Example

Partition by list of product catalog

```
CREATE TABLE products
(prod_id  int not null,
 prod_name text not null,
 prod_short_descr text not null,
 prod_long_descr text not null,
 prod_category varchar)
PARTITION BY LIST (prod_category);
```

```
CREATE TABLE product_clothing PARTITION OF products
FOR VALUES IN ('casual_clothing', 'business_attire', 'formal_clothing');

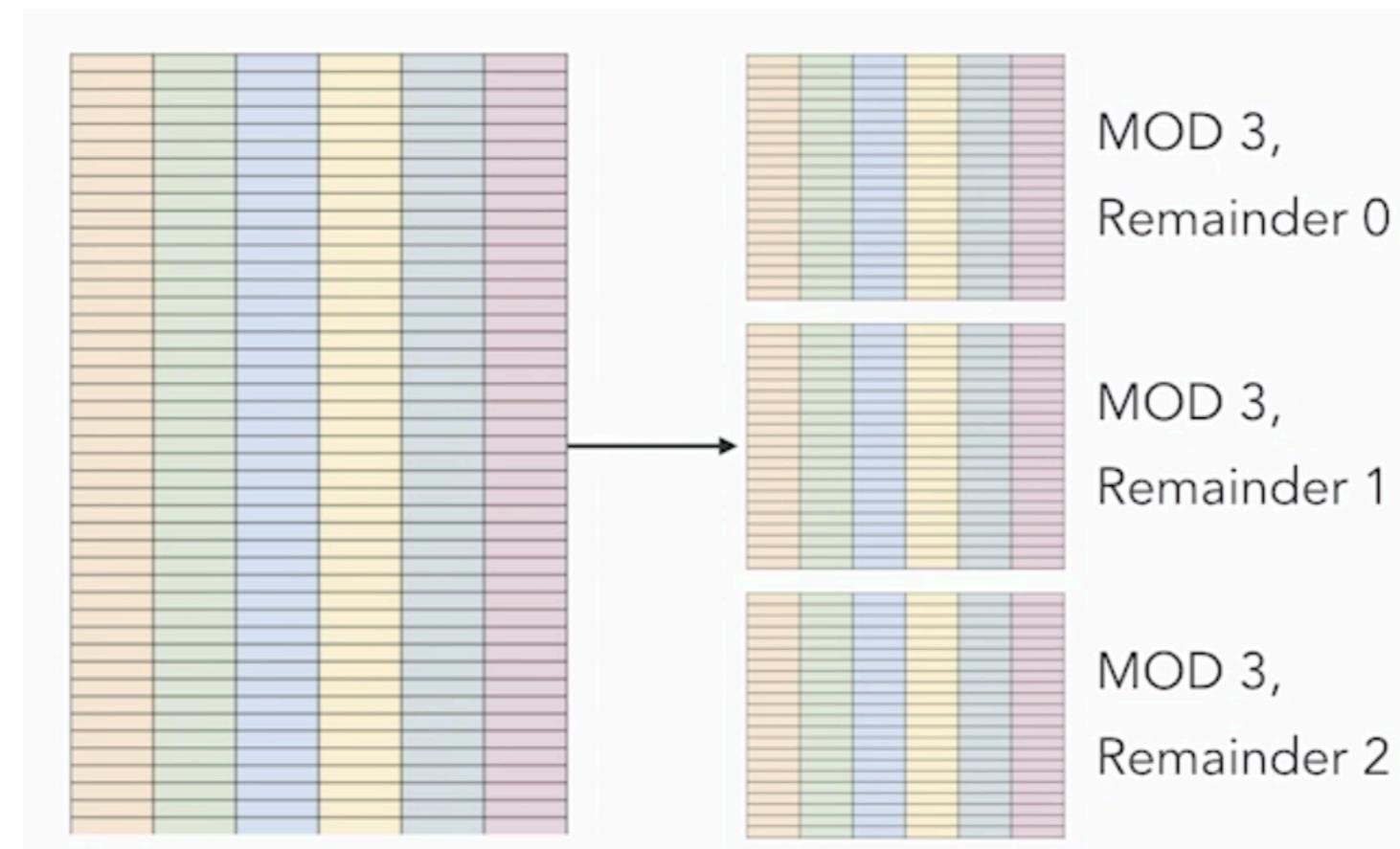
CREATE TABLE product_electronics PARTITION OF products
FOR VALUES IN ('mobile_phones', 'tablets', 'laptop_computers');

CREATE TABLE product_kitchen PARTITION OF products
FOR VALUES IN ('food_processor', 'cutlery', 'blenders');
```



Partition by hash

Partition on modulus of hash of partition keys



Example

Hash function on ci_id

```
CREATE TABLE customer_interaction
  (ci_id int not null,
   ci_url text not null,
   time_at_url int not null,
   click_sequence int not null)
PARTITION BY HASH (ci_id);
```



Example

Hash function on ci_id

```
CREATE TABLE customer_interaction
(ci_id int not null,
 ci_url text not null,
 time_at_url int not null,
 click_sequence int not null)
PARTITION BY HASH (ci_id);
```

```
CREATE TABLE customer_interaction_1 PARTITION OF customer_interaction
    FOR VALUES WITH (MODULUS 5, REMAINDER 0);
CREATE TABLE customer_interaction_2 PARTITION OF customer_interaction
    FOR VALUES WITH (MODULUS 5, REMAINDER 1);
CREATE TABLE customer_interaction_3 PARTITION OF customer_interaction
    FOR VALUES WITH (MODULUS 5, REMAINDER 2);
CREATE TABLE customer_interaction_4 PARTITION OF customer_interaction
    FOR VALUES WITH (MODULUS 5, REMAINDER 3);
CREATE TABLE customer_interaction_5 PARTITION OF customer_interaction
    FOR VALUES WITH (MODULUS 5, REMAINDER 4);
```



Scale with PostgreSQL

Partitioning
Replication
Clustering

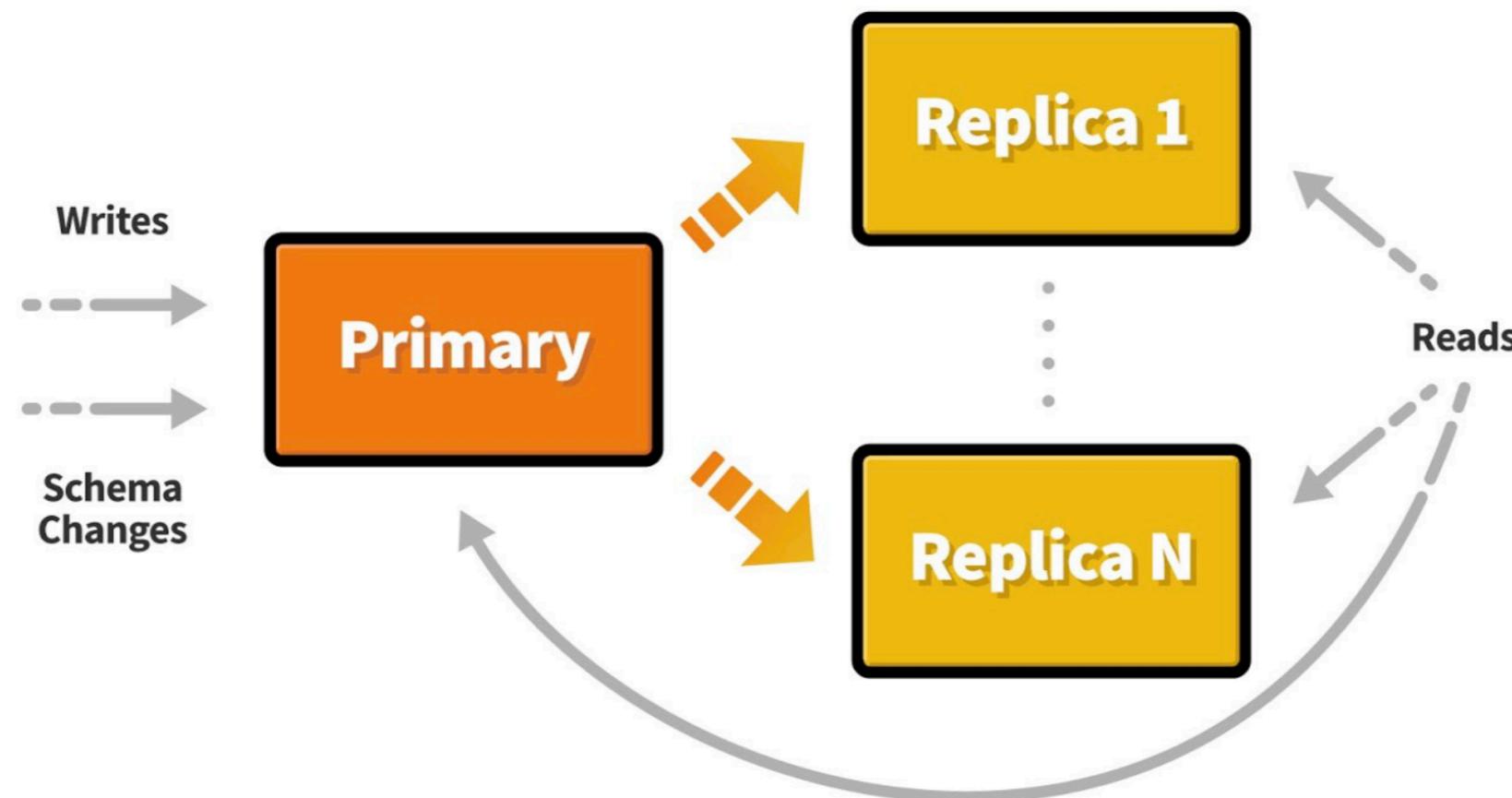


Replication

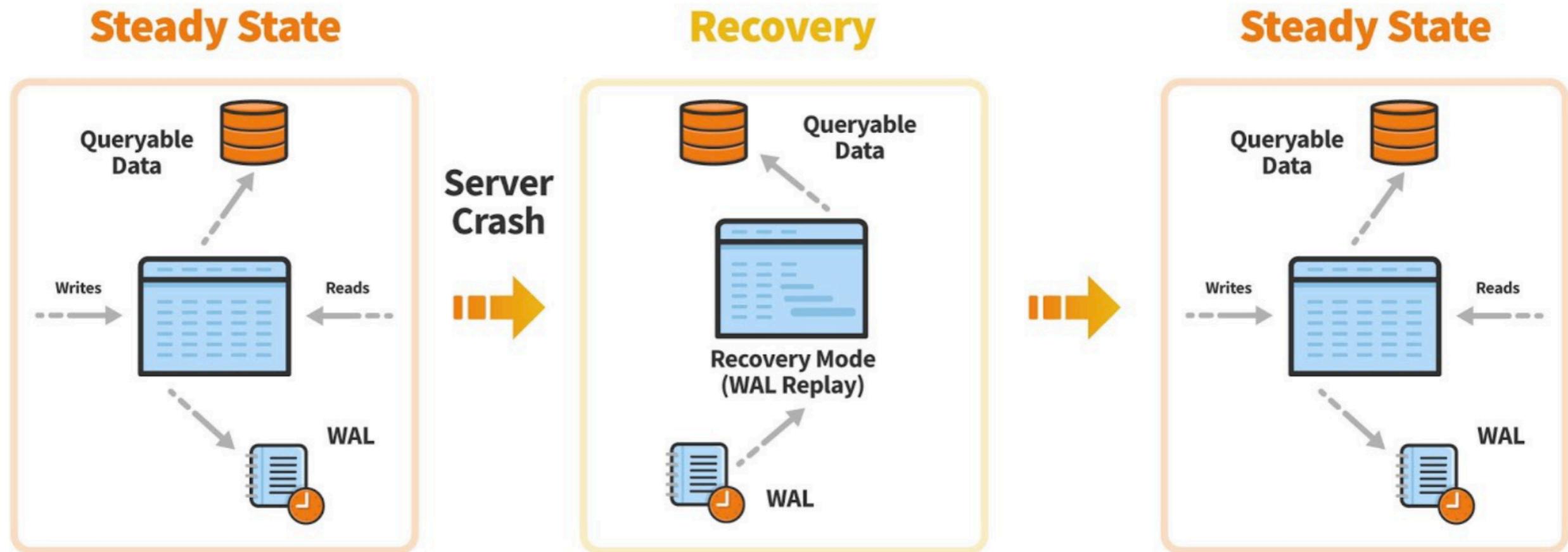


How an (N+1) node PostgreSQL cluster works ?

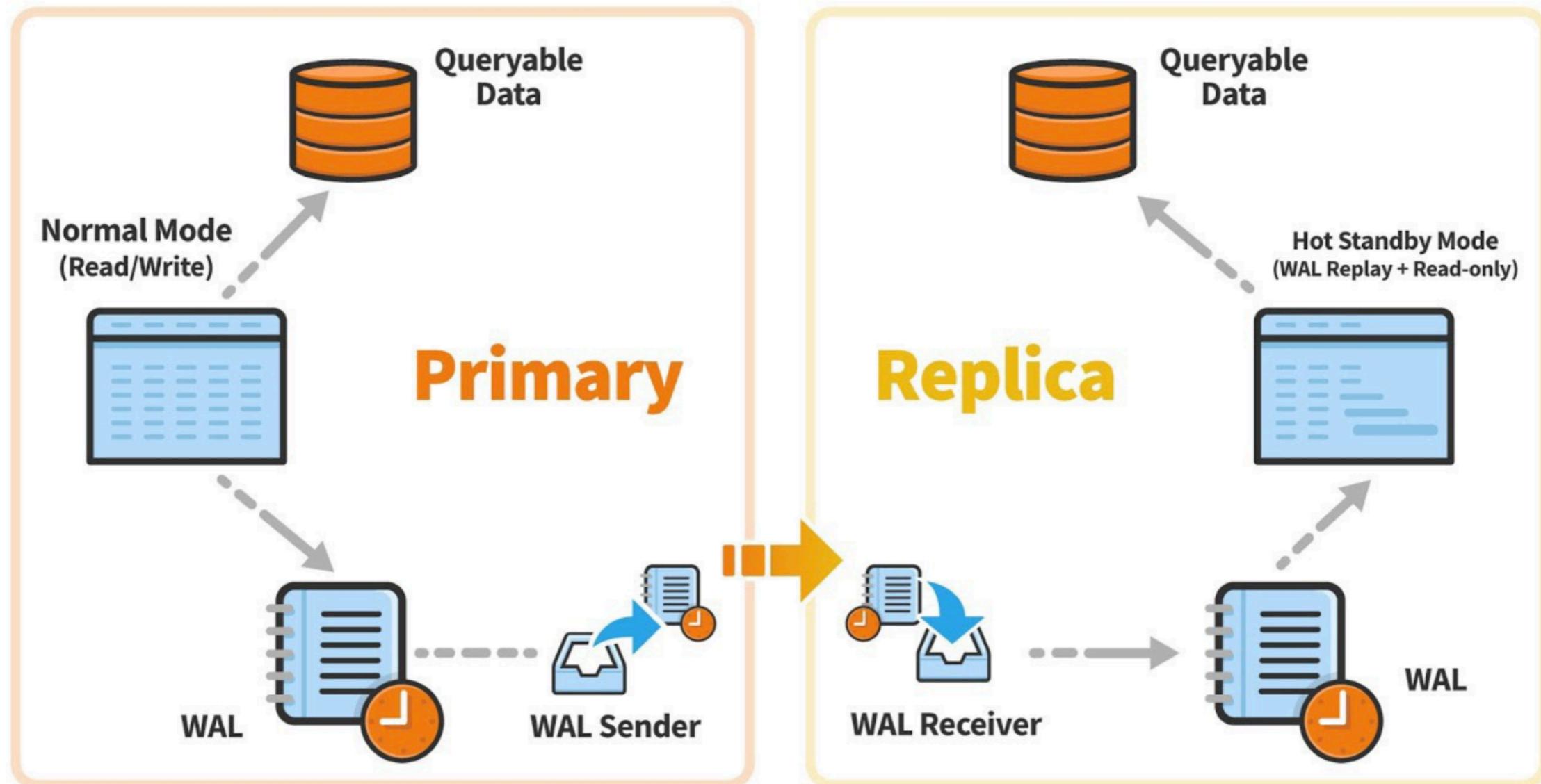
Using streaming replication



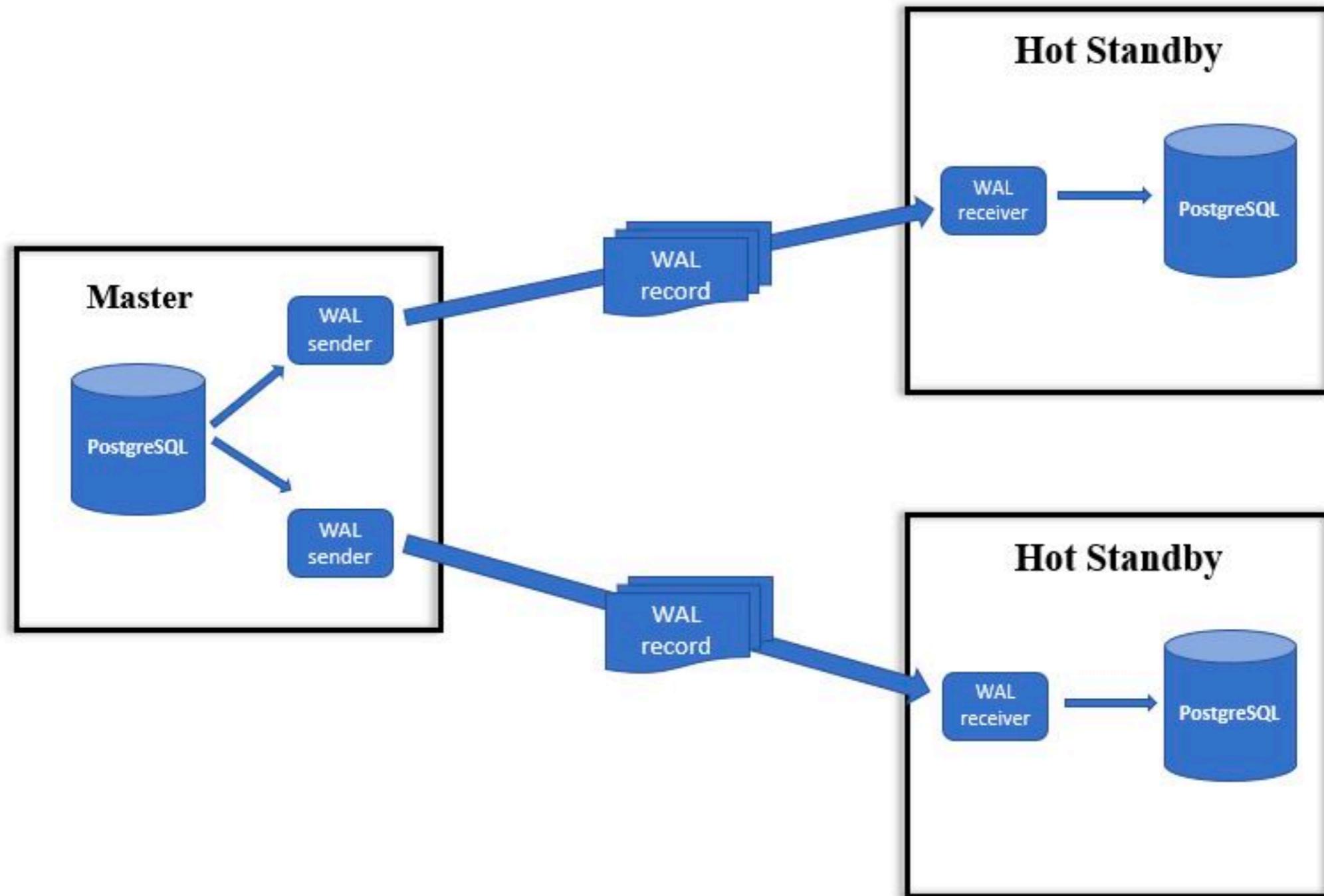
WAL (Write Ahead Log)



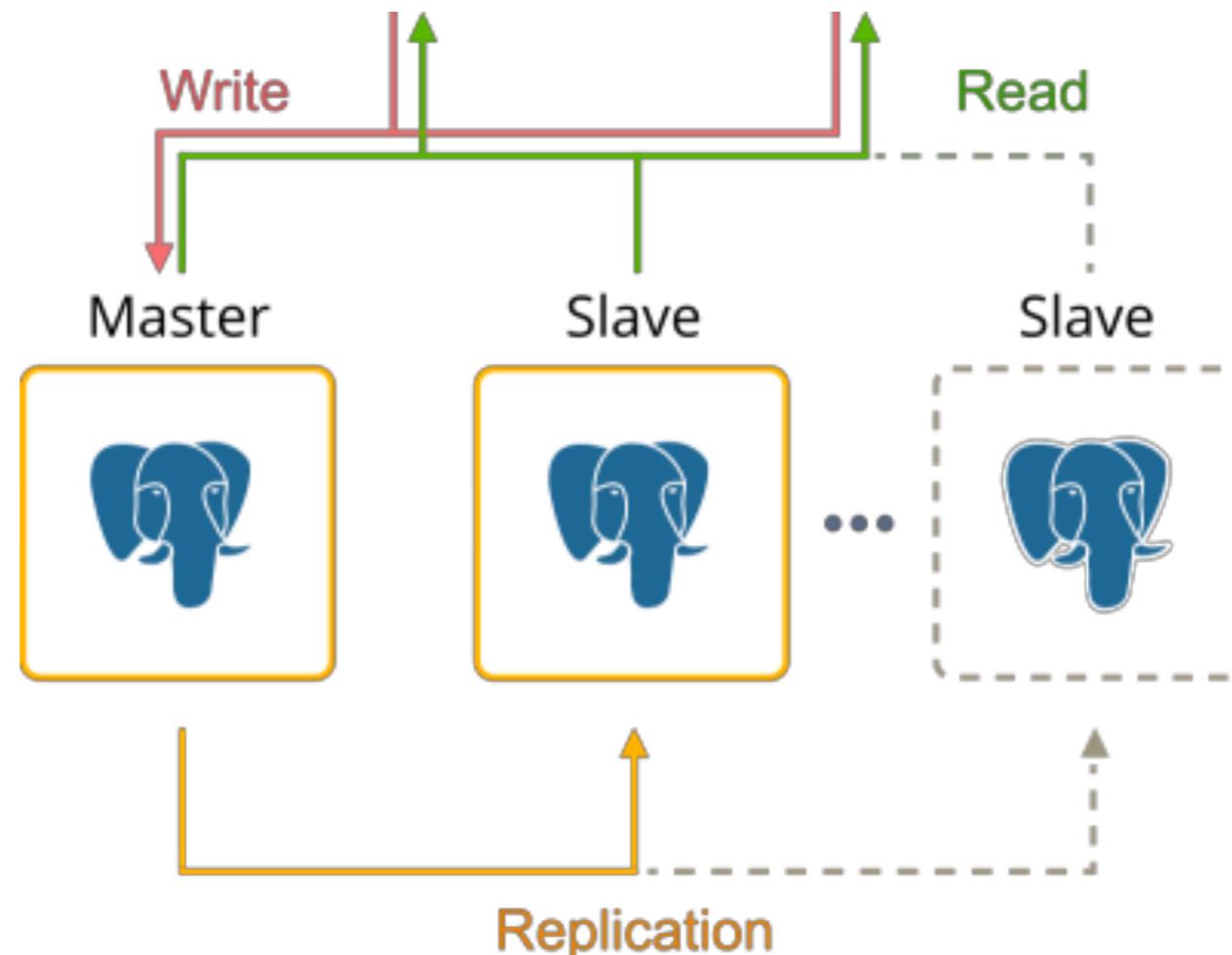
WAL and Replication



Master(primary) - Slave (standby)



Master - Slave



Replication modes

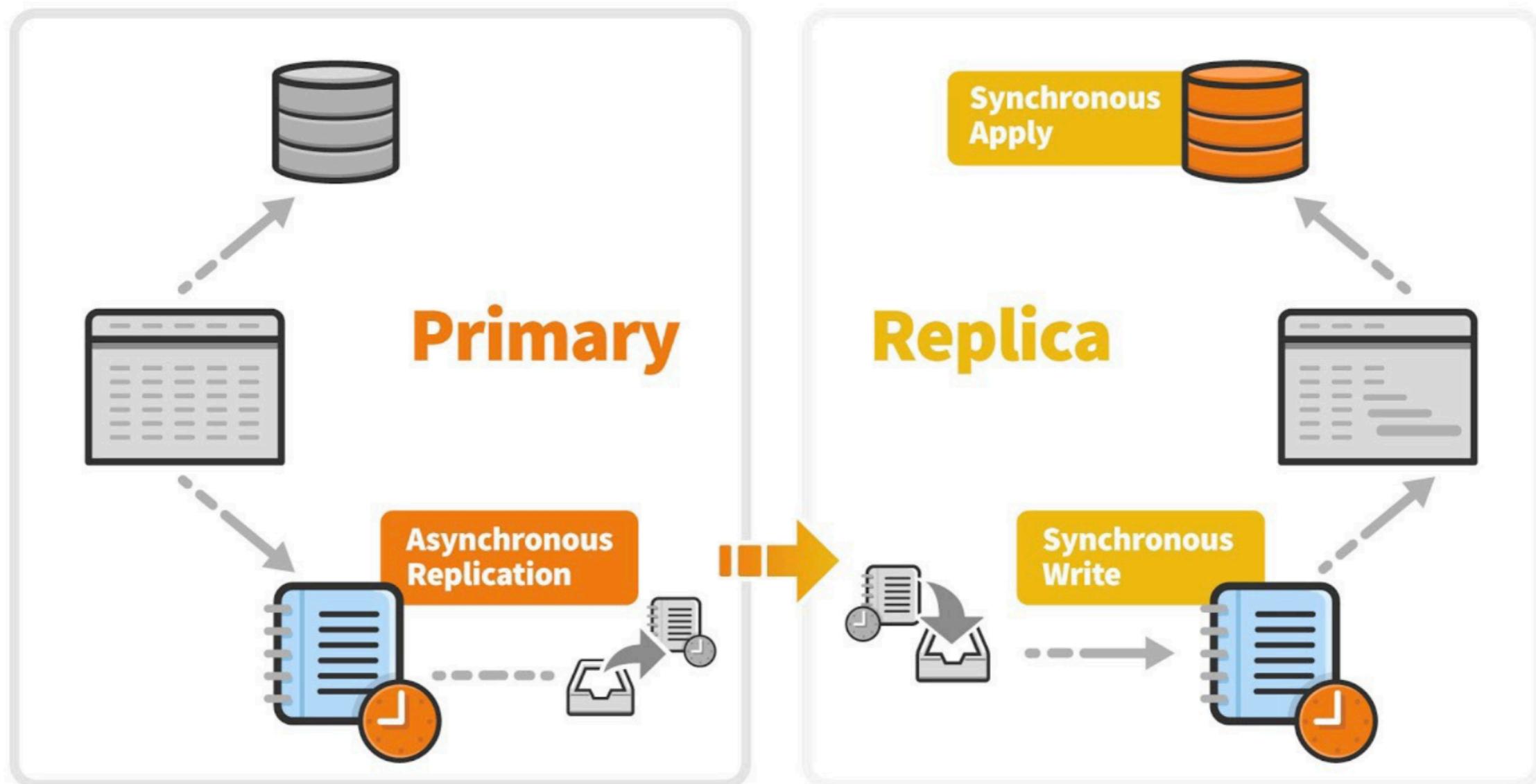
Asynchronous replication

Synchronous write replication

Synchronous apply replication



Replication modes



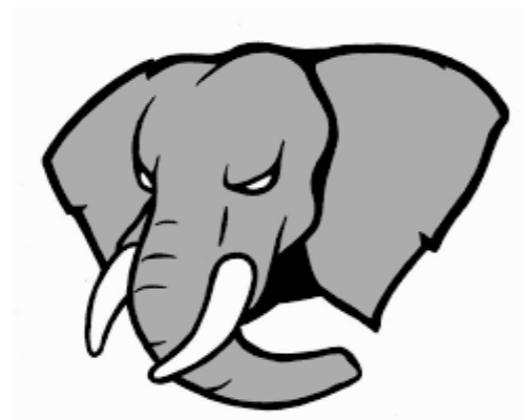
Performance

Replication mode	Write performance	Read consistency	Data loss
Async replication	Highest	Weakest, eventually consistent	Highest risk
Sync write replication	Medium	eventually consistent BUT less lag	Low risk
Sync apply replication	Lowest	Strong consistency	Lowest risk



Replication solutions

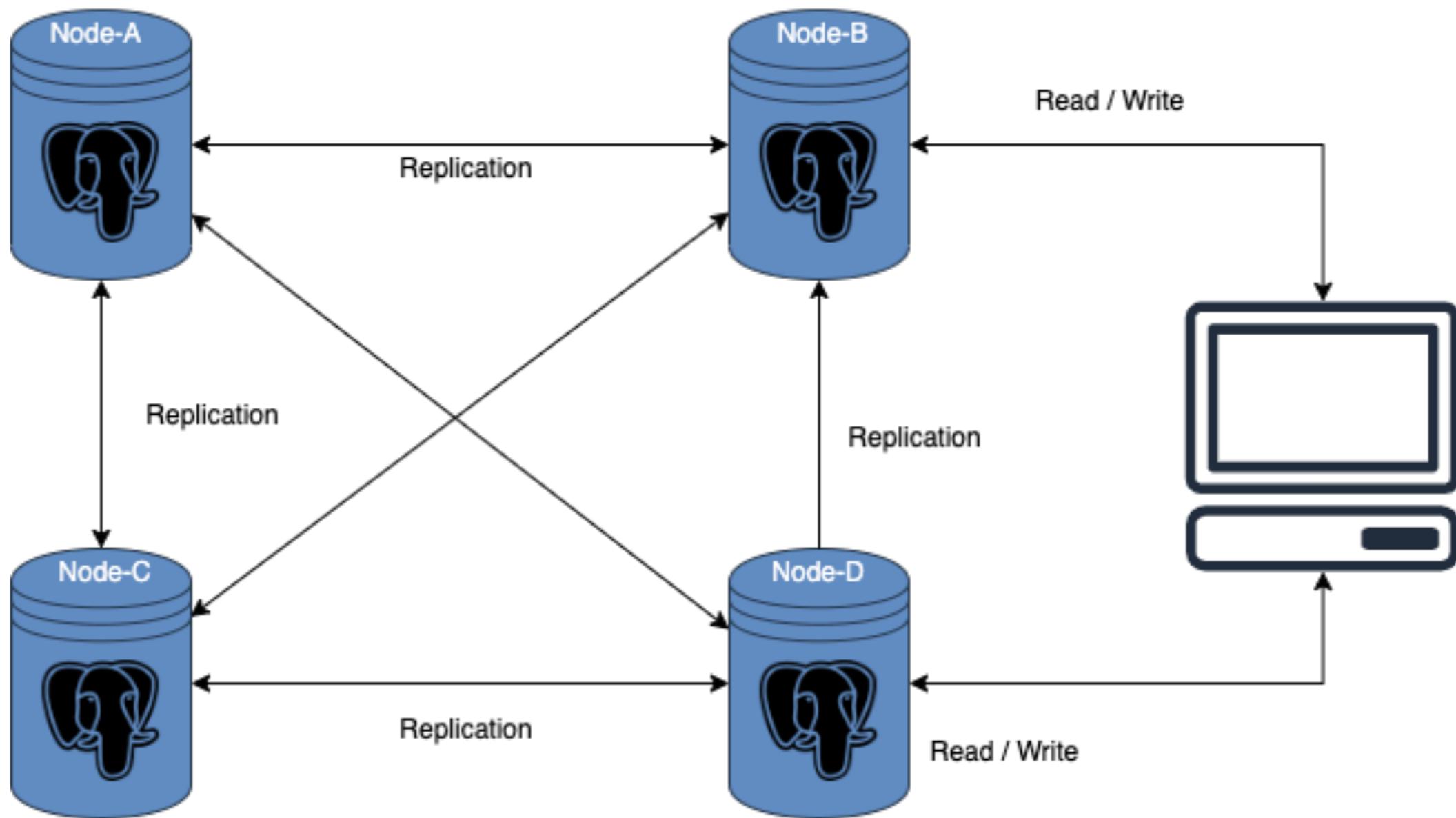
Slony-I
Pg-pool-II
Bucardo
Londiste



<https://www.percona.com/blog/2020/06/09/multi-master-replication-solutions-for-postgresql/>



Multi-master



Scale with PostgreSQL

Partitioning
Replication
Clustering



Clustering

