The Art and Science of Transportation Research in the AI Era

A Gentle Introduction to SQL

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Learning Goals

#1 Understand what is a database and most used types

#2 Understand what is a relational database

#3 How to retrieve data from a SQL database

#4 Further write Basic SQL syntax

Lecture Structure

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#1 About Database

#2 Types of Databases

#3 SQL 101

#1 About Database

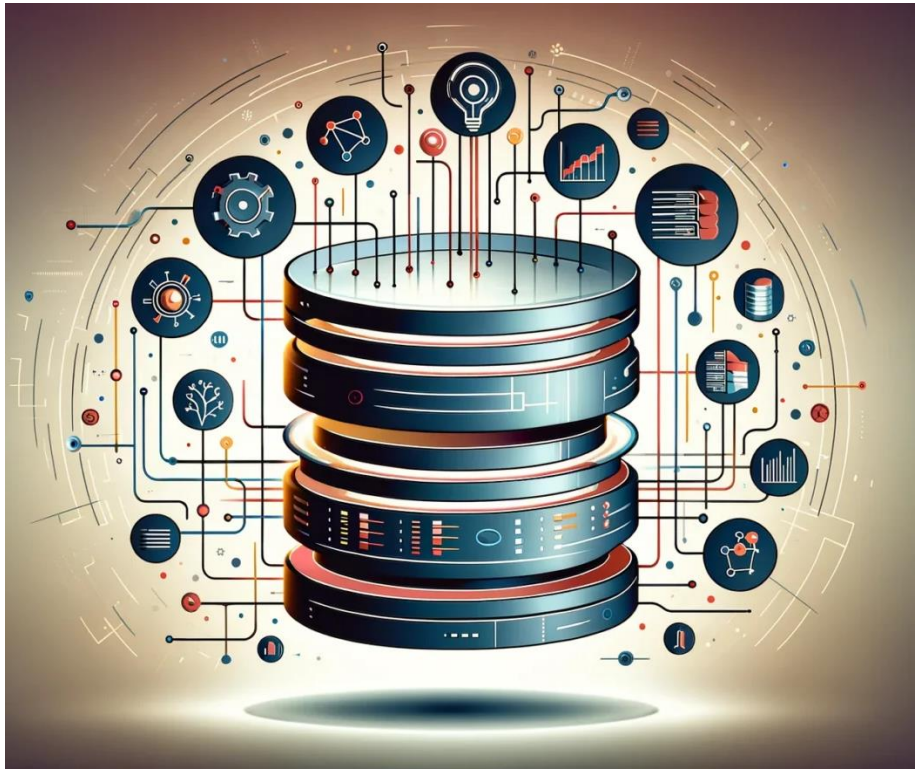
- A database is an **organized collection of structured information, or data, typically stored electronically in a computer system**. Databases are managed using database management systems (DBMS).

- The sum total of the database, the DBMS and the associated applications can be referred to as a **database system.**

Importance of Database:

- It gives us a **highly efficient method** for **handling large amount** of different types of data with ease.

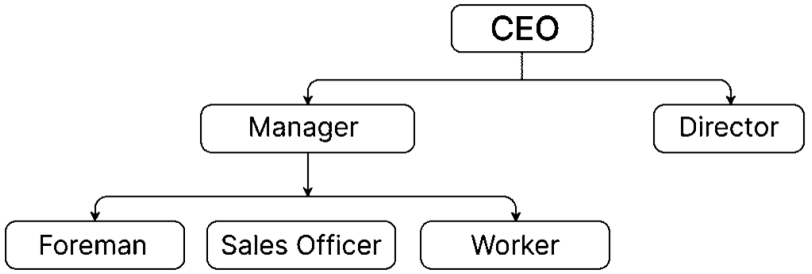
- It allows large amount of data to be **stored systematically** and these data to be easily retrieved, filtered, sorted and updated efficiently and accurately.



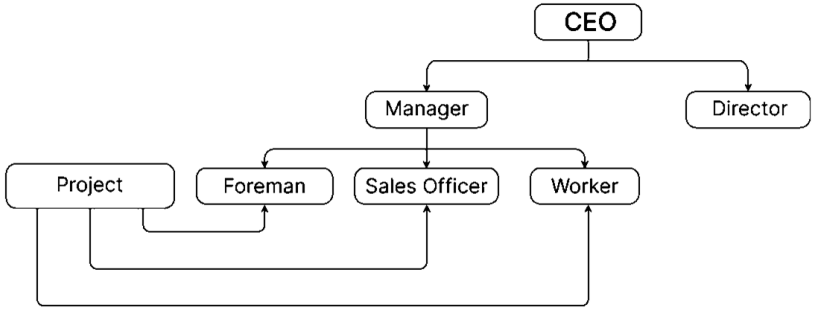
#2 Types of Database

- **Object-Oriented Databases:** Represent data as objects these objects can contain both data (attributes) and methods (functions/actions) and can model complex data structures. They are primarily used in specialized applications such as computer-aided design, multimedia.

- **Hierarchical Databases:** Organize data in a tree-like structure with a single root, branches, and leaves. In a hierarchical database, each record has a parent-child relationship making it useful for one-to-many relationships but limited in flexibility.



- **Network Databases:** Similar to hierarchical databases but allow multiple parent nodes, enabling more complex relationships and many-to-many connections.



#2.1 Relational Database

- **Relational Databases:** organize data into tables with **rows and columns**. They are widely used for structured data and ensure data integrity through relationships between tables.
- Within relational databases, tables are organized in **schemas**: container or namespace within a database that organizes and groups related objects, such as tables, views, indexes, stored procedures, and other database objects. It serves as a way to **logically separate and manage these objects within a database.**

SQL (Structured Query Language) is a programming language designed for managing data in a relational database.

- It was invented in 1974 by IBM and is the most common method of accessing data in relational databases today.

#2.1 Relational Database

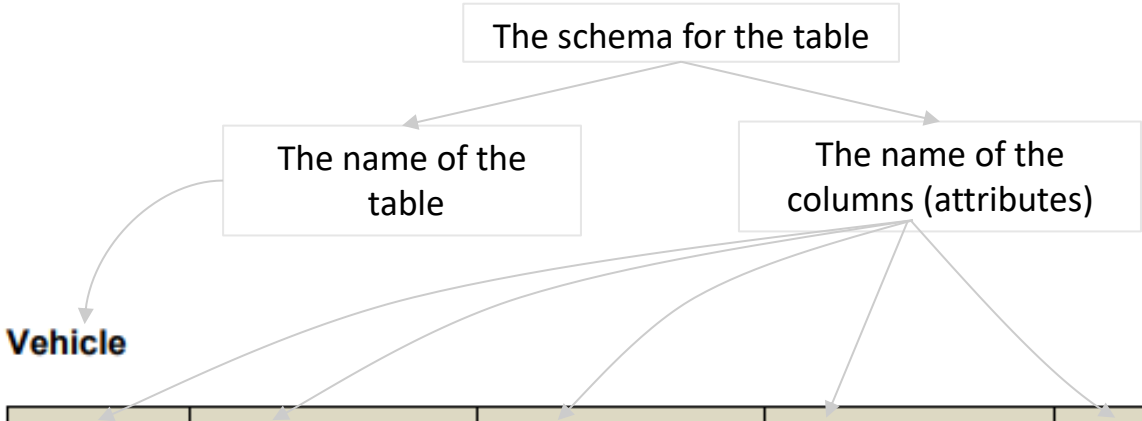
- For every column of every table the schema specifies **allowable value.** For example, **Year** column a is integer… etc

- The set of allowable values for a column is called **domain** or **type of the column.**

- It looks simple, but it is a **very crucial** because RDB are about **structure**. Each car will for sure have the **exact attributes**. This is exactly what we mean by a schema.

- The rest of the table is called **raws.**

- **The schema stays the same but the rows change as we add more data.**



Vehicle

Reg No	Make	Model	Year	Colour
BRG446	Ford	Meteor	2009	White
VRG655	Bmw	Coupe	2008	Blue
NMT667	Madza	Delivery Van	2010	Green
CCT899	Toyota	HiLuxe	2009	Red
FGR122	Mitsubishi	Magna	2007	Purple

Imagine that this table (or relation) has been defined to keep track of vehicles in a company

#2.1 Relational Database

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Table: Artists

ArtistID	Name	BirthYear	Nationality
1	Vincent van Gogh	1853	Dutch
2	Pablo Picasso	1881	Spanish
3	Frida Kahlo	1907	Mexican

ArtistID is the primary key because it uniquely identifies each artist.

Table: Exhibitions

ExhibitionID	ExhibitionName	Location	ArtworkID
1001	Impressionist Masters	The Louvre, Paris	101
1002	War and Peace in Art	Reina Sofía, Madrid	102
1003	Surrealism and Beyond	MoMA, New York	103

ExhibitionID is the primary key because it uniquely identifies each exhibition.

ArtworkID is the primary key because it uniquely identifies each artwork.

Table: Artworks

ArtworkID	Title	YearCreated	ArtistID
101	Starry Night	1889	1
102	Guernica	1937	2
103	The Two Fridas	1939	3

A primary key is a unique identifier for each record in a database table.

#2.1 Relational Database

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Foreign Key

The tables are linked together using a foreign key (in table Artworks) referring to the primary key (in table Artists).

Table: Artists

ArtistID	Name	BirthYear	Nationality
1	Vincent van Gogh	1853	Dutch
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Table: Artworks

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101	Starry Night	1889	1
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The tables are linked together using a foreign key (in table Exhibitions) referring to a primary key (in table Artworks).

Foreign Key

Table: Exhibitions

ExhibitionID	ExhibitionName	Location	ArtworkID
1001	Impressionist Masters	The Louvre, Paris	101
1002	War and Peace in Art	Reina Sofía, Madrid	102
1003	Surrealism and Beyond	MoMA, New York	103

A foreign key is used to create a relationship between two tables.

It is a column (or set of columns) in one table that refers to the primary key in another table.

This establishes a link between the records in the two tables.

The action of creating and joining the tables…etc is done using SQL!

#2.1 Relational Database

Activity

Goal: Understand the concept of a database table by creating a table yourself.

Pick a topic or activity you are interested in, for example:

Sports – teams and players

School – students and classes

Others

Create 2-3 tables to represent the topic or activity.

For each table, list the table name and 3-4 attributes.

For each table, list the primary and foreign key

Table Name:
Attributes:

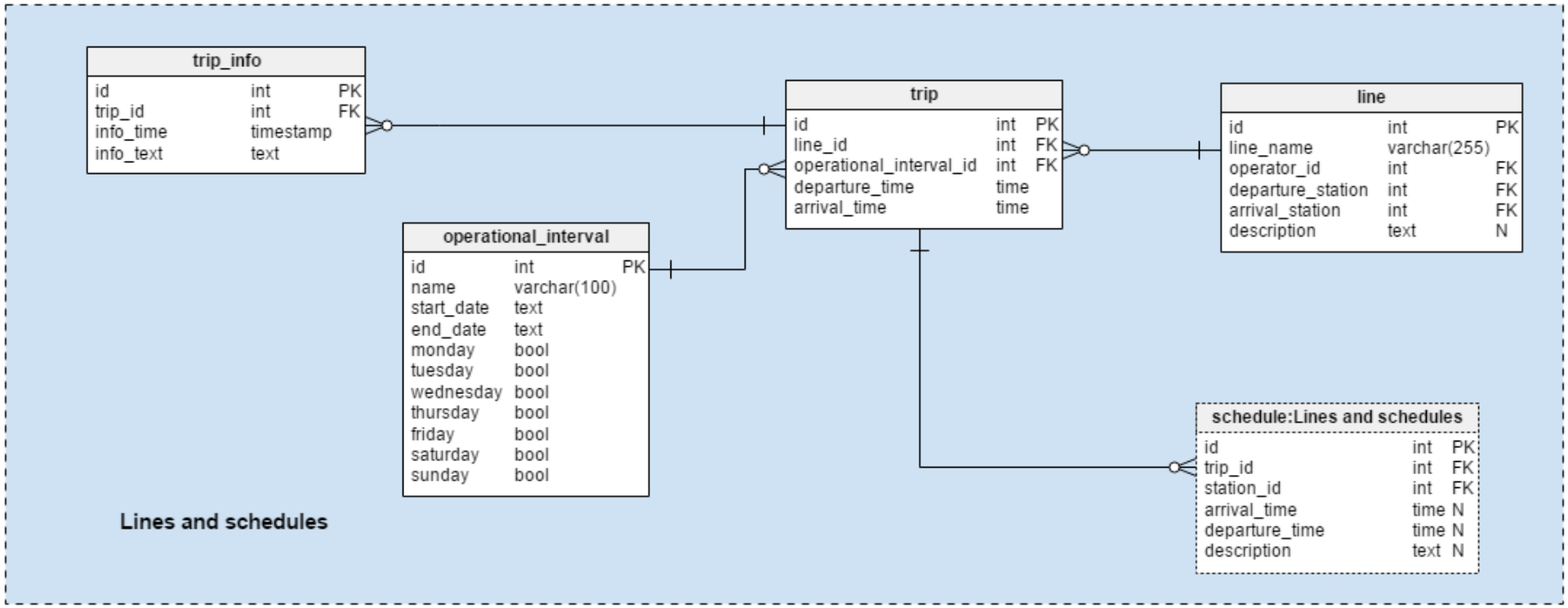
- Column name (domain)

#2.1 Relational Database

Data modelling is **the process of diagramming data flows.**

It provides a clear and structured visualization of **how data is organized, stored, and related within a database**.

With a clear understanding of how tables are related we can write **more efficient SQL queries.**



Data model in a relational database

We can identify the correct tables to join, select the right columns, and apply filters more accurately, which **improves the performance and accuracy of data retrieval.**

https://vertabelo.com/blog/traveling-by-bus-or-train-a-transport-hub-database-model/

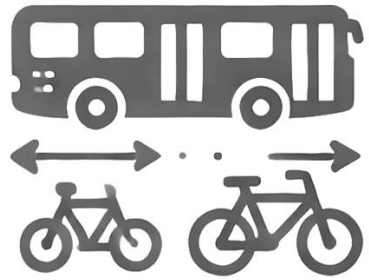
#2.1 Relational Database

Data Collection, Management, and Storage

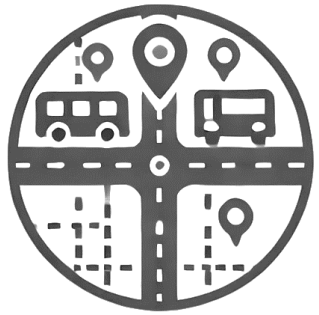
Research often involve large amounts of data from various sources, such as traffic sensors, GPS, surveys, and public transport systems. SQL databases are an **effective way to store, organize, and manage** this data for easy access and analysis.

Public Transport and Multimodal Studies

SQL can be used to link datasets from various modes of transport (e.g., bus schedules, bike-sharing data, vehicle traffic). Researchers can **run queries to study intermodal relationships**, identifying areas where modes can complement each other or where conflicts arise.



#2.1 Relational Database



Traffic Pattern Analysis and Modeling

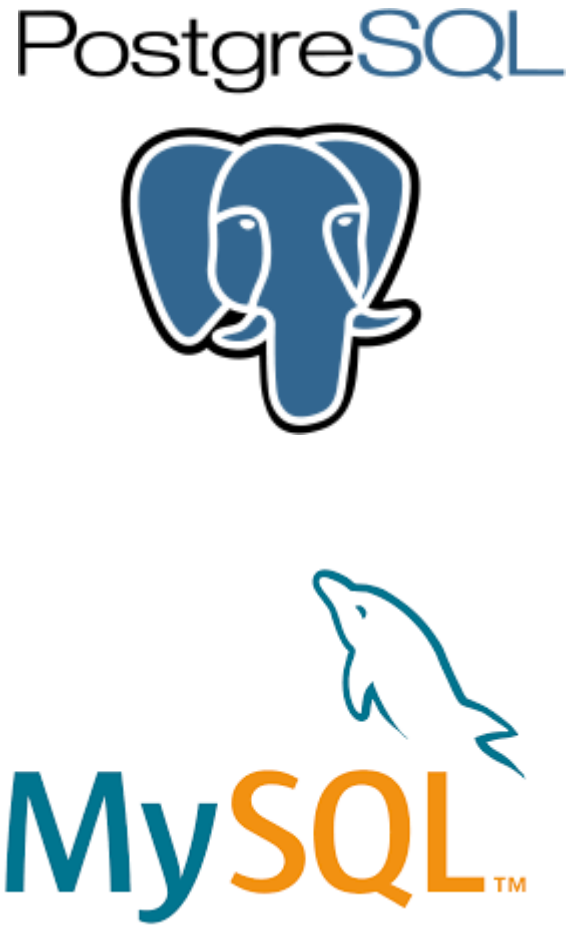
SQL can be used to query and analyze large datasets to **identify traffic patterns**, such as peak traffic periods, congestion points, or accident-prone areas. By applying SQL queries, researchers can derive insights from the data and build traffic models that inform planning decisions.

Geospatial Analysis with SQL and GIS

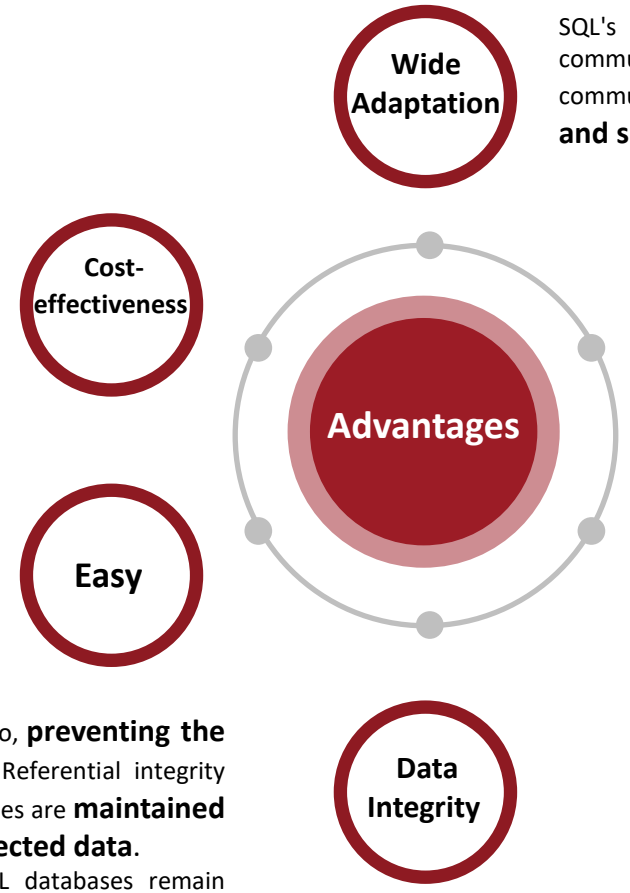
SQL can be integrated with Geographic Information Systems (GIS) to **enhance spatial data analysis**. SQL enables researchers to perform spatial queries on transportation networks. For instance, they can query for traffic data within a specific distance from major intersections or analyze traffic flow along specific corridors. Researchers can conduct studies on how traffic flows are influenced by land use patterns or how accessibility to public transport differs across urban areas.

#2.1 Relational Database

There are many relational databases that use SQL (Structured Query Language) as their primary language for interacting with the database, such as PostgreSQL, MySQL, SQLite, and SQL Server. All share the same basic structure of standard SQL, and the key commands are generally similar. However, **there are syntax differences** that are specific to their corresponding RDBMS.



#2.1 Relational Database



SQL's longevity and wide adoption have resulted in a thriving community of developers, enthusiasts, and experts. The vast SQL community provides **ample resources, documentation, and support for users at all levels of expertise**

SQL databases, especially open-source options like MySQL and PostgreSQL, offer a **cost-effective alternative** to proprietary database systems

Optimized for handling large volumes of data and can scale to meet the demands

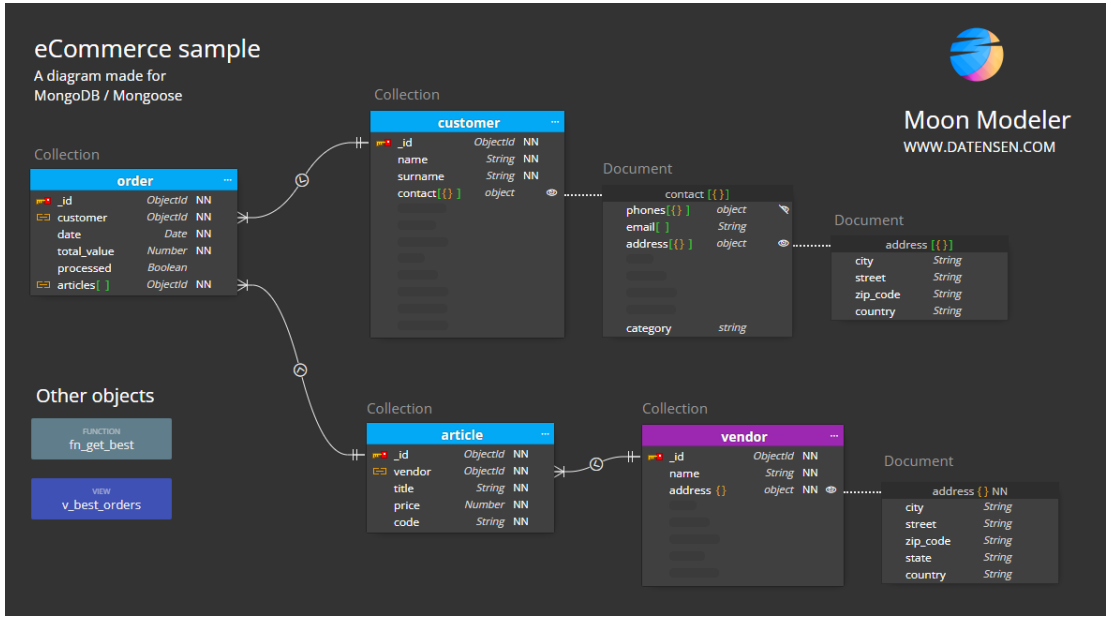
Easy data retrieval and manipulation

With features like encryption options and access controls, SQL databases **safeguard data from unauthorized access**

Constraints define rules that data must adhere to, **preventing the entry of invalid or inconsistent data**. Referential integrity ensures that relationships between different tables are **maintained correctly, avoiding orphaned or disconnected data**.
By adhering to these essential principles, SQL databases remain accurate, reliable, and consistent

#2.2 NoSQL

- NoSQL, also referred to as “not only SQL” or “non-SQL refers to Non-Relational Databases
- is commonly referenced in relation to SQL.
- NoSQL databases, in contrast to conventional relational databases, **do not rely on a predefined schema** and house data within one data structure, such as JSON document. Popular database of NoSQL are MongoDB and Cassandra.
- Offer **greater flexibility** in processing unstructured or semi-structured data.
- NoSQL Non-relational databases have existed since the late 1960s, but the name "NoSQL" was only coined in the early 2000s.



Non-Relational Database

Note: we want you to be familiar with the term NoSQL

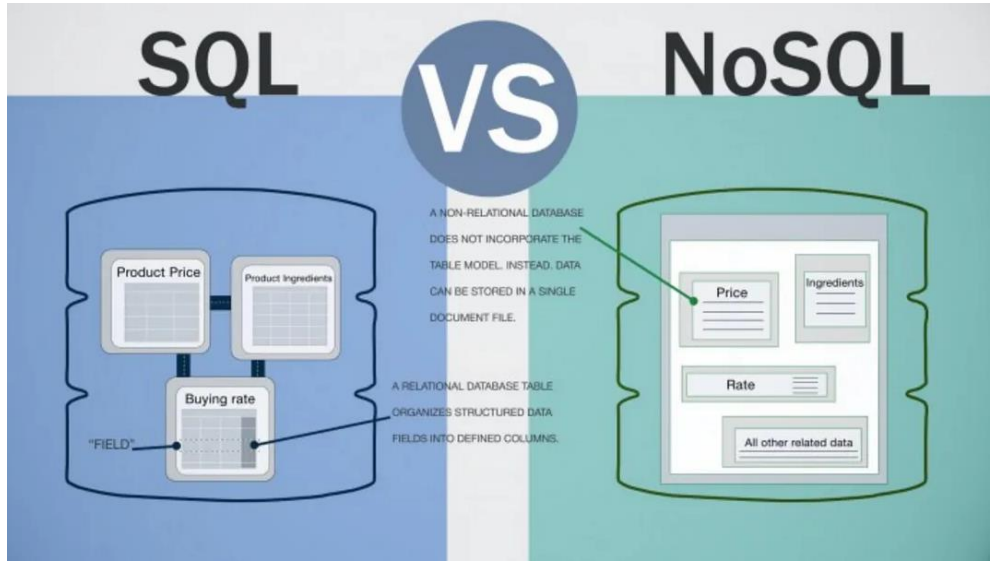
#2.3 SQL vs NoSQL

Structured predefined schema: SQL databases use a **predefined and fixed schema**, which dictates how data is organized. Data is stored in **tables, with rows and columns**. Each table is related to another table through **foreign keys**.

Example: In a transportation database, you might have a Vehicles table with columns like VehicleID, Make, Model, and Year. **Each row represents a different vehicle and will have the same exact columns.**

Flexible Schema: NoSQL databases **do not require a fixed schema**. They are designed to handle **unstructured or semi-structured data** and can store data in formats like documents, key-value pairs, graphs, or wide columns.

Example: In a document-based NoSQL database like MongoDB, a Vehicle might be stored as a document (similar to a JSON object) with fields like VehicleID, Make, Model, and Year. **Different vehicles can have different fields without adhering to a strict schema.**



#3 SQL 101

- SQL is needed by anyone who needs to create, modify, or communicate with relational databases.
- Commands such as SELECT, UPDATE, INSERT, DELETE, and so on remain largely unchanged.

```sql
SELECT * FROM employees;
```

This query selects all columns from the "employees" table.

```sql
UPDATE employees SET salary = 50000 WHERE id = 1;
```

This updates the salary to 50,000 for the employee with ID 1.

```sql
INSERT INTO employees (name, salary) VALUES ('John Doe', 45000);
```

This inserts a new employee named John Doe with a salary of 45,000.

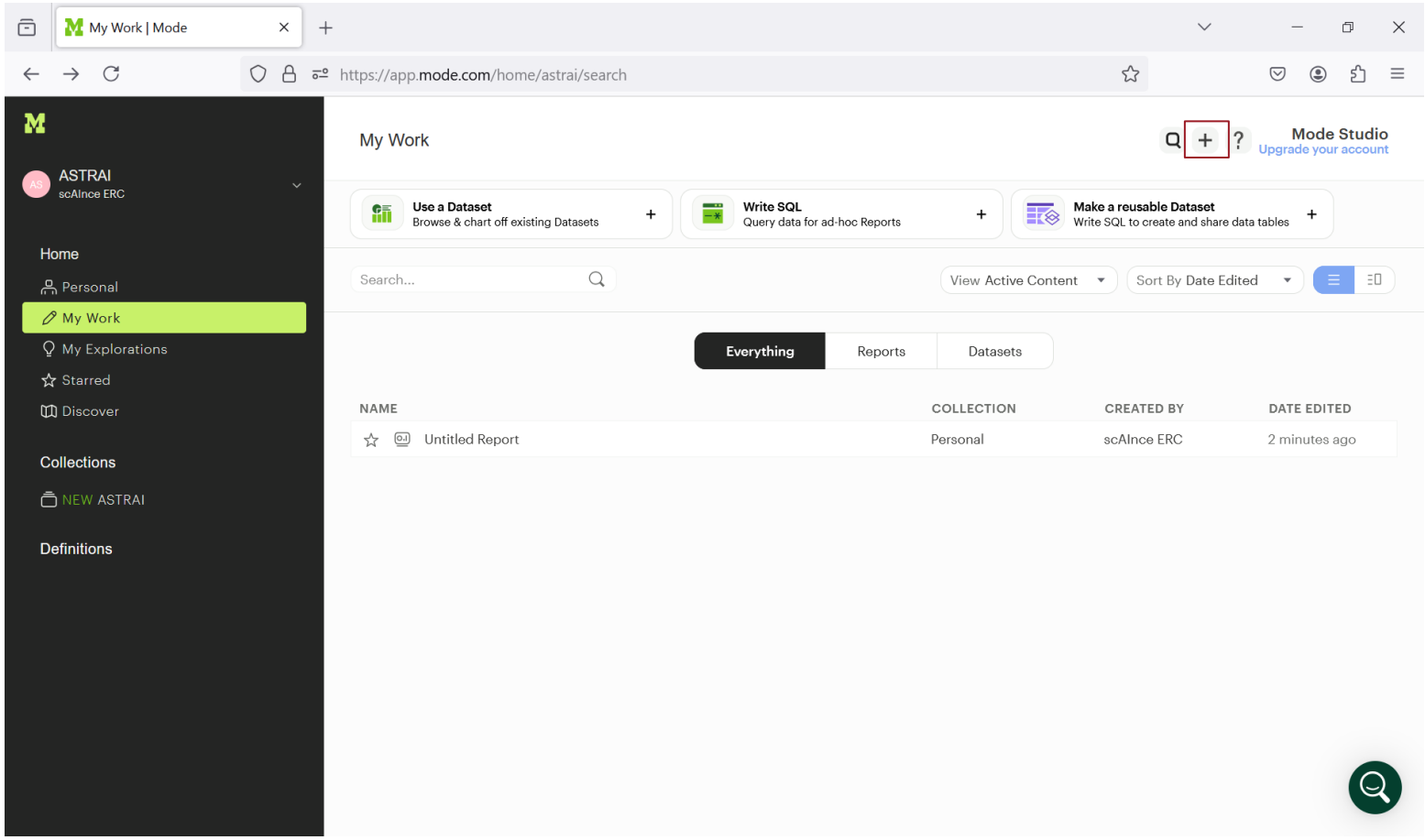
```sql
DELETE FROM employees WHERE id = 1;
```

This deletes the employee with ID 1 from the "employees" table.

We will focus on SELECT to pull out specific data points.

#3 SQL 101

- Mode is an open data analysis platform (also have paid version) that allows users to query data using SQL and also provides learning materials and a space for practice.
- Mode's SQL editor is designed to support standard SQL commands however, there may be minor syntax variations and specific functions unique to each database system.
- SQL commands are not case sensitive, but the data it self is!!



Mode Interface

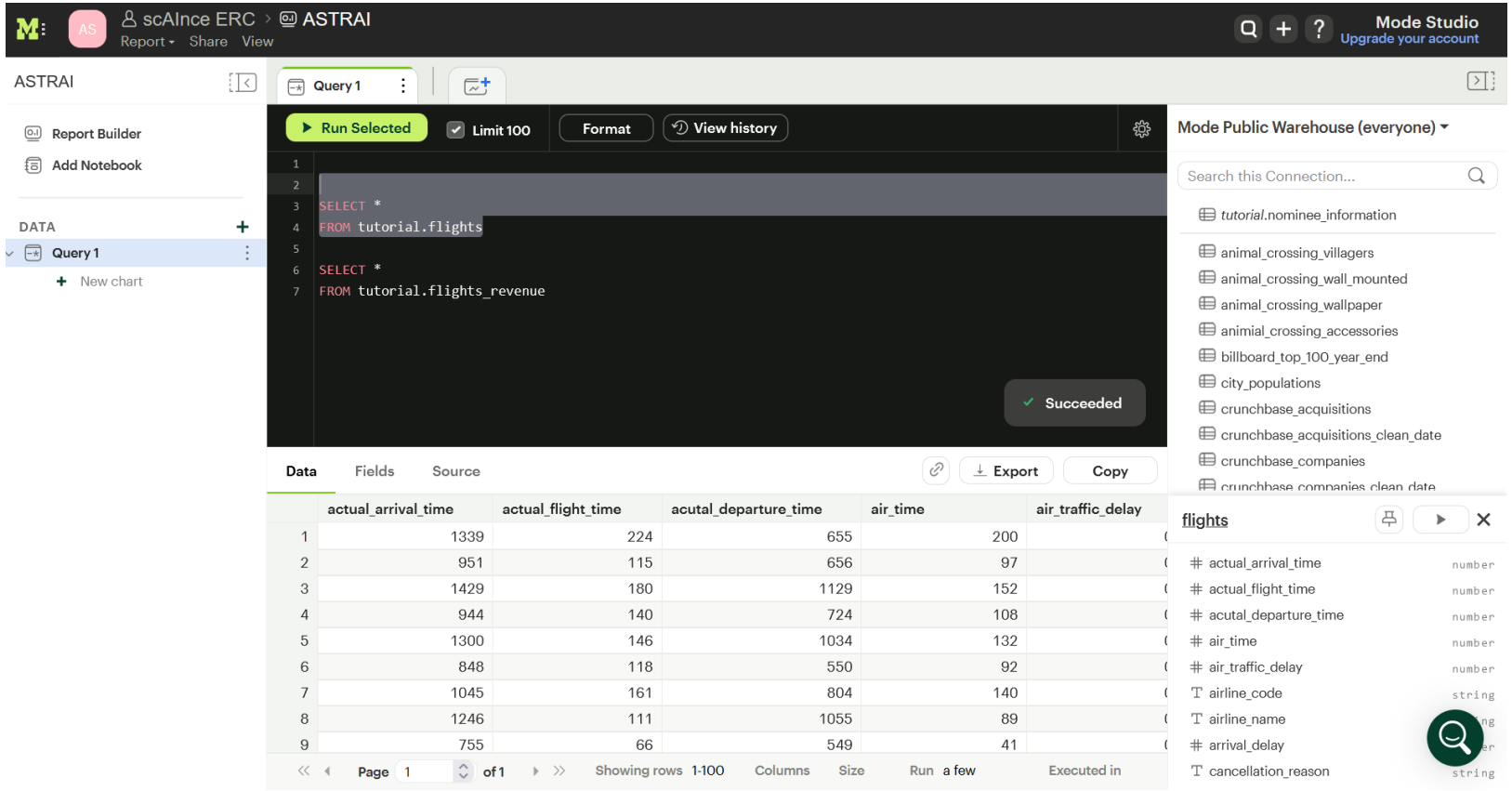
#3.1 SELECT FROM

Basic syntax: SELECT and FROM

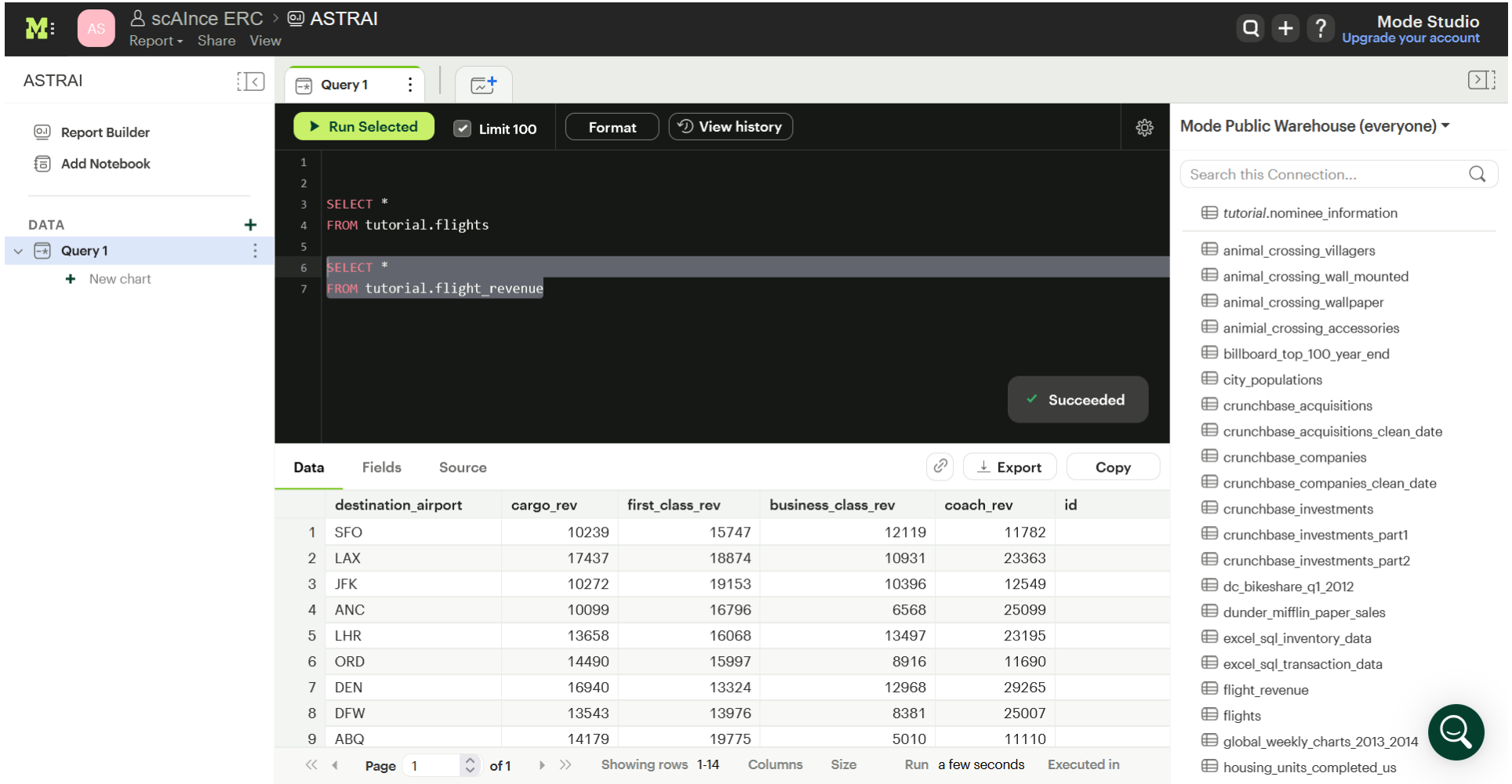
- There are two required ingredients in any SQL query: **SELECT** and **FROM**—and they have to be in that order.

- SELECT indicates which columns you'd like to view, and FROM identifies the table that they live in.

- *** means get me all the columns in the specific table.**



#3.1 SELECT FROM



#3.1 SELECT FROM

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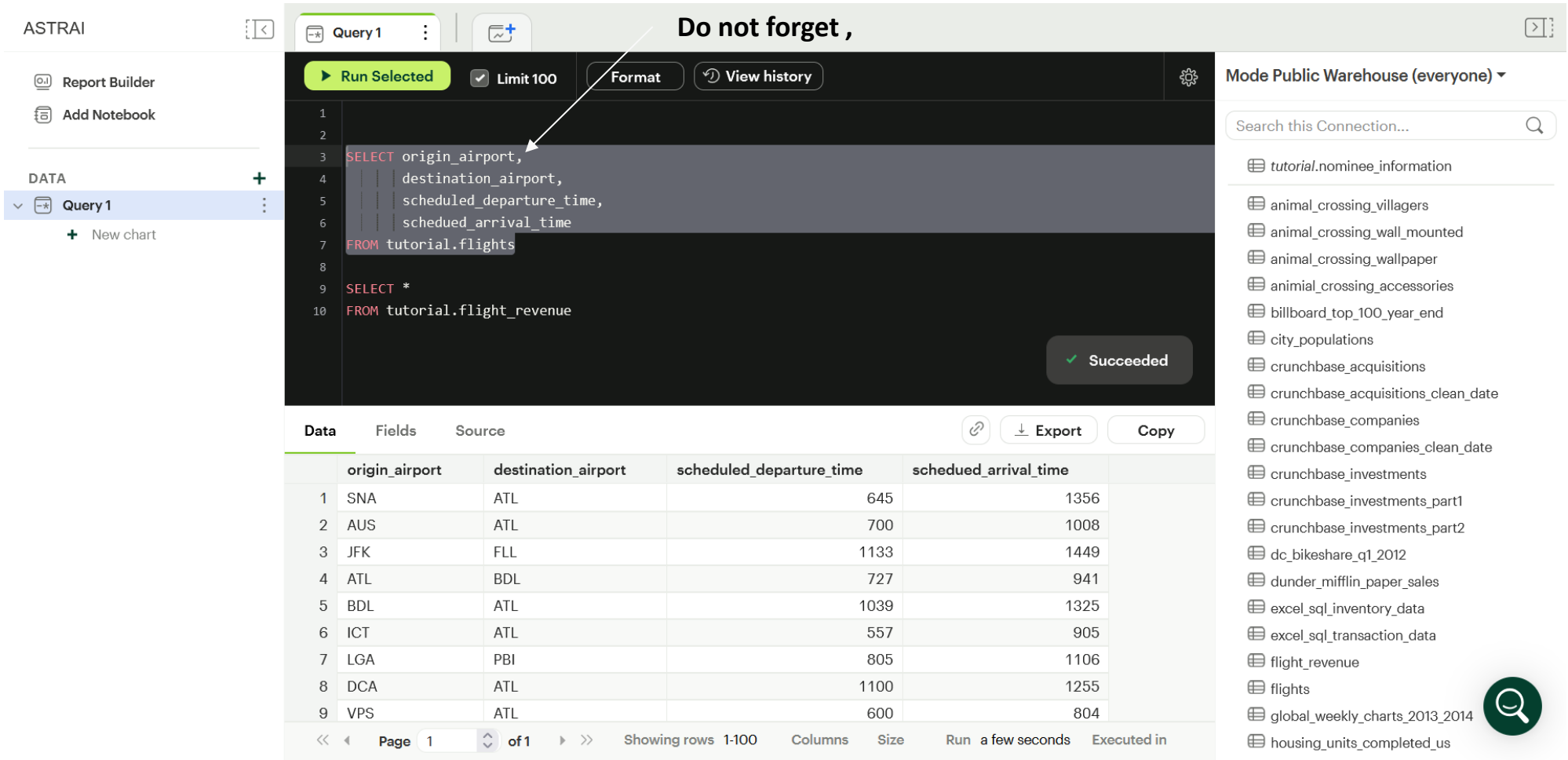
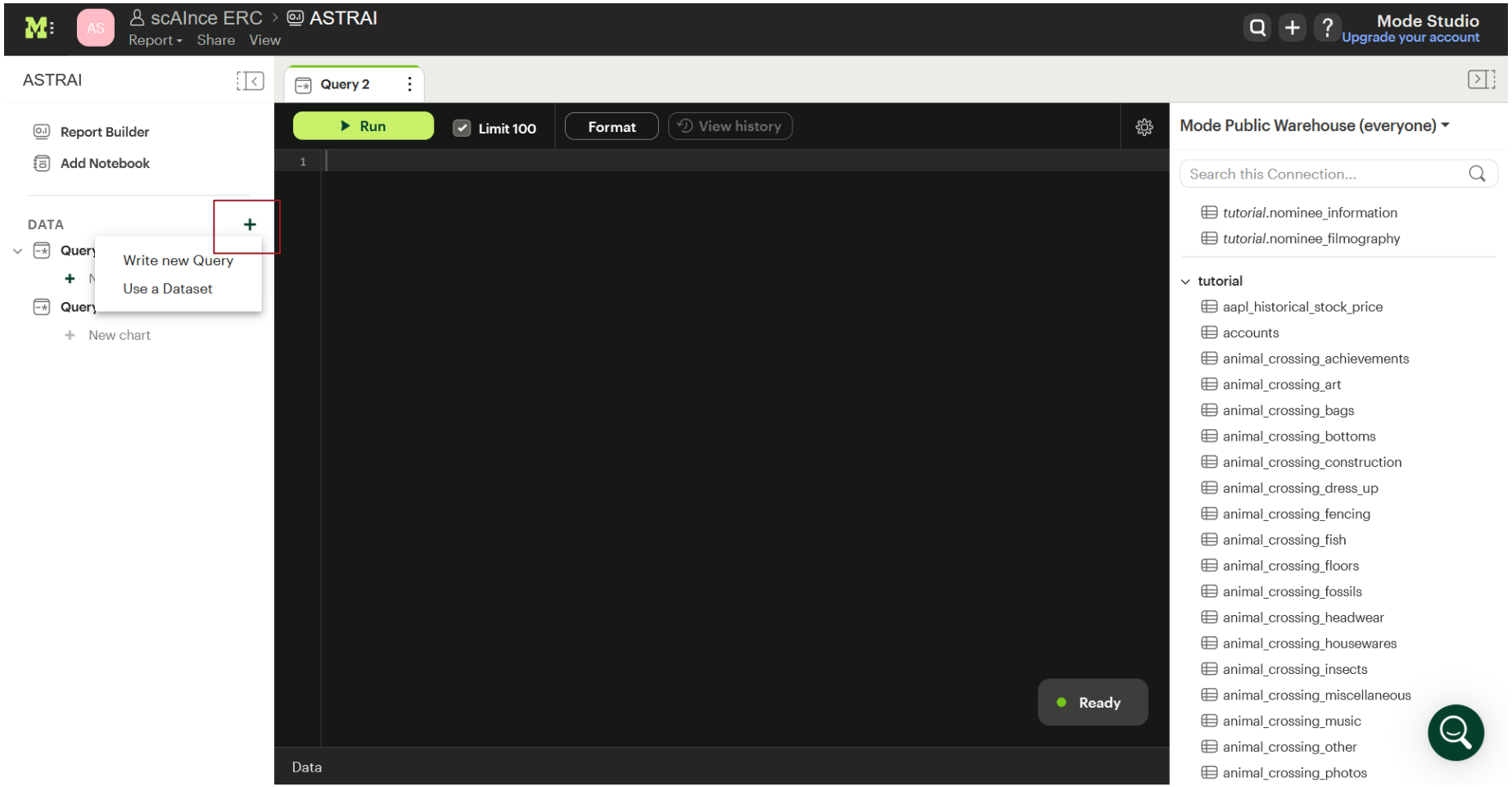
You can also select a specific column/s



#3.1 SELECT FROM



Writing a new Query

#3.1 SELECT FROM

1. Get Familiar with the columns in both tables tutorial.flights and tutorial.flight_revenue or any other tables using (*).

2. Select any four or more columns.

#3.2 WHERE Filter

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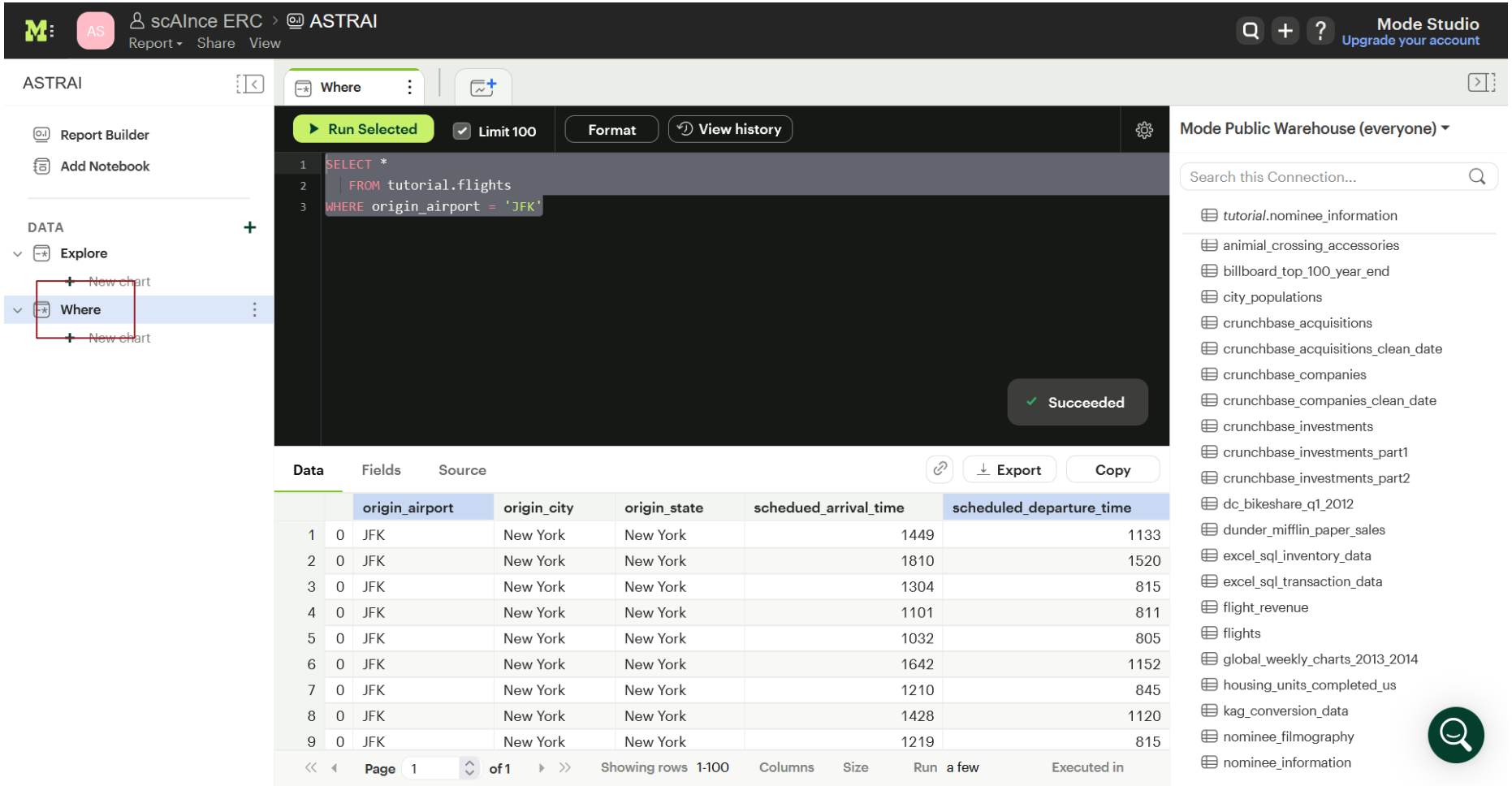
- The **WHERE** clause is used to filter records.
- It is used to extract only those records that **fulfill a specified condition**.
- Remember when using SQL, entire rows of data are **preserved together.** Meaning the operations typically affect entire rows of data, rather than individual columns or cells.
- The **clause order is important.** Therefore, writing what when is critical.
- The most basic way to filter data is using **1) comparison operators.**
- The easiest way to understand them is to start by looking at a list of them:

Equal to	`=`
Not equal to	`<>` or `!=`
Greater than	`>`
Less than	`<`
Greater than or equal to	`>=`
Less than or equal to	`<=`

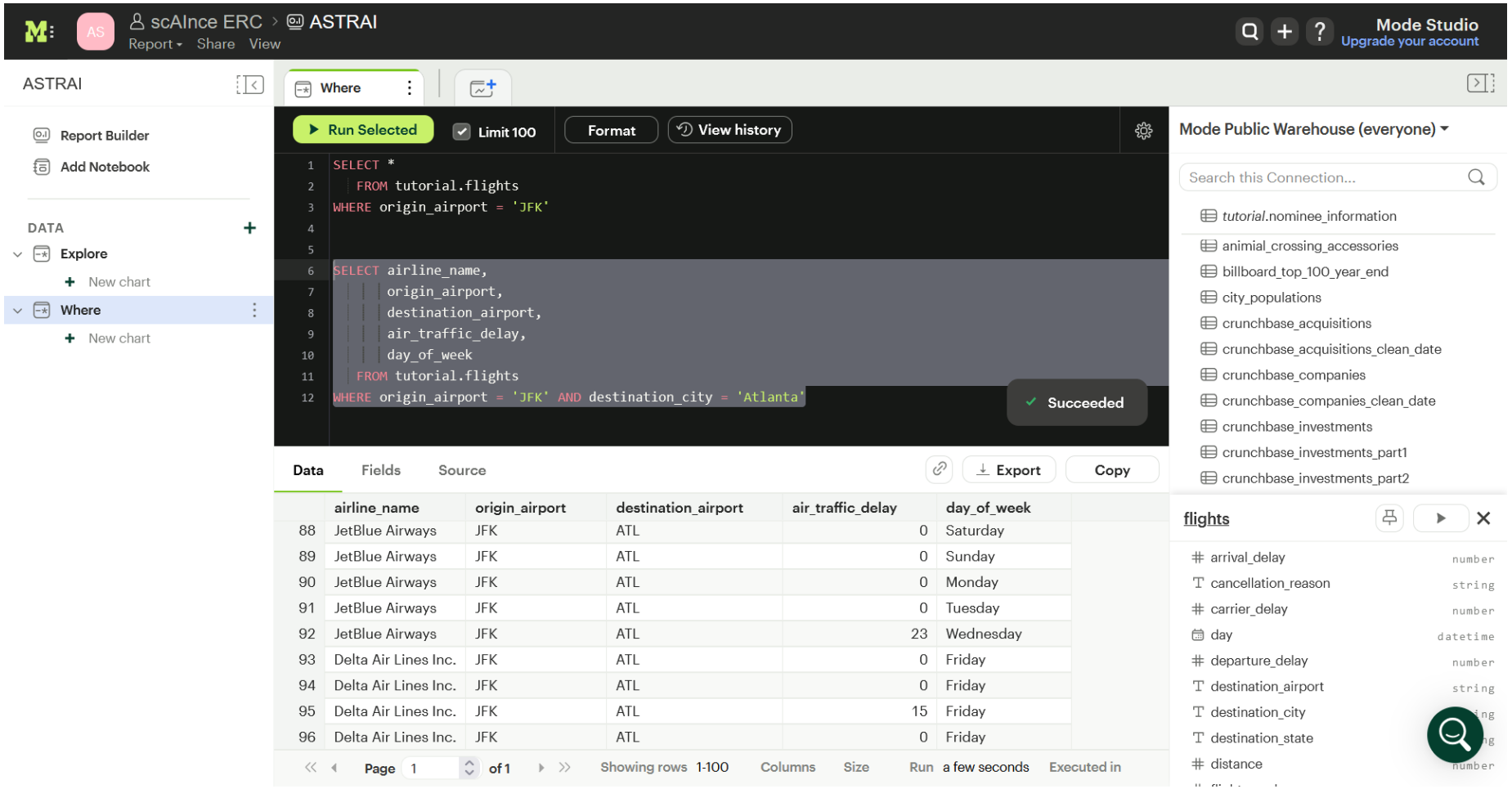
#3.2 WHERE Filter

Document



#3.2 WHERE Filter

2) Logical operators allow you to use multiple comparison operators in one query.



#3.2 WHERE Filter

Here are more logical operators:

- **LIKE** allows you to match similar values, instead of exact values.
- **IN** allows you to specify a list of values you'd like to include.
- **BETWEEN** allows you to select only rows within a certain range.
- **IS NULL** allows you to select rows that contain no data in a given column.
- **AND** allows you to select only rows that satisfy two conditions.
- **OR** allows you to select rows that satisfy either of two conditions.
- **NOT** allows you to select rows that do not match a certain condition.

What is the difference between zero and null value?

#3.2 WHERE Filter

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ASTRAI

Where

Run Selected | Limit 100 | Format | View history

```
1  SELECT *
2    FROM tutorial.flights
3  WHERE origin_airport = 'JFK'
4
5
6
7  SELECT destination_airport,
8         first_class_rev
9    FROM tutorial.flight_revenue
10 WHERE first_class_rev BETWEEN 16000 AND 17000
11
12
13
14
```

Succeeded

Data | Fields | Source | Export | Copy

	destination_airport	first_class_rev
1	SFO	15747
2	LAX	18874
3	JFK	19153
4	ANC	16796
5	LHR	16068
6	ORD	15997
7	DEN	13324
8	DFW	13976
9	ABQ	19775

Page 1 of 1 | Showing rows 1-14 | Columns | Size | Run a few seconds | Executed in

ASTRAI

Where

Run Selected | Limit 100 | Format | View history

```
1  SELECT *
2    FROM tutorial.flights
3  WHERE origin_airport = 'JFK'
4
5
6
7  SELECT destination_airport,
8         first_class_rev
9    FROM tutorial.flight_revenue
10 WHERE first_class_rev BETWEEN 16000 AND 17000
11
12
13
14
```

Succeeded

Data | Fields | Source | Export | Copy

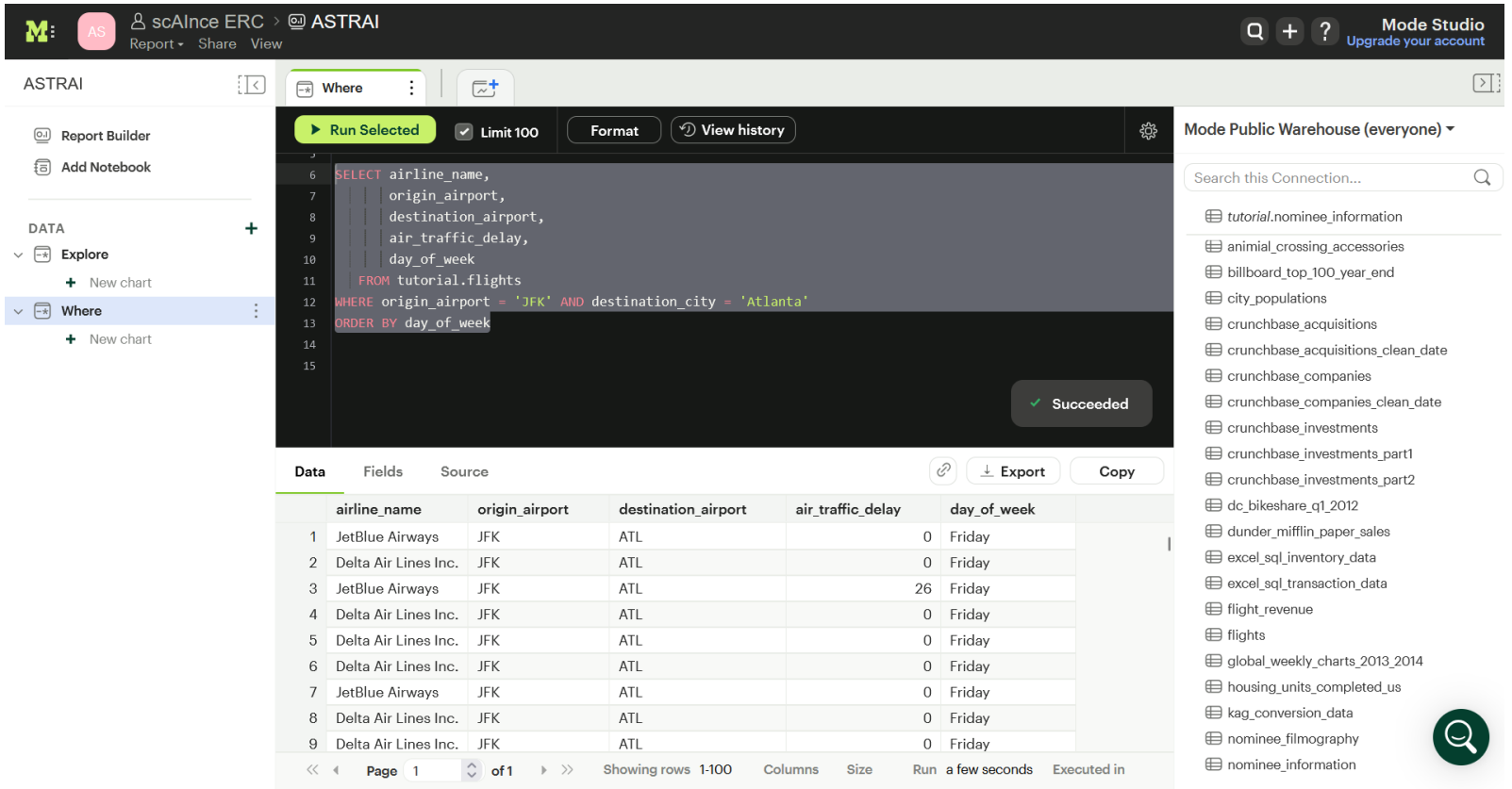
	destination_airport	first_class_rev
1	ANC	16796
2	LHR	16068

Page 1 of 1 | Showing rows 1-2 | Columns | Size | Run a few seconds | Executed in

What is the difference between these two queries?

#3.3 ORDER BY Sorting

Once you've learned how to filter data, it's time to learn how to sort data. The **ORDER BY** clause allows you to **reorder your results** based on the data in one or more columns. The ORDER BY keyword sorts the records in **ascending order by default**. To sort the records in descending order, use the DESC keyword.



What changed?

#3.3 ORDER BY Sorting

3. Pick a flight itinerary based on two criteria.
4. Order By a column of your choosing.

#3.4 AGGREGATION FUNCTIONS

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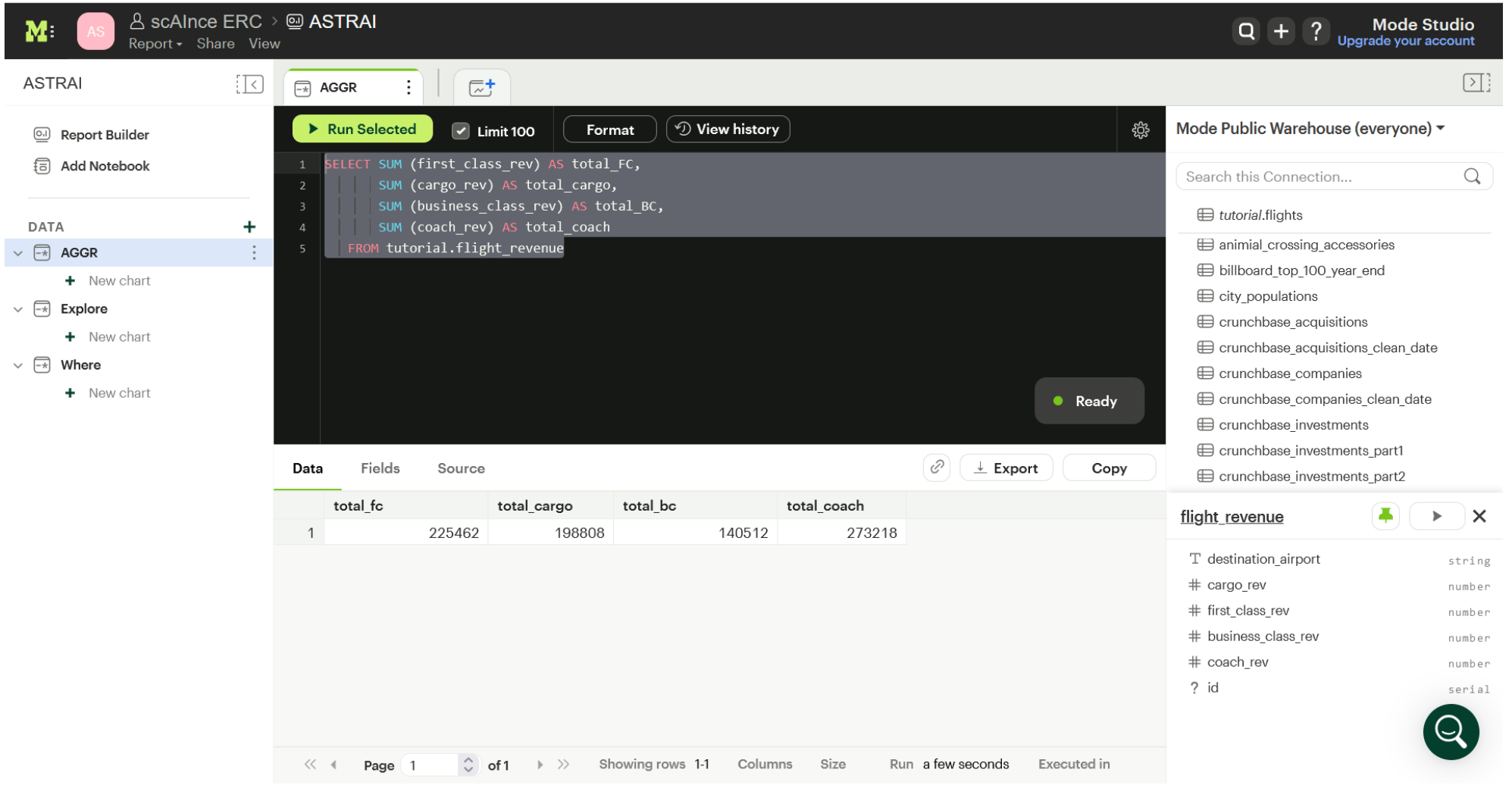
- The functions themselves **are the same ones** you will find in Excel or any other analytics program.
- They all **aggregate across the entire table**.

Here are the aggregation functions:

- **COUNT** counts how many rows are in a particular column.
- **SUM** adds together all the values in a particular column.
- **MIN** and **MAX** return the lowest and highest values in a particular column, respectively.
- **AVG** calculates the average of a group of selected values.

#3.4 AGGREGATION FUNCTIONS



#3.4 AGGREGATION FUNCTIONS

5. The lowest revenue in first_class_rev and highest revenue in business_class_rev

#3.4 AGGREGATION FUNCTIONS

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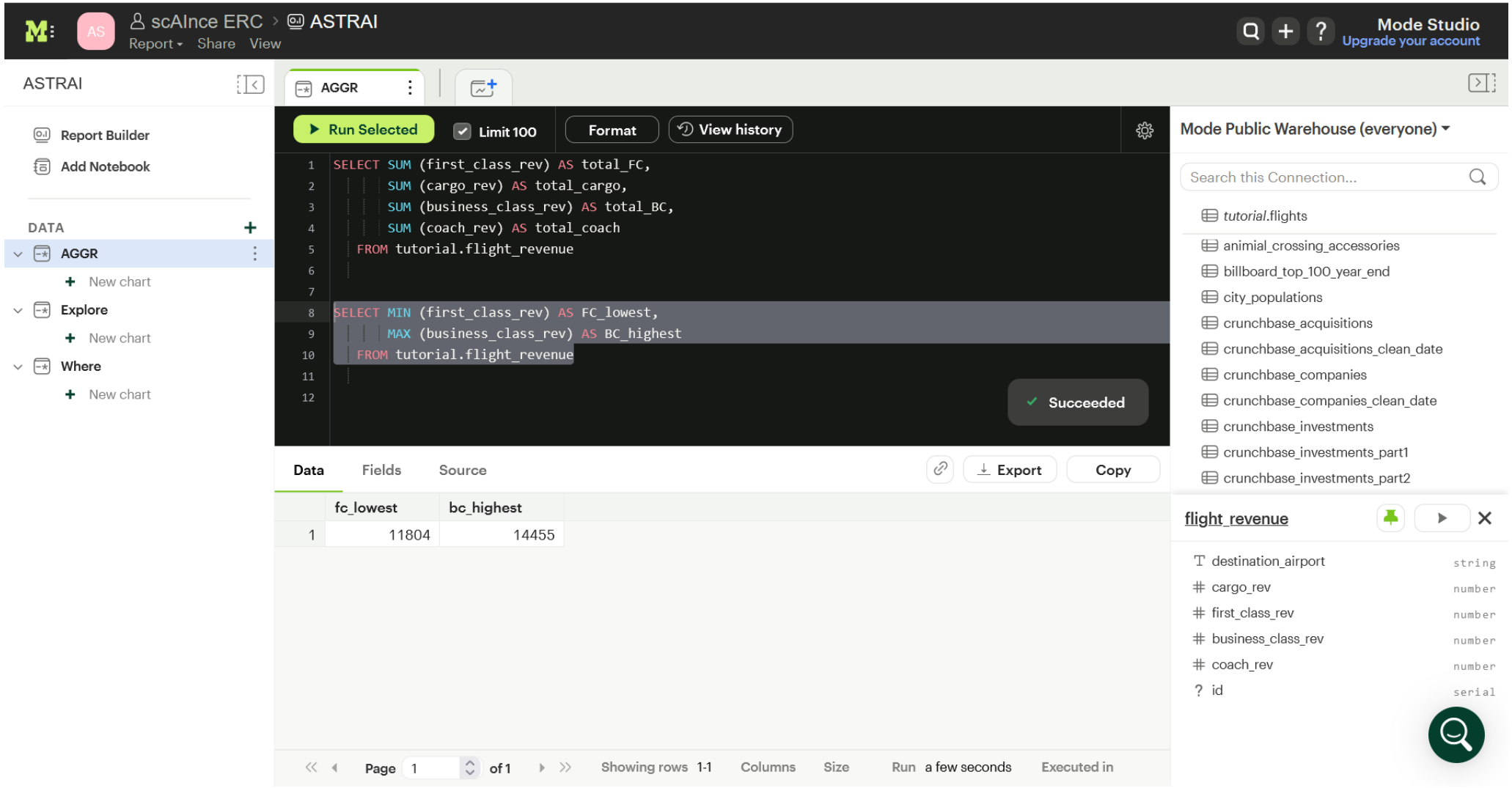
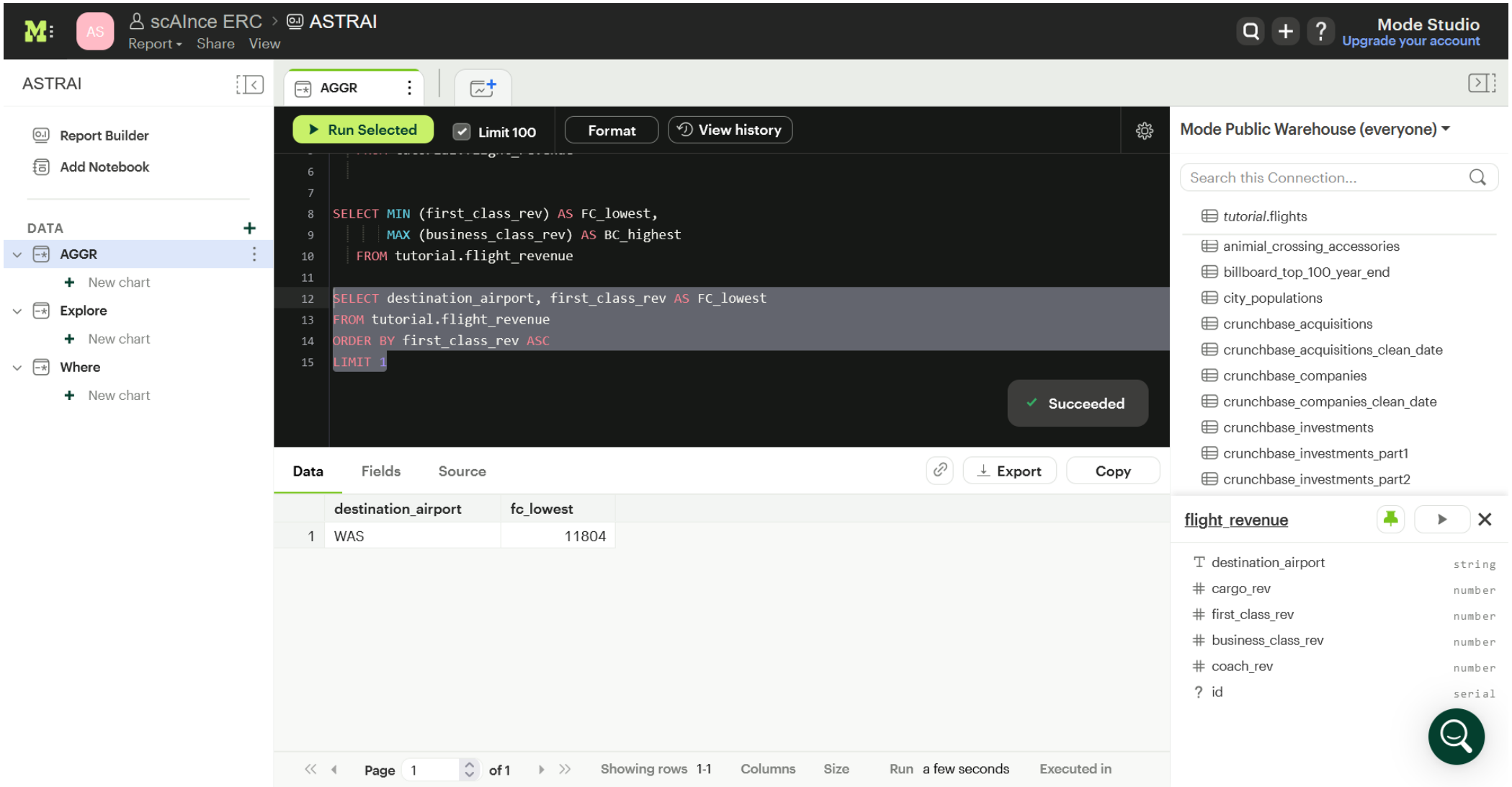


#3.4 AGGREGATION FUNCTIONS



- **THANK YOU**
- **DANKE**