# Apache Calcite

Julian Hyde | **AICamp** | 2018/10/16

# @julianhyde

SQL
Query planning
Query federation
BI & OLAP
Streaming
Hadoop

ASF member
Original author of Apache Calcite
PMC Apache Arrow, Calcite, Drill, Eagle, Kylin
Architect at Looker

# Apache Calcite

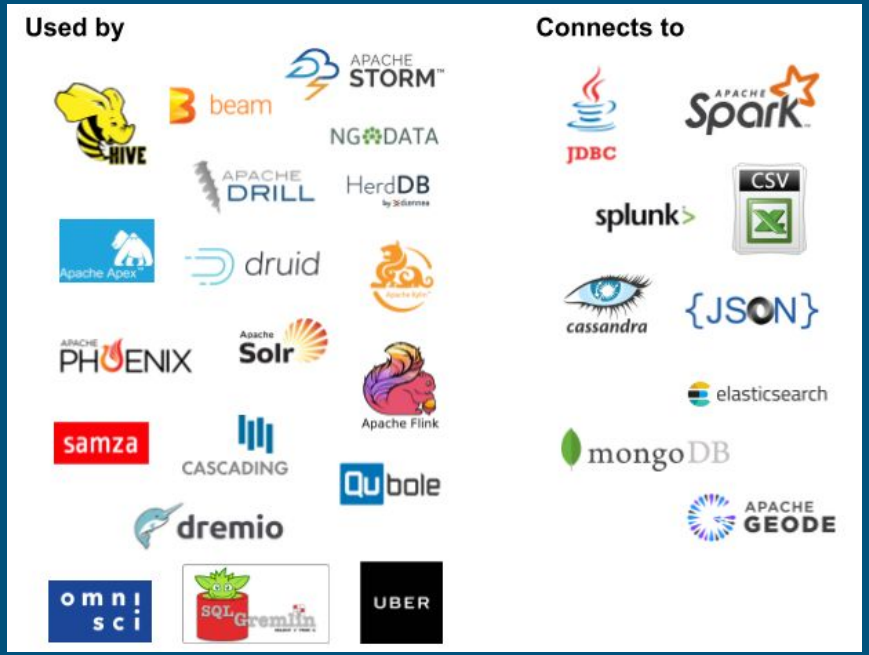

Apache top-level project

Query planning framework used in many projects and products

Also works standalone: embedded federated query engine with SQL / JDBC front end

Apache community development model

https://calcite.apache.org
https://github.com/apache/calcite



# Project goals

Make it easier to write a simple DBMS

Advance the state of the art for complex DBMS by pooling resources

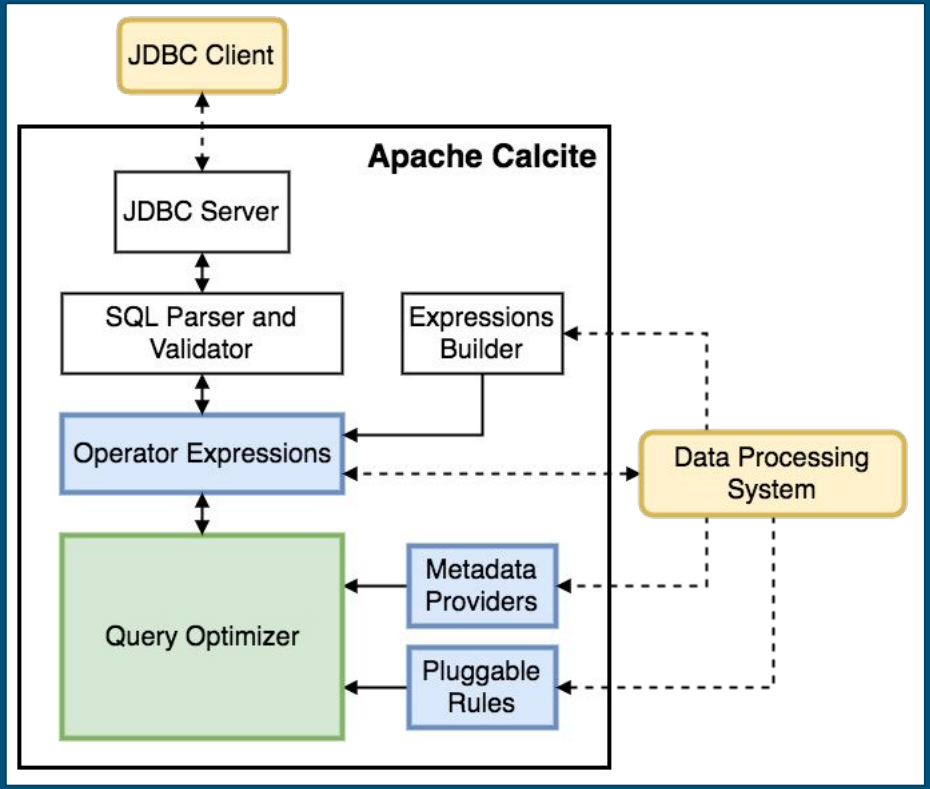
Bring database approaches to new areas (e.g. streaming)

Allow create a DBMS by composing pieces (federation, etc.)

Customize by plugging into framework, evolving framework when necessary

Apache license & governance

# Architecture




**Core** – Operator expressions (relational algebra) and planner (based on Volcano/Cascades[2])

**External** – Data storage, algorithms and catalog

**Optional** – SQL parser, JDBC & ODBC drivers

**Extensible** – Planner rewrite rules, statistics, cost model, algebra, UDFs

# Relational algebra

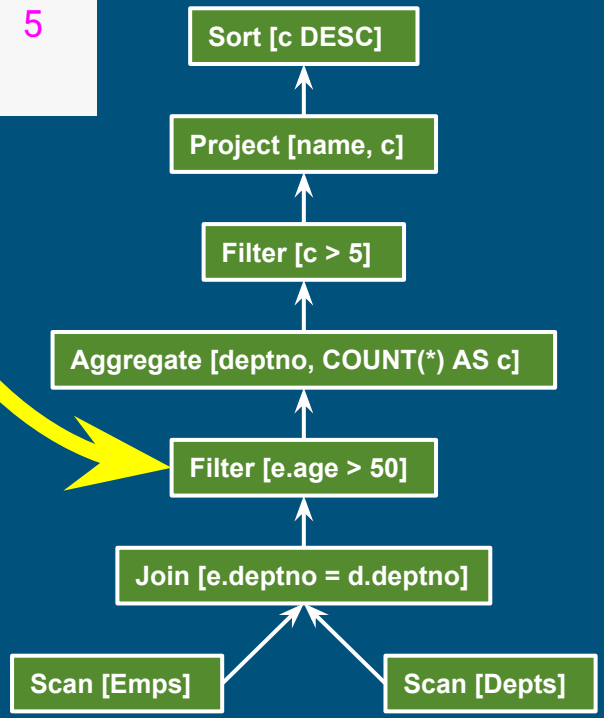
Based on set theory, plus operators: Project, Filter, Aggregate, Union, Join, Sort

Requires: declarative language (SQL), query planner

Original goal: data independence

Enables: query optimization, new algorithms and data structures

```
SELECT d.name, COUNT(*) AS c
FROM Emps AS e
JOIN Depts AS d USING (deptno)
WHERE e.age > 50
GROUP BY d.deptno
HAVING COUNT(*) > 5
ORDER BY c DESC
```



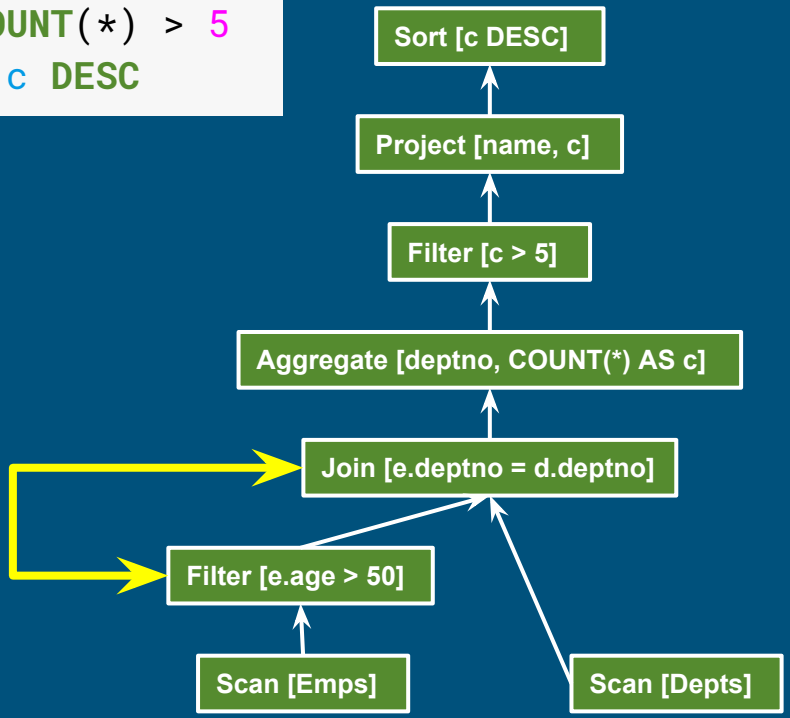
# Algebraic rewrite

Optimize by applying rewrite rules that preserve semantics

Hopefully the result is less expensive; but it's OK if it's not (planner keeps "before" and "after")

Planner uses dynamic programming, seeking the lowest total cost

```
SELECT d.name, COUNT(*) AS c
FROM (SELECT * FROM Emps
      WHERE e.age > 50) AS e
JOIN Depts AS d USING (deptno)
GROUP BY d.deptno
HAVING COUNT(*) > 5
ORDER BY c DESC
```



# Calcite framework

**Relational algebra**

RelNode (operator)
- TableScan
- Filter
- Project
- Union
- Aggregate
- …

RelDataType (type)
RexNode (expression)
RelTrait (physical property)
- RelConvention (calling-convention)
- RelCollation (sortedness)
- RelDistribution (partitioning)

RelBuilder

**SQL parser**

SqlNode
SqlParser
SqlValidator

**Metadata**

Schema
Table
Function
- TableFunction
- TableMacro

Lattice

**JDBC driver**

Remote driver
Local driver

**Transformation rules**

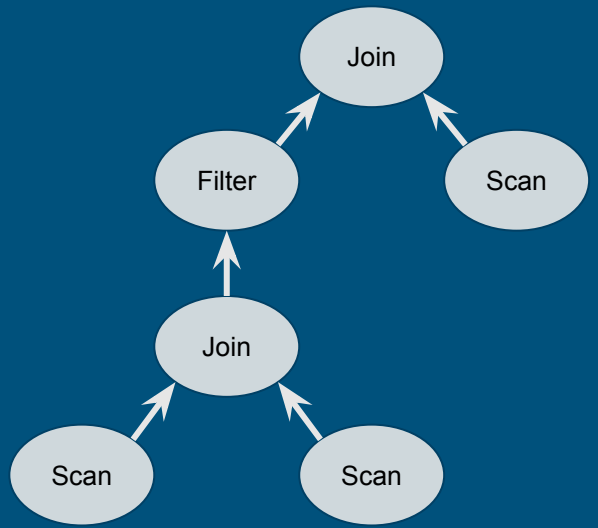
RelOptRule
- FilterMergeRule
- AggregateUnionTransposeRule
- 100+ more

Global transformations
- Unification (materialized view)
- Column trimming
- De-correlation

**Cost, statistics**

RelOptCost
RelOptCostFactory
RelMetadataProvider
- RelMdColumnUniqueness
- RelMdDistinctRowCount
- RelMdSelectivity

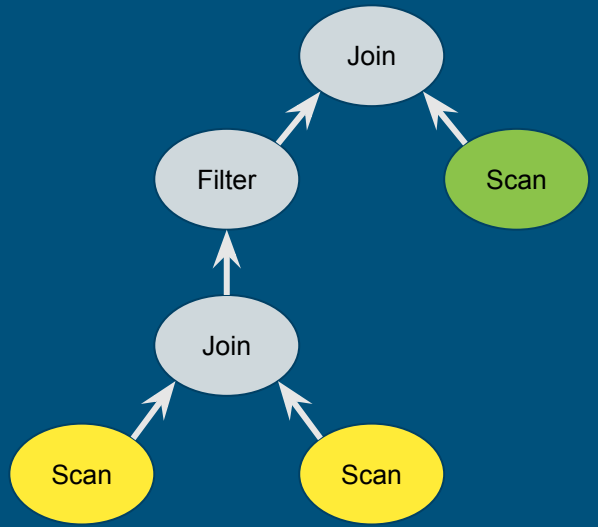
# Calling convention




Initially all nodes belong to “logical” calling convention

Logical calling convention cannot be implemented, so has infinite cost

# Calling convention

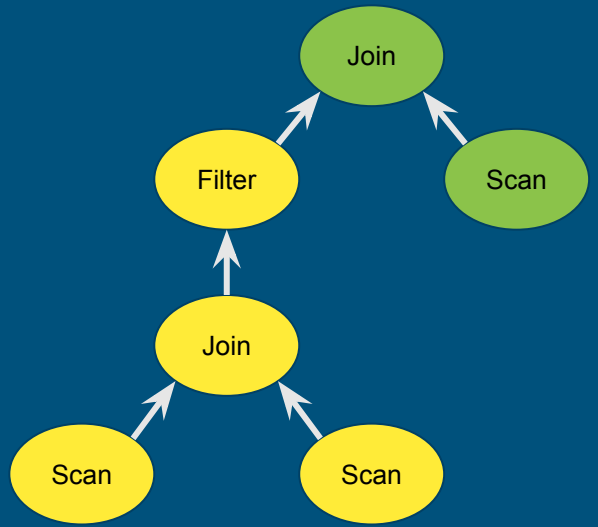



Tables can’t be moved so there is only one choice of calling convention for each table

Examples:

- Enumerable
- Druid
- Drill
- HBase
- JDBC

# Calling convention



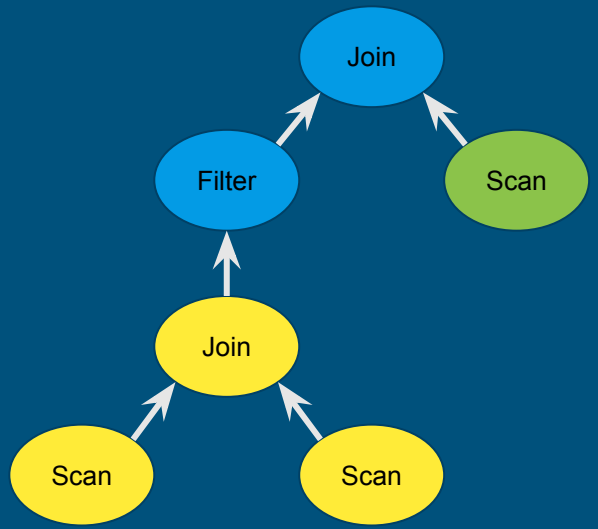

Rules fire to convert nodes to particular calling conventions

The calling convention propagates through the tree

LogicalFilter(YellowJoin) → YellowFilter(YellowJoin)

Because this is Volcano, each node can have multiple conventions

# Calling convention




We also consider “engines” -- calling conventions that do not have a storage format.

Examples are Drill, Spark, Presto.

To implement, we generate program that calls out to query1 and query2.

# Adapter

Implement `SchemaFactory` interface

Connect to a data source using parameters

Extract schema - return a list of tables

Push down processing to the data source:

- A set of planner rules
- Calling convention (optional)
- Query model & query generator (optional)

```
"schemas": [
 {
   "name": "HR",
   "type": "custom",
   "factory":
"org.apache.calcite.adapter.file.FileSchemaFactory",
   "operand": {
     "directory": "hr-csv"
   }
 }
]
```

```
$ ls -l hr-csv
-rw-r--r--  1 jhyde  staff   62 Mar 29 12:57 DEPTS.csv
-rw-r--r--  1 jhyde  staff  262 Mar 29 12:57 EMPS.csv.gz
$ ./sqlline  -u jdbc:calcite:model=hr.json -n scott -p tiger
sqlline> select count(*) as c from emp;
'C'
'5'
1 row selected (0.135 seconds)
```

# Algebra builder

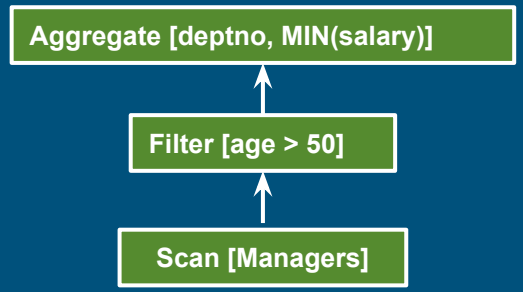
```
final FrameworkConfig config;
final RelBuilder builder = RelBuilder.create(config);
final RelNode node = builder
    .scan("EMPS")
    .aggregate(
        builder.groupKey("DEPTNO"), builder.count(false, "C"),
        builder.sum(false, "S", builder.field("SAL")))
    .filter(
        builder.call(SqlStdOperatorTable.GREATER_THAN,
            builder.field("C"), builder.literal(10)))
    .build();
System.out.println(RelOptUtil.toString(node));
```

```
SELECT deptno,
  COUNT(*) AS c,
  SUM(sal) AS s
FROM Emps
HAVING COUNT(*) > 10
```

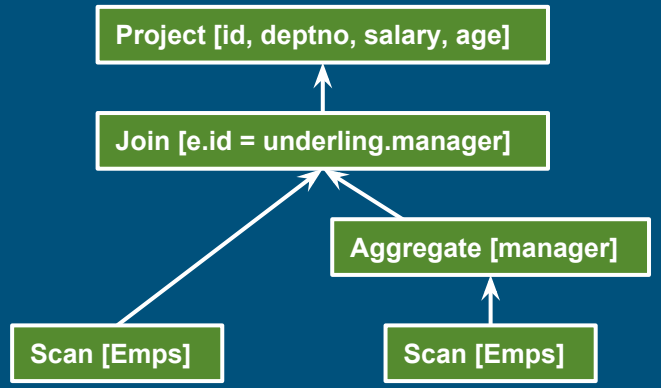
```
LogicalFilter(condition=[>($1, 10)])
    LogicalAggregate(group=[{7}], C=[COUNT()], S=[SUM($5)])
        LogicalTableScan(table=[[EMPS]])
```

# Views

```
SELECT deptno, MIN(salary)
FROM Managers
WHERE age > 50
GROUP BY deptno
```



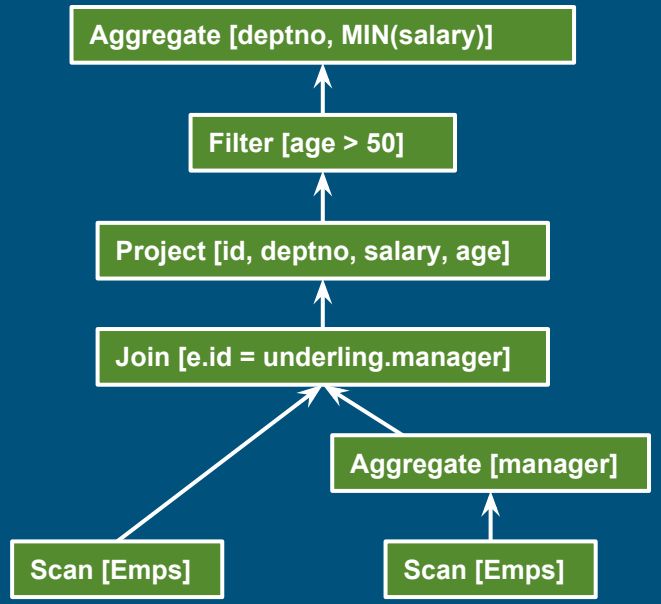

```
CREATE VIEW Managers AS
SELECT *
FROM Emps AS e
WHERE EXISTS (
  SELECT *
  FROM Emps AS underling
  WHERE underling.manager = e.id)
```



# View query (after expansion)

```
SELECT deptno, MIN(salary)
FROM Managers
WHERE age > 50
GROUP BY deptno
```

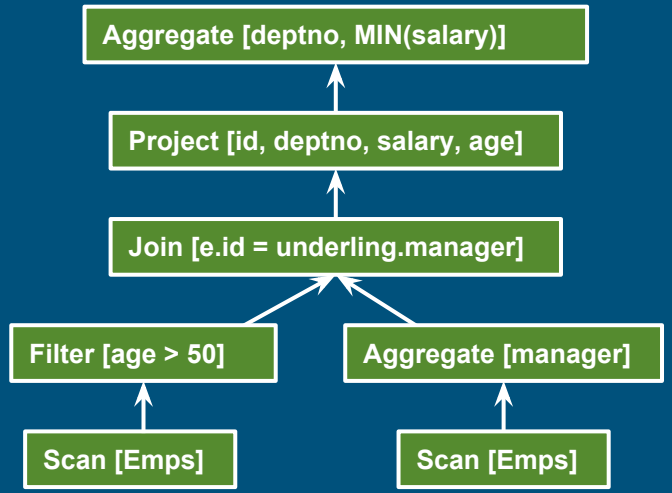
```
CREATE VIEW Managers AS
SELECT *
FROM Emps AS e
WHERE EXISTS (
  SELECT *
  FROM Emps AS underling
  WHERE underling.manager = e.id)
```



# View query (after pushing down filter)

```
SELECT deptno, MIN(salary)
FROM Managers
WHERE age > 50
GROUP BY deptno
```

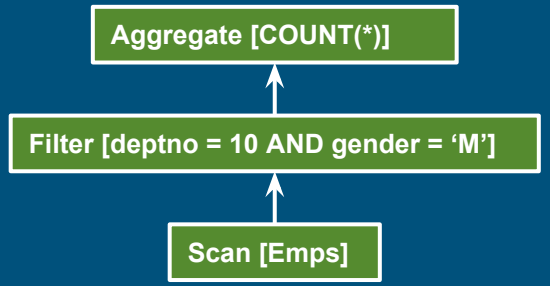
```
CREATE VIEW Managers AS
SELECT *
FROM Emps AS e
WHERE EXISTS (
  SELECT *
  FROM Emps AS underling
  WHERE underling.manager = e.id)
```



# Materialized view

```
CREATE MATERIALIZED VIEW
  EmpSummary AS
SELECT deptno, gender,
  COUNT(*) AS c, SUM(sal) AS s
FROM Emps
GROUP BY deptno, gender
```

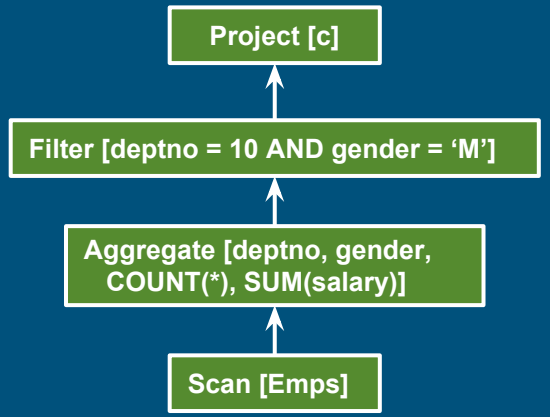

```
SELECT COUNT(*) AS c
FROM Emps
WHERE deptno = 10
AND gender = 'M'
```



# Materialized view: rewrite query to match

```
CREATE MATERIALIZED VIEW
  EmpSummary AS
SELECT deptno, gender,
  COUNT(*) AS c, SUM(sal) AS s
FROM Emps
GROUP BY deptno, gender
```

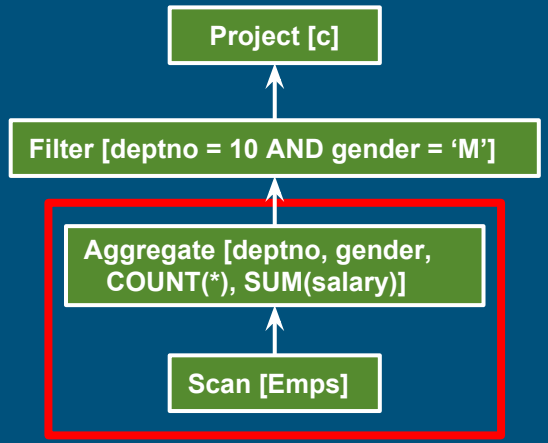

```
SELECT COUNT(*) AS c
FROM Emps
WHERE deptno = 10
AND gender = 'M'
```



# Materialized view: rewrite query to match

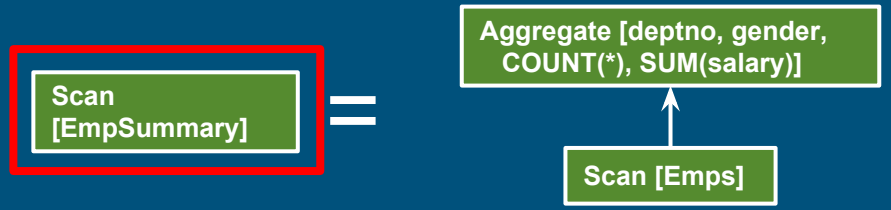
```
CREATE MATERIALIZED VIEW
  EmpSummary AS
SELECT deptno, gender,
  COUNT(*) AS c, SUM(sal) AS s
FROM Emps
GROUP BY deptno, gender
```


```
SELECT COUNT(*) AS c
FROM Emps
WHERE deptno = 10
AND gender = 'M'
```

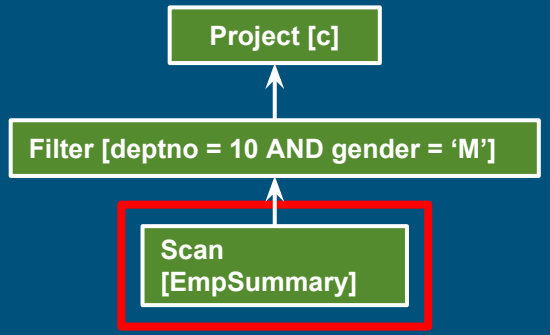


# Materialized view: substitute table scan

```
CREATE MATERIALIZED VIEW
  EmpSummary AS
SELECT deptno, gender,
  COUNT(*) AS c, SUM(sal) AS s
FROM Emps
GROUP BY deptno, gender
```



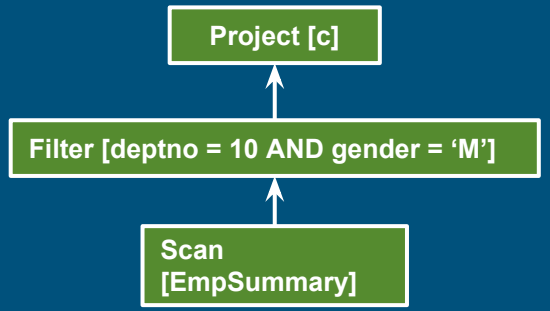

```
SELECT COUNT(*) AS c
FROM Emps
WHERE deptno = 10
AND gender = 'M'
```



# Materialized view: substitute table scan

```
CREATE MATERIALIZED VIEW
  EmpSummary AS
SELECT deptno, gender,
  COUNT(*) AS c, SUM(sal) AS s
FROM Emps
GROUP BY deptno, gender
```


```
SELECT c
FROM EmpSummary
WHERE deptno = 10
AND gender = 'M'
```



# Summary

Apache Calcite is a toolkit for **constructing your own DBMS**

Core is **Relational Algebra**

Optimize queries by applying **transformation rules** and choosing the best based upon **statistics**

**Calling conventions** allow you to represent hybrid queries

**Materialized views** allow you optimize your data by providing sorted, aggregate copies

# Thank you!
# Questions?

https://calcite.apache.org
@ApacheCalcite
@julianhyde