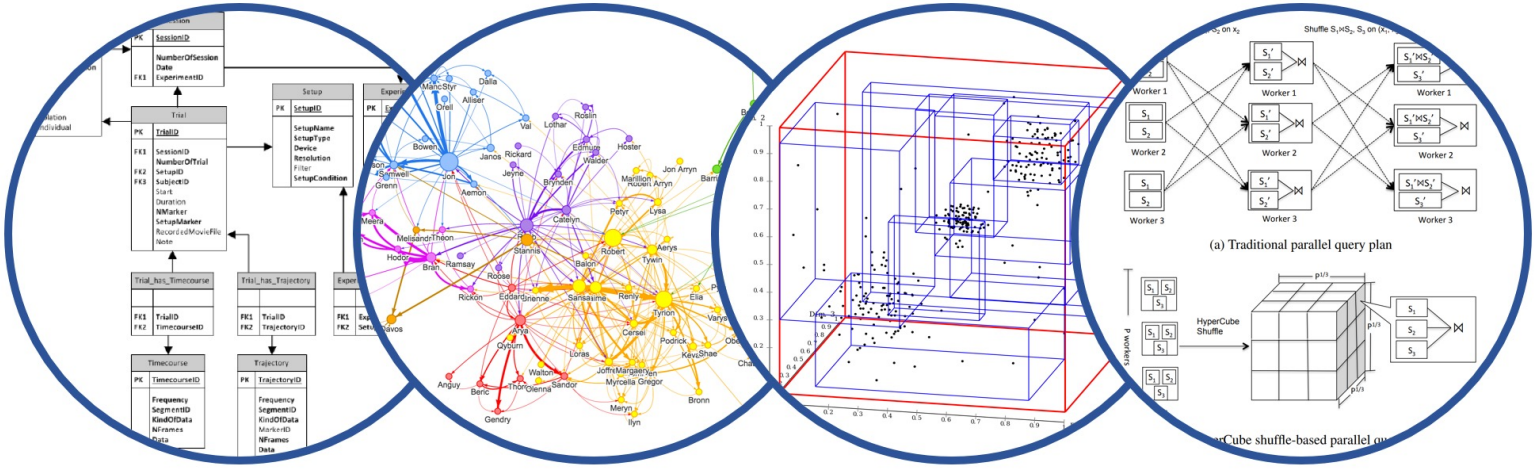


Introduction to Data Management

Aggregates and Grouping

Paul G. Allen School of Computer Science and Engineering
University of Washington, Seattle

Self Joins

Find all people who drive a Civic and Pinto

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

UserID	Car
123	Charger
567	Civic
567	Pinto

```
SELECT P.Name
  FROM Payroll AS P, Regist AS R
 WHERE P.UserID = R.UserID AND
       R.Car = 'Civic';
```

Self Joins

Find all people who drive a Civic and Pinto

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

UserID	Car
123	Charger
567	Civic
567	Pinto

```
SELECT P.Name, R1.Car, R2.Car
  FROM Payroll AS P, Regist AS R1, Regist AS R2
 WHERE P.UserID = R1.UserID AND
       P.UserID = R2.UserID AND
       R1.Car = 'Civic' AND
       R2.Car = 'Pinto';
```

Self Joins

Find all people who drive a Civic and Pinto

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

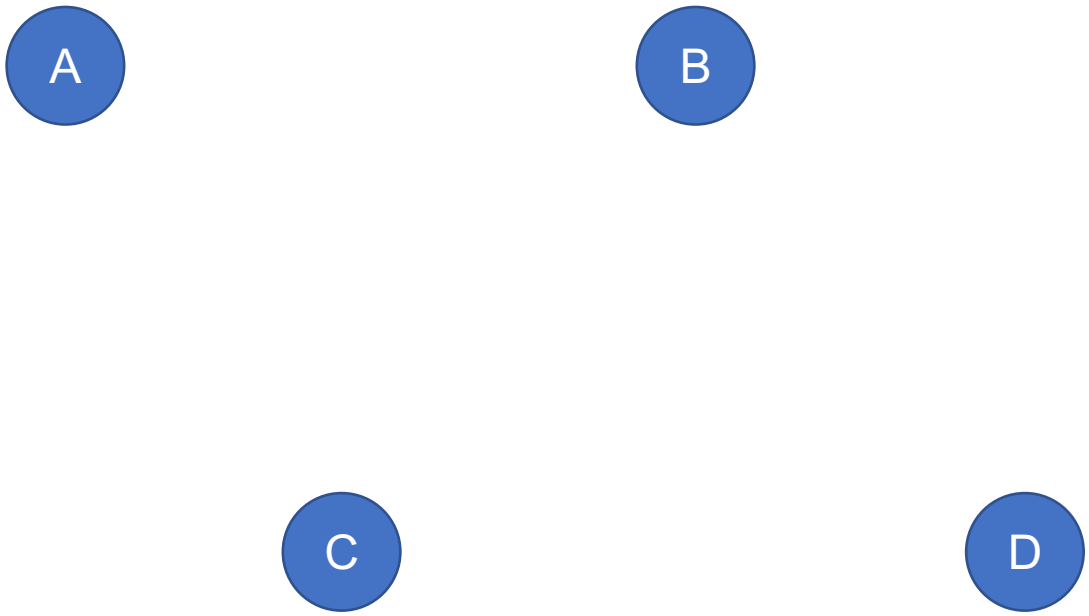
UserID	Car
123	Charger
567	Civic
567	Pinto

All pairs of cars a person can drive

```
SELECT P.Name, R1.Car, R2.Car
  FROM Payroll AS P, Regist AS R1, Regist AS R2
 WHERE P.UserID = R1.UserID AND
       P.UserID = R2.UserID AND
       R1.Car = 'Civic' AND
       R2.Car = 'Pinto';
```

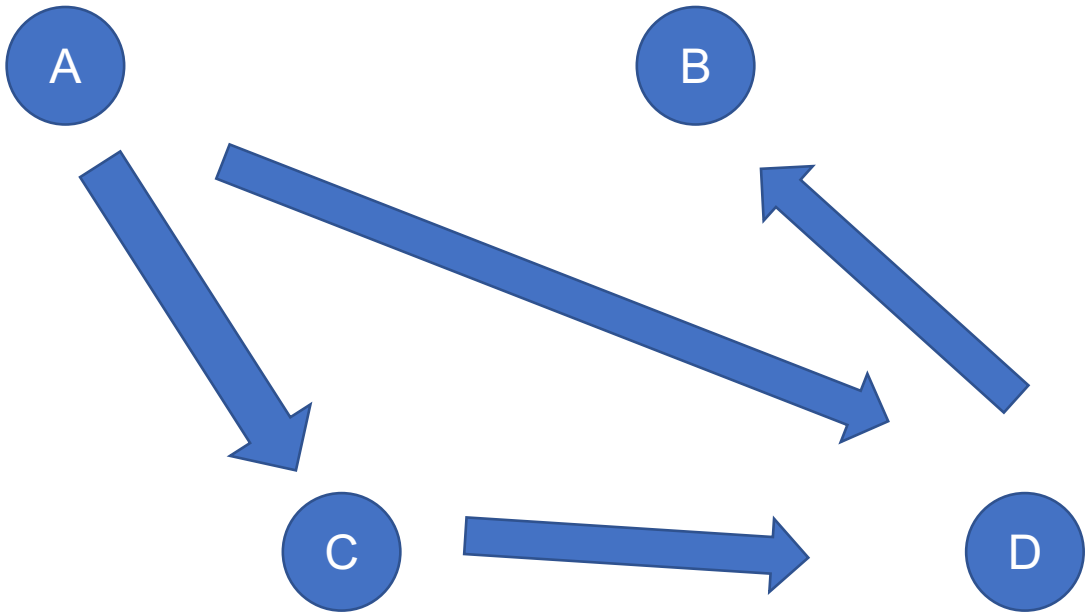
Recap – Self Joins

- Join to combine data from different tables



Recap – Self Joins

- Join to combine data from different tables



Goals for Today

- We have started to build our SQL toolbox
  - Not just reading and filtering data anymore
  - Starting to answer complex questions
- Today we want to effectively summarize results

Aggregation functions

- New class of SQL queries

Aggregates

Outline

- Aggregation functions
- GROUP BY and HAVING clauses in SQL
- The witnessing problem

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**

Actionable Results

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  - “How popular is this tv-show?”

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT
  - "Do I spend too much on coffee?"

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT
  - "Do I spend too much on coffee?" → SUM

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT
  - "Do I spend too much on coffee?" → SUM
  - "Am I being ripped off by this car dealership?"

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT
  - "Do I spend too much on coffee?" → SUM
  - "Am I being ripped off by this car dealership?" → AVG

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT
  - "Do I spend too much on coffee?" → SUM
  - "Am I being ripped off by this car dealership?" → AVG
  - "Who got the highest grade in the class?"

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT
  - "Do I spend too much on coffee?" → SUM
  - "Am I being ripped off by this car dealership?" → AVG
  - "Who got the highest grade in the class?" → MAX

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT
  - "Do I spend too much on coffee?" → SUM
  - "Am I being ripped off by this car dealership?" → AVG
  - "Who got the highest grade in the class?" → MAX
  - "What's the cheapest food on the Ave?"

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - "How popular is this tv-show?" → COUNT
  - "Do I spend too much on coffee?" → SUM
  - "Am I being ripped off by this car dealership?" → AVG
  - "Who got the highest grade in the class?" → MAX
  - "What's the cheapest food on the Ave?" → MIN

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - COUNT
  - SUM
  - AVG
  - MAX
  - MIN

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - COUNT
  - SUM
  - AVG
  - MAX
  - MIN

  } Very common attributes found in DBMS

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - SELECT **COUNT**(*) FROM StreamingViews …
  - SELECT **SUM**(cost) FROM CoffeeReceipts …
  - SELECT **AVG**(price) FROM CarDealers …
  - SELECT **MAX**(score) FROM StudentGrades …
  - SELECT **MIN**(price) FROM AveLunchPrices …

AGG(attr) → computes **AGG** over non-NULL values
AGG(DISTINCT attr) is also possible

Actionable Results

- We need summaries of data because we are often trying to **make decisions** and **succinctly convey information**
  - SELECT **COUNT**(*) FROM StreamingViews …
  - SELECT **SUM**(cost) FROM CoffeeReceipts …
  - SELECT **AVG**(price) FROM CarDealers …
  - SELECT **MAX**(score) FROM StudentGrades …
  - SELECT **MIN**(price) FROM AveLunchPrices …

COUNT(*) → # of rows regardless of NULL

Example 1

What is the average salary of people in our dataset?

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
567	Pinto

Example 1

What is the average salary of people in our dataset?

```
SELECT AVG(P.Salary)
  FROM Payroll AS P;
```

AVG(P.Salary)
75000

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
567	Pinto

Example 2

How many professors are in the dataset?

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
567	Pinto

Example 2

How many professors are in the dataset?

```
SELECT COUNT(*)
  FROM Payroll AS P
 WHERE P.Job = 'Prof';
```

COUNT(*)
2

Aggregate happens after WHERE statement

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
567	Pinto

Example 2

How many TAs are there and what is their average salary?

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
567	Pinto

Example 2

How many TAs are there and what is their average salary?

```
SELECT COUNT(*), AVG(P.Salary)
  FROM Payroll AS P
 WHERE P.Job = 'TA';
```

COUNT(*)	AVG(P.Salary)
2	55000

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
567	Pinto

Example 2

How many TAs are there and what is their average salary?

```
SELECT COUNT(*) AS Num_TAs,
       AVG(P.Salary) AS Avg_Salary
  FROM Payroll AS P
 WHERE P.Job = 'TA';
```

Num_TAs	Avg_Salary
2	55000

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
567	Pinto

Aggregation Semantics

What am I aggregating over in a SELECT-FROM-WHERE query with joins?

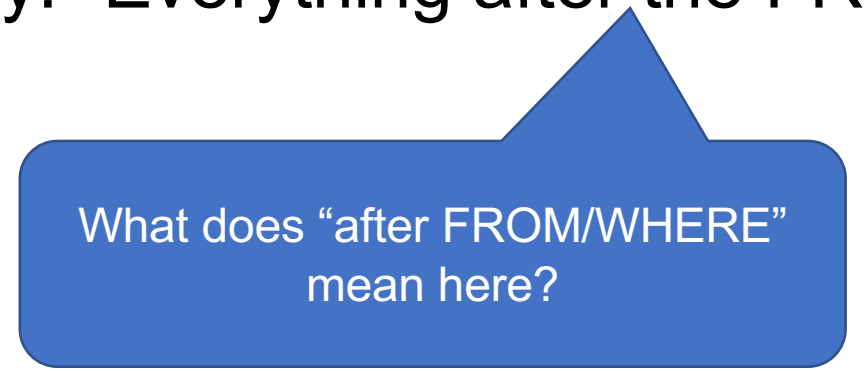
Intuitively: “Everything after the FROM/WHERE”

What does “after FROM/WHERE” mean here?

Aggregation Semantics

What am I aggregating over in a SELECT-FROM-WHERE query with joins?

Intuitively: “Everything after the FROM/WHERE”



In SQL, the joins and where statements produce one **intermediate relation**, after which the aggregate is calculated.

Aggregation Semantics

Will this query get me the correct calculation for average salary of all people who own cars?

```
SELECT AVG(P.Salary)
  FROM Payroll AS P, Regist AS R
 WHERE P.UserID = R.UserID;
```

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
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Regist

UserID	Car
123	Charger
567	Civic
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Aggregation Semantics

Will this query get me the correct calculation for average salary of all people who own cars?

```
SELECT AVG(P.Salary)
  FROM Payroll AS P, Regist AS R
 WHERE P.UserID = R.UserID;
```

Should be 70,000, let's find out if that's what we get

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
567	Pinto

Aggregation Semantics

```
SELECT AVG(P.Salary)
  FROM Payroll AS P, Regist AS R
 WHERE P.UserID = R.UserID;
```

$$\text{Join}_{P.UserID=R.UserID}$$

UserID	Name	Job	Salary
123	Jack	TA	50000
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Aggregation Semantics

```
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```

P.UserID	P.Name	P.Job	P.Salary	R.UserID	R.Car
123	Jack	TA	50000	123	Charger
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567	Magda	Prof	90000	567	Pinto

$$\text{Join}_{P.UserID=R.UserID}$$

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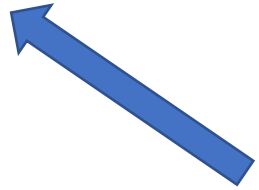

$\text{Aggregate}_{AVG(P.Salary)}$

P.UserID	P.Name	P.Job	P.Salary	R.UserID	R.Car
123	Jack	TA	50000	123	Charger
567	Magda	Prof	90000	567	Civic
567	Magda	Prof	90000	567	Pinto

$\text{Join}_{P.UserID=R.UserID}$

UserID	Name	Job	Salary
123	Jack	TA	50000
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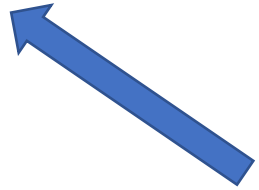

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UserID	Car
123	Charger
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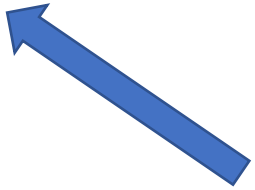
Aggregation Semantics

```
SELECT AVG(P.Salary)
  FROM Payroll AS P, Regist AS R
 WHERE P.UserID = R.UserID;
```

AVG(P.Salary)
76666



$\text{Aggregate}_{AVG(P.Salary)}$

P.UserID	P.Name	P.Job	P.Salary	R.UserID	R.Car
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UserID	Name	Job	Salary
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Aggregation Semantics

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SELECT AVG(P.Salary)
  FROM Payroll AS P, Regist AS R
 WHERE P.UserID = R.UserID;
```

AVG(P.Salary)
76666

Not 70,000!

$$\text{Aggregate}_{AVG(P.Salary)}$$

P.UserID	P.Name	P.Job	P.Salary	R.UserID	R.Car
123	Jack	TA	50000	123	Charger
567	Magda	Prof	90000	567	Civic
567	Magda	Prof	90000	567	Pinto

$$\text{Join}_{P.UserID=R.UserID}$$

UserID	Name	Job	Salary
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UserID	Car
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567	Pinto

Aggregation Semantics

```
SELECT AVG(P.Salary)
  FROM Payroll AS P, Regist AS R
 WHERE P.UserID = R.UserID;
```

AVG(P.Salary)
76666

90000 was counted twice…

$$\text{Aggregate}_{AVG(P.Salar}$$

P.UserID	P.Name	P.Job	P.Salary	R.UserID	R.Car
123	Jack	TA	50000	123	Charger
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567	Magda	Prof	90000	567	Pinto

$$\text{Join}_{P.UserID=R.UserID}$$

UserID	Name	Job	Salary
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UserID	Car
123	Charger
567	Civic
567	Pinto

Aggregation Semantics

Compute the average salary of all people who own cars?

(Did not work, need subqueries for this)

Compute the **minimum** salary of all people who own cars?

(This will work, check for yourself!)

```
SELECT MIN(P.Salary)
  FROM Payroll AS P, Regist AS R
 WHERE P.UserID = R.UserID;
```

Payroll

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Regist

UserID	Car
123	Charger
567	Civic
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Aggregation Semantics

```
SELECT AVG(P.Salary)
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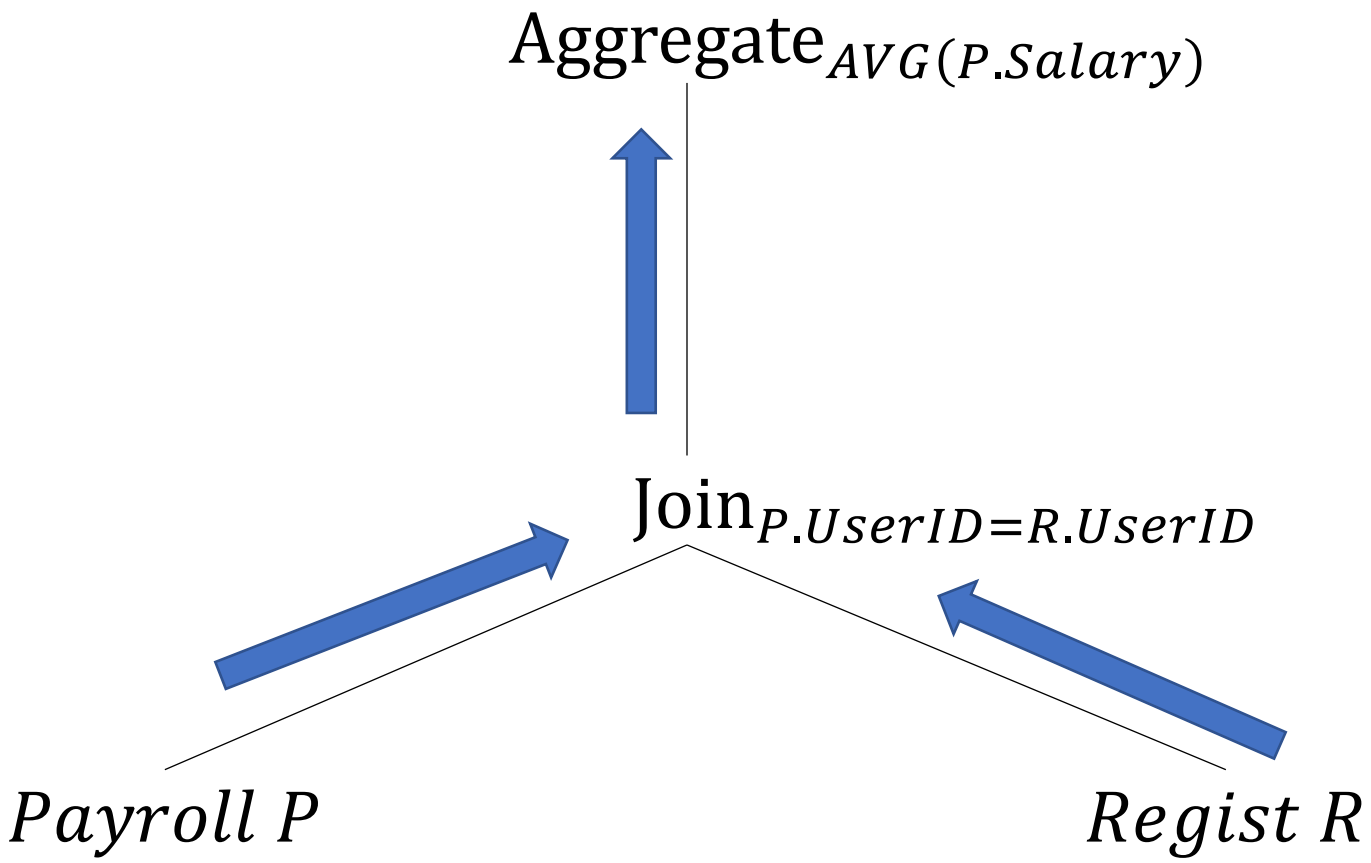

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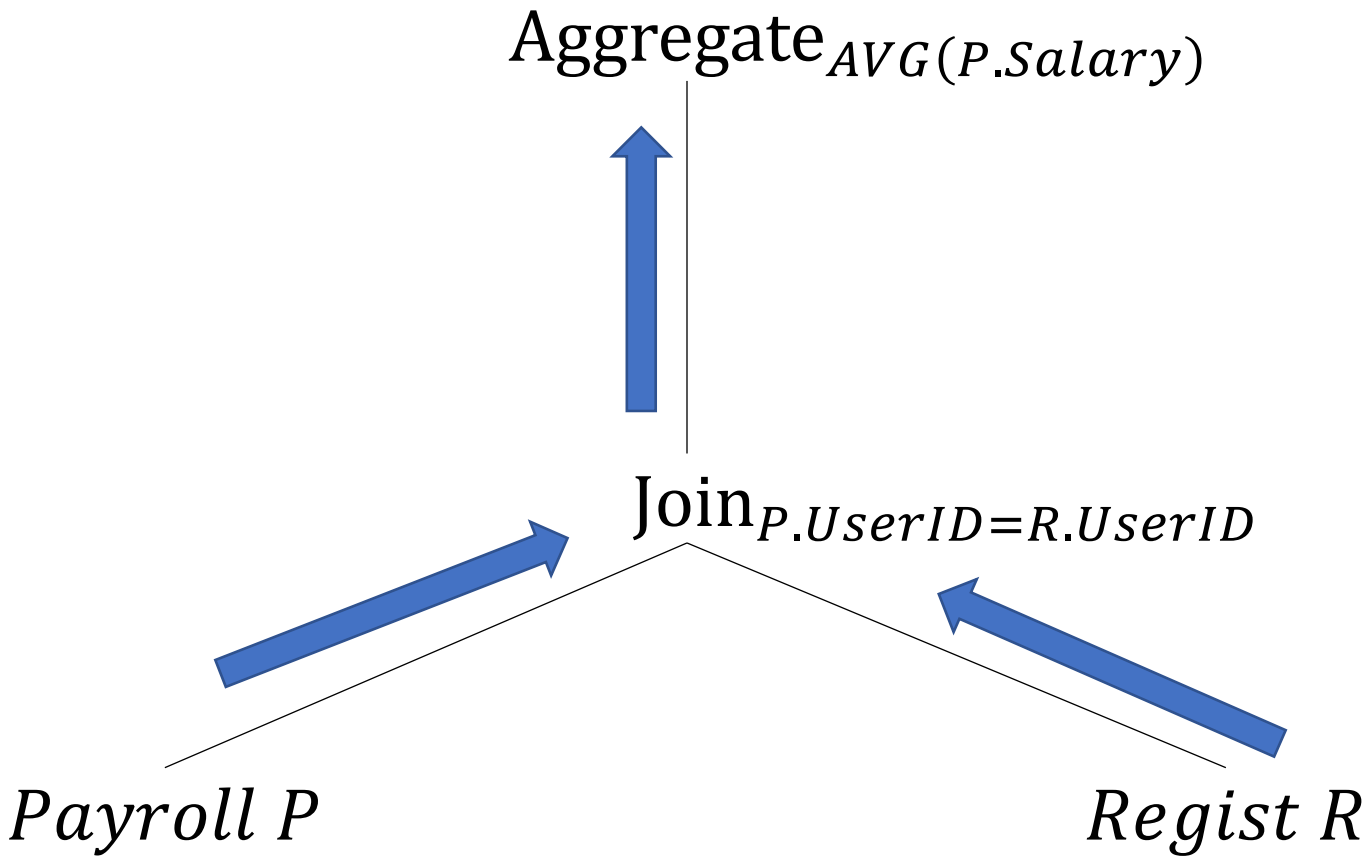

Aggregation Semantics

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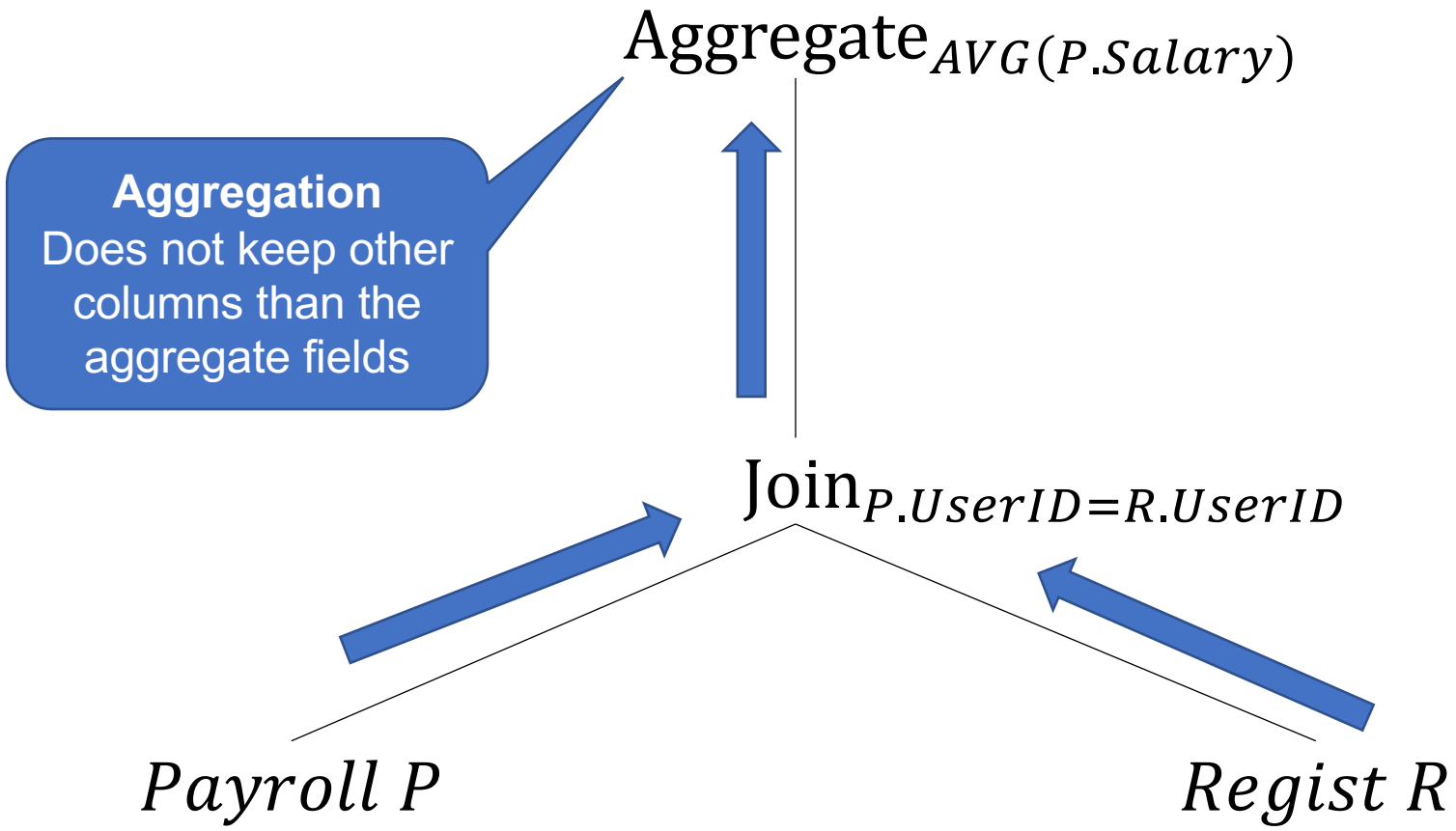

Grouping

- SQL allows you to specify what groups your query operates over
  - Sometimes a “whole-table” aggregation is too coarse-grained
  - We can partition our data based on **matching attribute values**

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- SQL allows you to specify what groups your query operates over
  - Sometimes a “whole-table” aggregation is too coarse-grained
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UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

```
...
GROUP BY Job
...
```

Grouping

- SQL allows you to specify what groups your query operates over
  - Sometimes a “whole-table” aggregation is too coarse-grained
  - We can partition our data based on **matching attribute values**

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

```
...
GROUP BY Job
...
```

Grouping Example

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Grouping Example

```
SELECT Job, MAX(Salary)
  FROM Payroll
 GROUP BY Job
```

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Job	MAX(Salary)
TA	60000
Prof	100000

Grouping Example

```
SELECT Job, AVG(Salary)
  FROM Payroll
 GROUP BY Job
```

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Job	AVG(Salary)
TA	55000
Prof	95000

Grouping on Multiple Attributes

What if we care about both Job and Year?

```
SELECT Job, AVG(Salary)
  FROM Payroll
 GROUP BY Job
```

UserID	Name	Job	Year	Salary
123	Jack	TA	1	50000
345	Allison	TA	2	60000
567	Magda	Prof	1	90000
789	Dan	Prof	2	100000

Job	AVG(Salary)
TA	55000
Prof	95000

Grouping on Multiple Attributes

What if we care about both Job and Year?

```
SELECT Year, AVG(Salary)
  FROM Payroll
 GROUP BY Year
```

UserID	Name	Job	Year	Salary
123	Jack	TA	1	50000
345	Allison	TA	2	60000
567	Magda	Prof	1	90000
789	Dan	Prof	2	100000

Year	AVG(Salary)
1	70000
2	80000

Grouping on Multiple Attributes

Job and Year together?

```
SELECT Job, Year, AVG(Salary)
  FROM Payroll
 GROUP BY Job, Year
```

UserID	Name	Job	Year	Salary
123	Jack	TA	1	50000
345	Allison	TA	2	60000
567	Magda	Prof	1	90000
789	Dan	Prof	2	100000

Job	Year	Salary
TA	1	50000
TA	2	60000
Prof	1	90000
Prof	2	100000

Filtering Groups with HAVING

```
SELECT Job, MAX(Salary)
  FROM Payroll
 GROUP BY Job
HAVING MIN(Salary) > 80000
```

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Filtering Groups with HAVING

```
SELECT Job, MAX(Salary)
  FROM Payroll
 GROUP BY Job
HAVING MIN(Salary) > 80000
```

UserID	Name	Job	Salary
123	Jack	TA	50000
345	Allison	TA	60000
567	Magda	Prof	90000
789	Dan	Prof	100000

Job	MAX(Salary)
Prof	100000

Aggregation RA

How is aggregation processed internally?

```
SELECT Job, MAX(Salary)
  FROM Payroll
 GROUP BY Job
HAVING MIN(Salary) > 80000
```

Aggregation RA

How is aggregation processed internally?

```
SELECT Job, MAX(Salary)
  FROM Payroll
 GROUP BY Job
HAVING MIN(Salary) > 80000
```

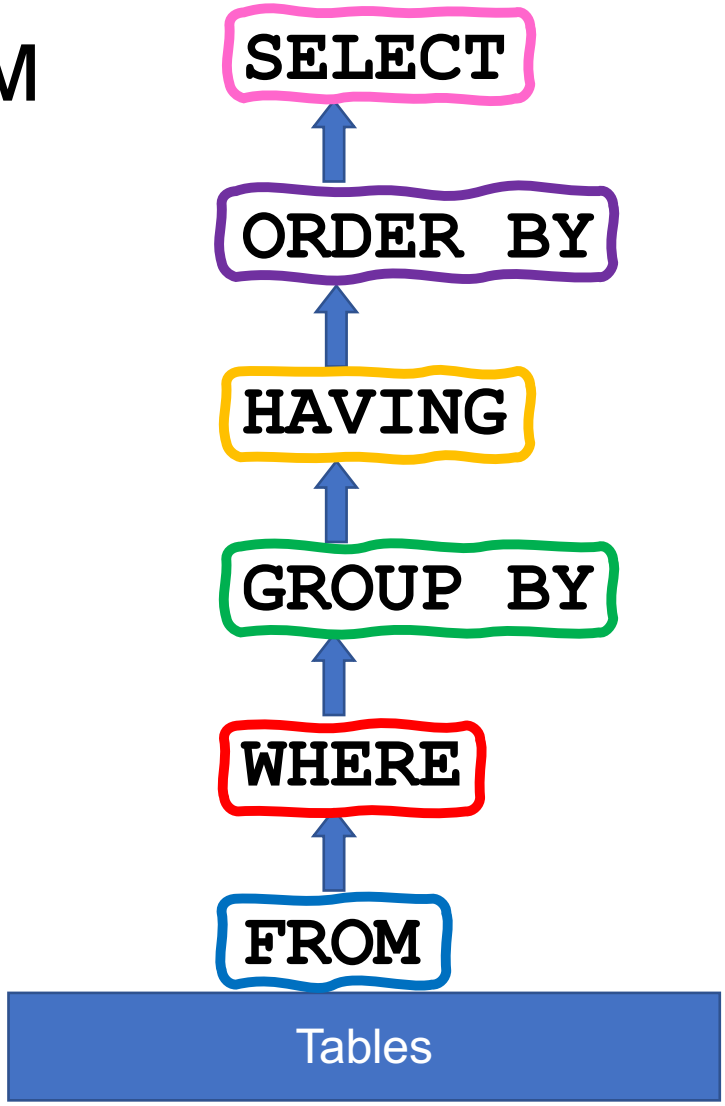
Our first preview of Relational Algebra:

"Having" applies **after** grouping the big intermediate table

SQL and RA Vocab Summary

FWGHOS™

```
SELECT ...
  FROM ...
 WHERE ...
GROUP BY ...
HAVING ...
ORDER BY ...
```



Aggregation RA

```
SELECT Job, MAX(Salary)
  FROM Payroll
 GROUP BY Job
HAVING MIN(Salary) > 80000
```

UserID	Name	Job	Salary
…	…	…	…

Aggregation RA

```
SELECT Job, MAX(Salary)
  FROM Payroll
 GROUP BY Job
HAVING MIN(Salary) > 80000
```

$$\text{Aggregate}_{Job,\ MAX(P.Salary)\rightarrow maxSal,\ MIN(P.Salary)\rightarrow minSal}$$

UserID	Name	Job	Salary
…	…	…	…

Aggregation RA

```
SELECT Job, MAX(Salary)
  FROM Payroll
 GROUP BY Job
HAVING MIN(Salary) > 80000
```

Job	maxSal	minSal
TA	60000	50000
Prof	100000	90000

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…	…	…	…

Preview: Relational Algebra

```
SELECT  ...
  FROM  ...
 WHERE  ...
 GROUP  BY  ...
HAVING  ...
 ORDER  BY  ...
```

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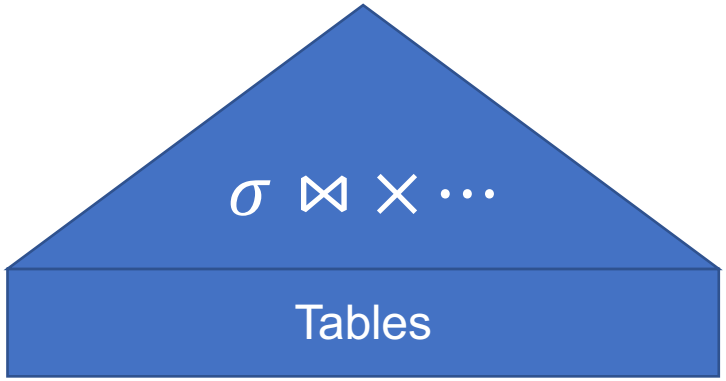

SQL and RA Vocab Summary

```
SELECT  ...
  FROM  ...
 WHERE  ...
 GROUP  BY  ...
HAVING  ...
 ORDER  BY  ...
```

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Selection
Join
Cartesian Product

$\sigma \bowtie \times \cdots$

Tables

SQL and RA Vocab Summary

```
SELECT ...
  FROM ...
 WHERE ...
 GROUP BY ...
HAVING ...
 ORDER BY ...
```

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Aggregation

$\sigma \bowtie \times \cdots$

Tables

SQL and RA Vocab Summary

```
SELECT  ...
  FROM  ...
 WHERE  ...
 GROUP  BY  ...
HAVING  ...
 ORDER  BY  ...
```

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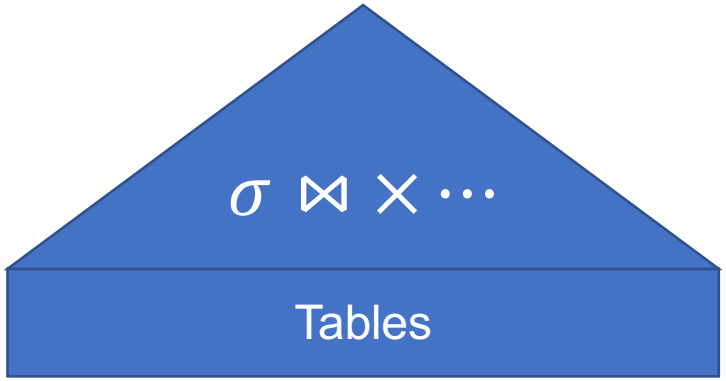

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```
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  FROM  ...
 WHERE  ...
 GROUP  BY  ...
HAVING  ...
 ORDER  BY  ...
```
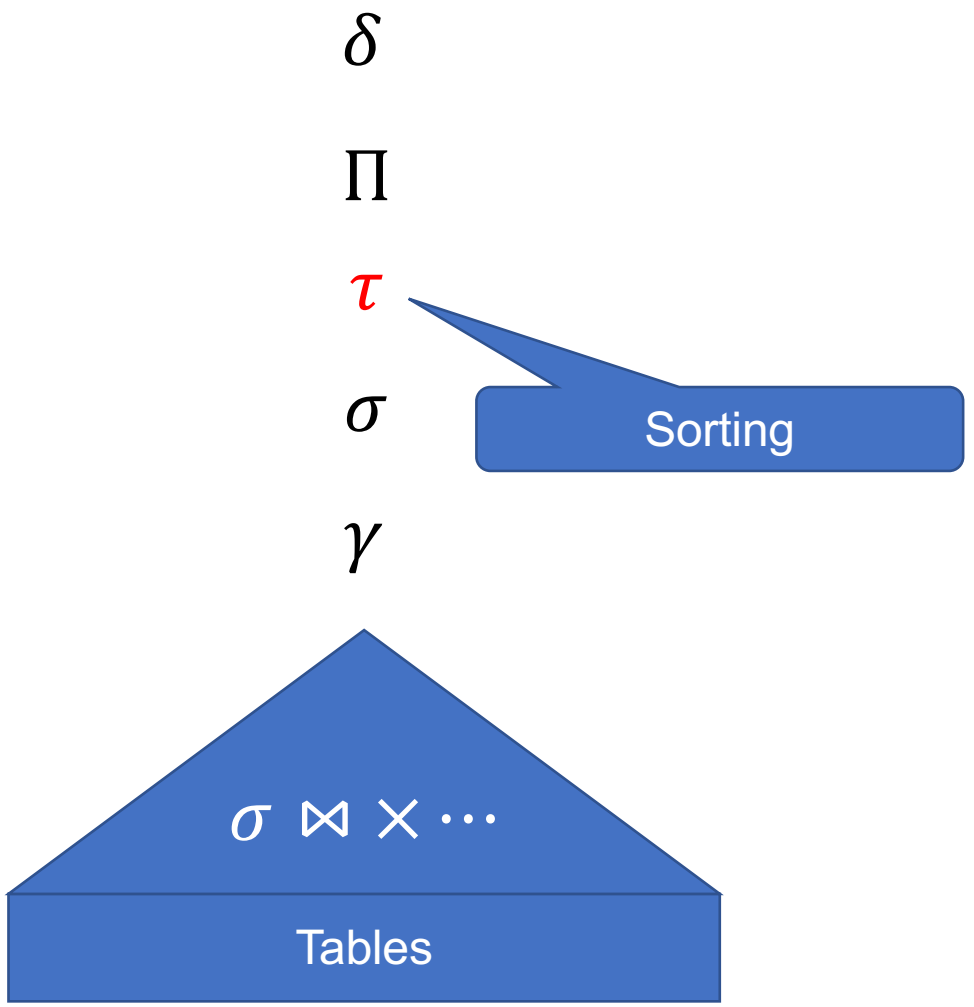
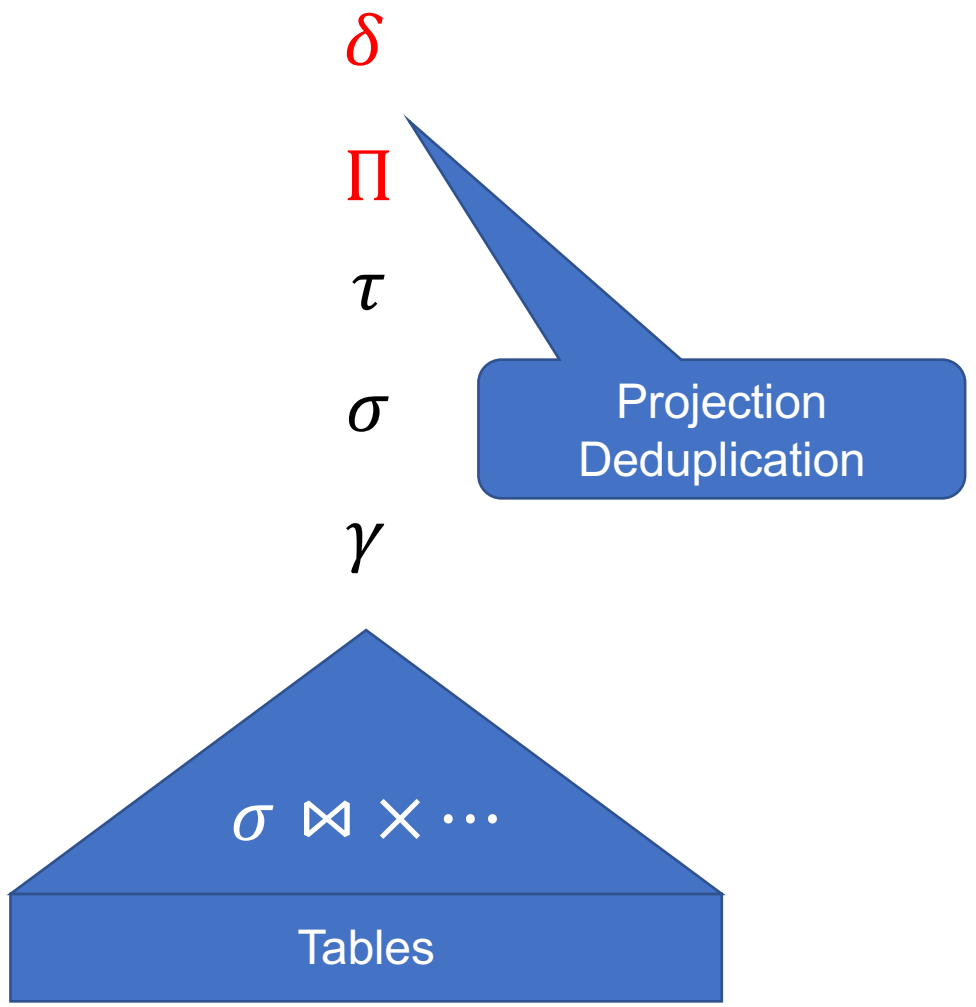



SQL and RA Vocab Summary

```
SELECT ...
  FROM ...
 WHERE ...
 GROUP BY ...
HAVING ...
 ORDER BY ...
```



SQL and RA Vocab Summary

FWGHOS

```
SELECT ...
  FROM ...
 WHERE ...
 GROUP BY ...
HAVING ...
 ORDER BY ...
```

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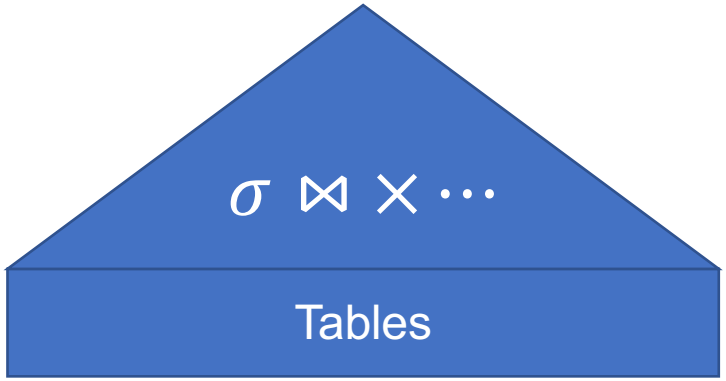

Recap: Grouping

```
SELECT Product, SUM(quantity)
FROM Purchases
GROUP BY Product
HAVING SUM(quantity) > 20
```

Product	Price	Quantity	Month
Bagel	3	20	Jan
Bagel	1.50	20	Feb
Banana	0.5	50	Feb
Banana	5	10	March
Apple	4	10	March

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Bagel	1.50	20	Feb
Banana	0.5	50	Feb
Banana	5	10	March
Apple	4	10	March

Product	SUM(quantity)
Bagel	40
Banana	60

Recap: Semantics

First evaluate the FROM clause

Next evaluate the WHERE clause

Group the attributes in the GROUPBY

Eliminate groups based on HAVING

Sort the results based on ORDER BY

Last evaluate the SELECT clause

FWGHOS

Recap - General form of Group By

```
   SELECT S
     FROM R1, …, Rn
    WHERE C1
GROUP BY a1, …, ak
   HAVING C2
```

S = any attributes a_1, …, a_k and/or any aggregates, but no other attributes

C1 = any condition on the attributes in R_1, …, R_n

C2 = any condition on the aggregate expressions and attributes a_1, …, a_k

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