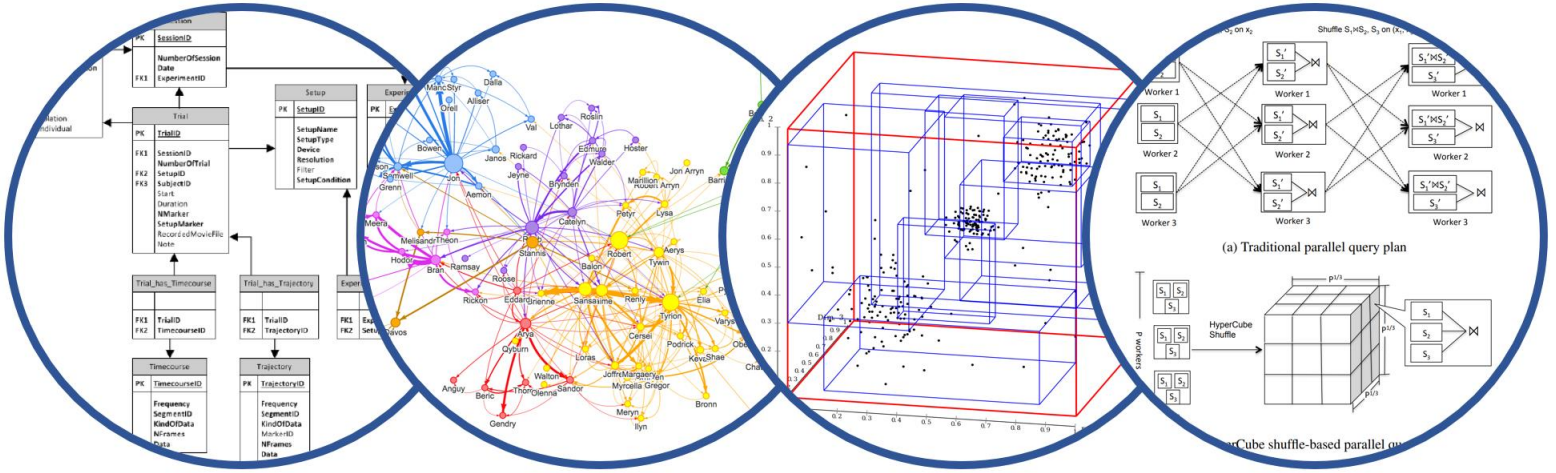

Introduction to Data Management

Joins and Aggregates

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Announcements

- Homework 2 out now!
  - Due Monday 10/16 at 11pm
  - First step is creating tables and importing database
    - Be sure to import in csv mode (the file format)
    - Turn on foreign key constraint checks:

      PRAGMA foreign_keys=ON;

Announcements

- Make sure to format SQL queries in readable way
- Style suggestions in message board post: https://edstem.org/us/courses/17047/discussion/983642
- Usually capitalization of SELECT, FROM, WHERE and indentation is most helpful

Example:

```
select m.id, m.name from movie m
where m.year > 1940 and m.year < 1950 and
m.rating > 4.5
```

```
SELECT m.id, m.name
FROM Movie m
WHERE  m.year > 1940 AND
       m.year < 1950 AND
       m.rating > 4.5
```

Recap: Grouping

GROUP BY:

Group rows based on matching attribute values

HAVING:

Eliminate groups based on aggregate information

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

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

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

Recap - General form of Group By

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

S = any attributes $a_1, \ldots, a_k$ and/or any aggregates, but no other attributes

C1 = any condition on the attributes in $R_1, \ldots, R_n$

C2 = any condition on the aggregate expressions and attributes $a_1, \ldots, a_k$

Recap - General form of Group By

To say SELECT a_1 …

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

S = any attributes $a_1, \ldots, a_k$ and/or any aggregates, but no other attributes

C1 = any condition on the attributes in $R_1, \ldots, R_n$

C2 = any condition on the aggregate expressions and attributes $a_1, \ldots, a_k$

Recap - General form of Group By

To say SELECT a_1 …

…or HAVING a_1 = <something>

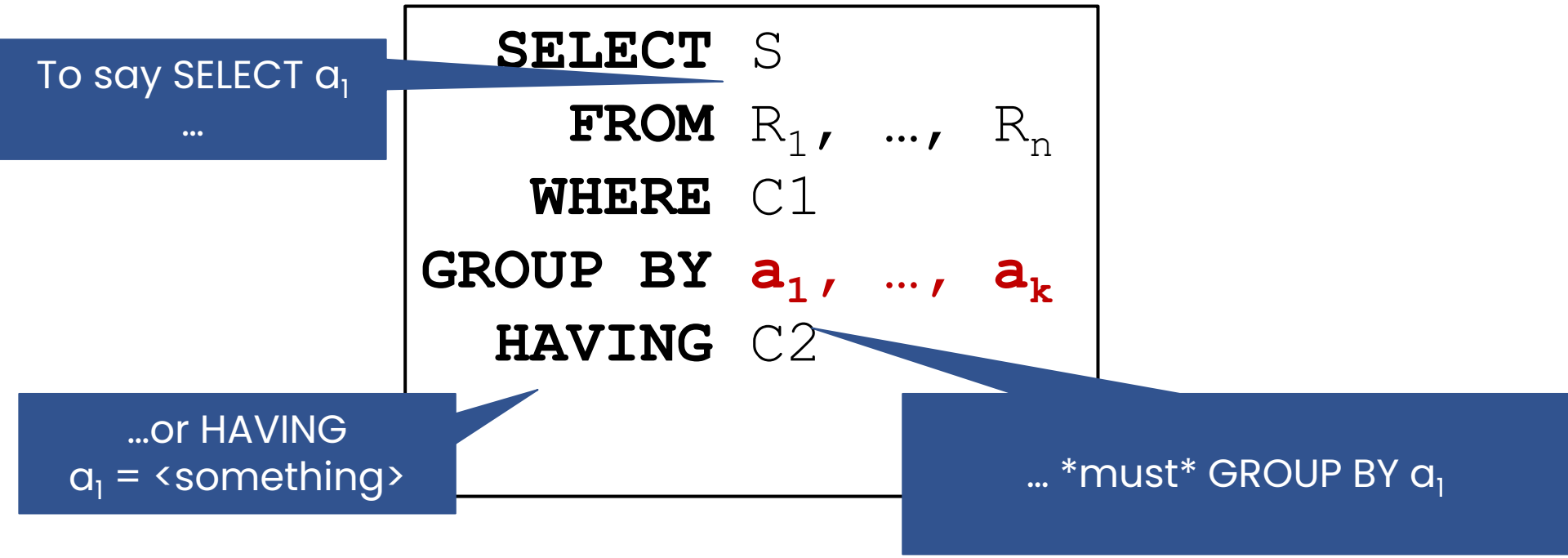
```
SELECT  S
FROM    R1, …, Rn
WHERE   C1
GROUP BY a1, …, ak
HAVING  C2
```

S = any attributes $a_1, \ldots, a_k$ and/or any aggregates, but no other attributes

C1 = any condition on the attributes in $R_1, \ldots, R_n$

C2 = any condition on the aggregate expressions and attributes $a_1, \ldots, a_k$

Recap - General form of Group By



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

Outline

- Combining joins and aggregates
- The witnessing problem
  - (also known as ‘argmax’)

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

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

UserID	Car	Year
123	Charger	2009
567	Civic	2016
567	Pinto	2000
789	Camry	2018

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

Aggregate - COUNT and likely a GROUP

Attributes from two tables = JOIN

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

UserID	Car	Year
123	Charger	2009
567	Civic	2016
567	Pinto	2000
789	Camry	2018

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

Step 1: think about the join

```
SELECT ...
  FROM Payroll p, Regist r
 WHERE p.UserID = r.UserID
```

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

UserID	Car	Year
123	Charger	2009
567	Civic	2016
567	Pinto	2000
789	Camry	2018

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

Step 1: think about the join


```
SELECT ...
  FROM Payroll p, Regist r
 WHERE p.UserID = r.UserID
```

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

UserID	Car	Year
123	Charger	2009
567	Civic	2016
567	Pinto	2000
789	Camry	2018

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

Step 1: think about the join

```
SELECT ...
  FROM Payroll p, Regist r
 WHERE p.UserID = r.UserID
```

p.UserID	p.Name	p.Job	p.Salary	r.UserId	r.Car	r.Year
123	Jack	TA	50000	123	Charger	2009
567	Magda	Prof	90000	567	Civic	2016
567	Magda	Prof	90000	567	Pinto	2000
789	Dan	Prof	100000	789	Camry	2018

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

Step 1: think about the join...and where

```
SELECT ...
  FROM Payroll p, Regist r
 WHERE p.UserID = r.UserID AND
       r.Year < 2017
```

p.UserID	p.Name	p.Job	p.Salary	r.UserId	r.Car	r.Year
123	Jack	TA	50000	123	Charger	2009
567	Magda	Prof	90000	567	Civic	2016
567	Magda	Prof	90000	567	Pinto	2000

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

Step 1: think about the join...and where

Step 2: do the group-by on the join

```
SELECT p.Name, COUNT(*)
  FROM Payroll p, Regist r
 WHERE p.UserID = r.UserID AND
       r.Year < 2017
GROUP BY p.Name
```

p.UserID	p.Name	p.Job	p.Salary	r.UserId	r.Car	r.Year
123	Jack	TA	50000	123	Charger	2009
567	Magda	Prof	90000	567	Civic	2016
567	Magda	Prof	90000	567	Pinto	2000

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

Step 1: think about the join...and where

Step 2: do the group-by on the join

```
   SELECT p.Name, COUNT(*) AS count
     FROM Payroll p, Regist r
    WHERE p.UserID = r.UserID AND
          r.Year < 2017
GROUP BY p.Name
```

p.Name	count
Jack	1
Magda	2

Aggregates + Joins

Goal: how many cars made before 2017 does each person drive?

Step 1: think about the join...and where

Step 2: do the group-by on the join

```
   SELECT p.Name, COUNT(*) AS count
     FROM Payroll p, Regist r
    WHERE p.UserID = r.UserID AND
          r.Year < 2017
 GROUP BY p.UserID, p.Name
```

Probably want to group by UserID too, in case multiple people have the same name

p.Name	count
Jack	1
Magda	2

Including Empty Groups

Notice that empty groups were not included

- some people didn't have a car
- some people only had a new car

```
SELECT p.Name, COUNT(*) AS count
  FROM Payroll p, Regist r
 WHERE p.UserID = r.UserID AND
       r.Year < 2017
GROUP BY p.UserID, p.Name
```

p.Name	count
Jack	1
Magda	2

Including Empty Groups

Notice that empty groups were not included

- some people didn't have a car
- some people only had a

COUNT(*) will never be 0 for groups

```
SELECT p.Name, COUNT(*) AS count
  FROM Payroll p, Regist r
 WHERE p.UserID = r.UserID AND
       r.Year < 2017
GROUP BY p.UserID, p.Name
```

p.Name	count
Jack	1
Magda	2

Including Empty Groups

How many cars does each person drive?
(Remove our “older than 2017” constraint.)

Any ideas for which type of join we could use?

```
   SELECT p.Name, COUNT(*) AS count
     FROM Payroll p, Regist r
    WHERE p.UserID = r.UserID
 GROUP BY p.UserID, p.Name
```

Including Empty Groups

```
SELECT p.Name, COUNT(r.UserID) AS count
  FROM Payroll p LEFT OUTER JOIN
       Regist r
    ON p.UserID = r.UserID
GROUP BY p.UserID, p.Name
```

p.UserID	p.Name	p.Job	p.Salary	r.UserId	r.Car	r.Year
123	Jack	TA	50000	123	Charger	2009
456	Allison	TA	60000	NULL	NULL	NULL
567	Magda	Prof	90000	567	Civic	2016
567	Magda	Prof	90000	567	Pinto	2000
789	Dan	Prof	100000	789	Camry	2018

Including Empty Groups

```
SELECT p.Name, COUNT(r.UserID) AS count
  FROM Payroll p LEFT OUTER JOIN
       Regist r
    ON p.UserID = r.UserID
GROUP BY p.UserID, p.Name
```

p.UserID	p.Name	p.Job	p.Salary	r.UserId	r.Car	r.Year
123	Jack	TA	50000	123	Charger	2009
456	Allison	TA	60000	NULL	NULL	NULL
567	Magda	Prof	90000	567	Civic	2016
567	Magda	Prof	90000	567	Pinto	2000
789	Dan	Prof	100000	789	Camry	2018

Including Empty Groups

```
   SELECT p.Name, COUNT(r.UserID) AS count
     FROM Payroll p LEFT OUTER JOIN
          Regist r
       ON p.UserID = r.UserID
GROUP BY p.UserID, p.Name
```

p.Name	count
Jack	1
Allison	0
Magda	2
Dan	1

Including Empty Groups

COUNT(attr) excludes NULL, so can be 0

```
SELECT p.Name, COUNT(r.UserID) AS count
  FROM Payroll p LEFT OUTER JOIN
       Regist r
    ON p.UserID = r.UserID
GROUP BY p.UserID, p.Name
```

p.Name	count
Jack	1
Allison	0
Magda	2
Dan	1

Difference between count(attr) and count(*)

```
SELECT p.Name, COUNT(*) AS count
  FROM Payroll p LEFT OUTER JOIN
       Regist r
    ON p.UserID = r.UserID
GROUP BY p.UserID, p.Name
```

BE CAREFUL!!!
COUNT(*) makes the answer wrong

p.Name	count
Jack	1
Allison	**1**
Magda	2
Dan	1

New Pattern

Return the person with the highest salary for each job type

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

New Pattern

Return the person with the highest salary for each job type

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

New Pattern

Return the person with the highest salary for each job type

Single field equality with aggregate

Aggregate value

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

The Witnessing Problem

- Also known as argmax/argmin
- Ex: Return the person with the highest salary for each job type

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

The Witnessing Problem

- Also known as argmax/argmin
- Ex: Return the person with the highest salary for each job type

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

Easy right?

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

The Witnessing Problem

- Also known as argmax/argmin
- Ex: Return the person with the highest salary for each job type

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

Easy right?

WRONG!

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

The Witnessing Problem

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

Name	MAX(Salary)
???	60000
???	100000

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

The Witnessing Problem

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

Name	MAX(Salary)
???	60000
???	100000

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

The Witnessing Problem

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

"Failed to execute query. Error: Column 'Payroll.name' is invalid in the select list because it is not contained in either an aggregate function or the GROUP BY clause."

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

The Witnessing Problem

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

“Failed to execute query. Error: Column 'Payroll.name' is invalid in the select list because it is not contained in either an aggregate function or the GROUP BY clause.”

WARNING: SQLite will allow this, and it shouldn’t!!!

```
FROM Payroll
GROUP BY Job
```

The Witnessing Problem

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

SELECT, HAVING, ORDER BY
Must use aggregate functions or attributes in GROUP BY

???	MAX(Salary)
	60000
???	100000

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

The Witnessing Problem

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

Return the person with the highest salary for each job type

How do we witness the maxima for a group?

Discuss!

Conceptual ideas are great

The Witnessing Problem

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

Return the person with the highest salary for each job type

Main idea: we need to join the respective maxima to each row

The Witnessing Problem

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

How do we get the maximum for each job type?

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

Job	MAX(Salary)
TA	60000
Prof	100000

The Witnessing Problem

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

Return the person with the highest salary for each job type

Main idea: we need to join the respective maxima to each row

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

Job	maxima
TA	60000
Prof	100000

The Witnessing Problem

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

Return the person with the highest salary for each job type

Main idea: we need to join the respective maxima to each row

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

The Witnessing Problem

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

Return the person with the highest salary for each job type

```
SELECT P1.Name, MAX(P2.Salary)
  FROM Payroll AS P1, Payroll AS P2
 WHERE P1.Job = P2.Job
 GROUP BY P2.Job, P1.Salary, P1.Name
HAVING P1.Salary = MAX(P2.Salary)
```

The Witnessing Problem

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

Return the person with the highest salary for each job type

the maxima

```
SELECT P1.Name, MAX(P2.Salary)
  FROM Payroll AS P1, Payroll AS P2
 WHERE P1.Job = P2.Job
 GROUP BY P2.Job, P1.Salary, P1.Name
HAVING P1.Salary = MAX(P2.Salary)
```

The Witnessing Problem

```
SELECT P1.Name, MAX(P2.Salary)
  FROM Payroll AS P1, Payroll AS P2
 WHERE P1.Job = P2.Job
 GROUP BY P2.Job, P1.Salary, P1.Name
HAVING P1.Salary = MAX(P2.Salary)
```

Join on “original” grouping attributes

P1 P2

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

The Witnessing Problem

```
SELECT P1.Name, MAX(P2.Salary)
  FROM Payroll AS P1, Payroll AS P2
 WHERE P1.Job = P2.Job
 GROUP BY P2.Job, P1.Salary, P1.Name
HAVING P1.Salary = MAX(P2.Salary)
```

Group on additional attributes that you are argmax-ing for

P1 P2

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

The Witnessing Problem

```
SELECT P1.Name, MAX(P2.Salary)
  FROM Payroll AS P1, Payroll AS P2
 WHERE P1.Job = P2.Job
 GROUP BY P2.Job, P1.Salary, P1.Name
HAVING P1.Salary = MAX(P2.Salary)
```

Group on additional attributes that you are argmax-ing for

P1 P2

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

The Witnessing Problem

```
SELECT P1.Name, MAX(P2.Salary)
  FROM Payroll AS P1, Payroll AS P2
 WHERE P1.Job = P2.Job
 GROUP BY P2.Job, P1.Salary, P1.Name
HAVING P1.Salary = MAX(P2.Salary)
```

Group on additional attributes that you are argmax-ing for

P1 P2

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

The Witnessing Problem

```
SELECT P1.Name, MAX(P2.Salary)
  FROM Payroll AS P1, Payroll AS P2
 WHERE P1.Job = P2.Job
 GROUP BY P2.Job, P1.Salary, P1.Name
HAVING P1.Salary = MAX(P2.Salary)
```

P1				P2			
UserID	**Name**	**Job**	**Salary**	**UserID**	**Name**	**Job**	**Salary**
123	Jack	TA	50000	123	Jack	TA	50000
123	Jack	TA	50000	345	Allison	TA	60000
345	Allison	TA	60000	345	Allison	TA	60000
345	Allison	TA	60000	123	Jack	TA	50000
567	Magda	Prof	90000	567	Magda	Prof	90000
567	Magda	Prof	90000	789	Dan	Prof	100000
789	Dan	Prof	100000	789	Dan	Prof	100000
789	Dan	Prof	100000	567	Magda	Prof	90000

The Witnessing Problem

```
SELECT P1.Name, MAX(P2.Salary)
  FROM Payroll AS P1, Payroll AS P2
 WHERE P1.Job = P2.Job
 GROUP BY P2.Job, P1.Salary, P1.Name
HAVING P1.Salary = MAX(P2.Salary)
```

Name	MAX(Salary)
Allison	60000
Dan	100000

Takeaways

- FWGHOS
- Combining techniques (aggregates and joins) allows you to answer complex questions (e.g. witnessing queries)