CSE 344

JUNE 25TH

GROUPING/AGGREGATION

CH. 6.3-6.4

ADMINISTRIVIA

- **WQ1 due tonight**

- **HW1 due Wednesday**
  - can leave out sqlite-specific (.e.g., .mode commands)
    - grader uses JDBC (covered later) to check results
    - alternatively: pull a new copy of Grader from upstream
  - run the script to tag and push your assignment
    - check on gitlab after submitting
  - run grader on attu to make sure it passes

REVIEW

- **Relational data model**
  - database is a collection of tables
  - table has a set of named & typed columns
  - table contains a list of (unordered) rows
  - query results can be ordered and/or include duplicates
- **Joins**
  - put related tables back together to answer questions
  - SELECT ... FROM A, B ...
  - SELECT ... FROM A JOIN B ...
  - SELECT ... FROM A JOIN B ON ...
  - with no join condition, result is the Cartesian product
  - outer join adds match with NULLs when no other matches

(INNER) JOINS

```
SELECT  x1.a1, x2.a2, … xm.am
FROM    R1 as x1, R2 as x2, … Rm as xm
WHERE   Cond
```

```
for x1 in R1:
  for x2 in R2:
    ...
      for xm in Rm:
        if Cond(x1, x2…):
          output(x1.a1, x2.a2, … xm.am)
```

This is called nested loop semantics since we are interpreting what a join means using a nested loop

ANOTHER EXAMPLE

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

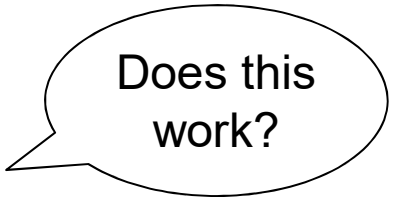
Retrieve all USA companies that manufacture products in both ‘gadget’ and ‘photography’ categories

ANOTHER EXAMPLE

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

Retrieve all USA companies that manufacture products in both ‘gadget’ and ‘photography’ categories

```
SELECT DISTINCT z.cname
FROM Product x, Company z
WHERE z.country = ’USA’
  AND x.manufacturer = z.cname
  AND x.category = 'gadget’
  AND x.category = 'photography;
```



ANOTHER EXAMPLE

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

Retrieve all USA companies that manufacture products in both ‘gadget’ and ‘photography’ categories

```
SELECT DISTINCT z.cname
FROM Product x, Company z
WHERE z.country = ’USA’
  AND x.manufacturer = z.cname
  AND (x.category = 'gadget’
       OR x.category = 'photography);
```

What about this?

ANOTHER EXAMPLE

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

Retrieve all USA companies that manufacture products in both ‘gadget’ and ‘photography’ categories

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = ’USA’
  AND x.manufacturer = z.cname
  AND y.manufacturer = z.cname
  AND x.category = 'gadget’
  AND y.category = 'photography;
```

Need to include Product twice!

SELF-JOINS AND TUPLE VARIABLES

Find USA companies that manufacture both products in the 'gadgets' and 'photo' category

Joining Product with Company is insufficient: need to join Product, with Product, and with Company

When a relation occurs twice in the FROM clause we call it a self-join; in that case we must use tuple variables (why?)

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

x

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

x

y

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

x

y

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

z

cname	country
GizmoWorks	USA
Hitachi	Japan

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

x

y

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

z

cname	country
GizmoWorks	USA
Hitachi	Japan

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

x

y

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

z

cname	country
GizmoWorks	USA
Hitachi	Japan

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

x

y

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

z

cname	country
GizmoWorks	USA
Hitachi	Japan

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

x

y

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

z

cname	country
GizmoWorks	USA
Hitachi	Japan

SELF-JOINS

```
SELECT DISTINCT z.cname
FROM   Product x, Product y, Company z
WHERE  z.country = 'USA'
       AND x.category = 'gadget'
       AND y.category = 'photo'
       AND x.manufacturer = z.cname
       AND y.manufacturer = z.cname;
```

Product

x

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

y

Company

z

cname	country
GizmoWorks	USA
Hitachi	Japan

x.pname	x.category	x.manufacturer	y.pname	y.category	y.manufacturer	z.cname	z.country
Gizmo	gadget	GizmoWorks	MultiTouch	Photo	GizmoWorks	GizmoWorks	USA

OUTER JOINS

```
Product(name, category)
Purchase(prodName, store)

-- prodName is foreign key
```

```
SELECT Product.name, Purchase.store
FROM   Product, Purchase
WHERE  Product.name = Purchase.prodName
```

We want to include products that are never sold,
but some are not listed! Why?

OUTER JOINS

```
Product(name, category)
Purchase(prodName, store)

-- prodName is foreign key
```

```
SELECT Product.name, Purchase.store
FROM   Product LEFT OUTER JOIN Purchase ON
       Product.name = Purchase.prodName
```

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product LEFT OUTER JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product LEFT OUTER JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL

```
SELECT Product.name, Purchase.store
FROM   Product FULL OUTER JOIN Purchase ON
       Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
Phone	Foo

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL
NULL	Foo

OUTER JOINS

```
tableA (LEFT/RIGHT/FULL) OUTER JOIN tableB ON p
```

Left outer join:

- Include tuples from `tableA` even if no match

Right outer join:

- Include tuples from `tableB` even if no match

Full outer join:

- Include tuples from both even if no match

In all cases:

- Patch tuples without matches using `NULL`

QUERY COMPLEXITY

- **As the information we want gets more complex, we need to utilize more elements of the RDBMS**
  - Multi-table queries -> join
  - Data statistics -> grouping

QUERY COMPLEXITY

- **As the information we want gets more complex, we need to utilize more elements of the RDBMS**
  - Multi-table queries -> join
  - Data statistics -> grouping
- **Whatever you can do in SQL, you should**
  - (DBMSs are good at their job!)
  - Query optimization
  - Basic analysis tools
    - Sum, min, average, max, count

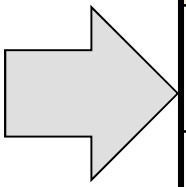
GROUPING AND AGGREGATION

```
Purchase(product, price, quantity)
```

Find total quantities for all sales over $1, by product.

GROUPING AND AGGREGATION

Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
Banana	0.5	50
Banana	2	10
Banana	4	10



Product	TotalSales
Bagel	40
Banana	20

```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
WHERE    price > 1
GROUP BY product
```

OTHER EXAMPLES

Compare these two queries:

```
SELECT   product, count(*)
FROM     Purchase
GROUP BY product
```

```
SELECT  month, count(*)
FROM    Purchase
GROUP BY month
```

```
SELECT  product,
        sum(quantity) AS SumQuantity,
        max(price) AS MaxPrice
FROM    Purchase
GROUP BY product
```

What does it return?

NEED TO BE CAREFUL…

```
SELECT product,
       max(quantity)
FROM   Purchase
GROUP BY product
```

Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
Banana	0.5	50
Banana	2	10
Banana	4	10

NEED TO BE CAREFUL…

```
SELECT product,
       max(quantity)
FROM   Purchase
GROUP BY product
```

```
SELECT   product, quantity
FROM     Purchase
GROUP BY product
-- what does this mean?
```

Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
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Banana	2	10
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NEED TO BE CAREFUL…

```
SELECT product,
       max(quantity)
FROM   Purchase
GROUP BY product
```

```
SELECT   product, quantity
FROM     Purchase
GROUP BY product
-- what does this mean?
```

Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
Banana	0.5	50
Banana	2	10
Banana	4	10

Product	Max(quantity)
Bagel	20
Banana	50

NEED TO BE CAREFUL…

```
SELECT product,
       max(quantity)
FROM   Purchase
GROUP BY product
```

```
SELECT   product, quantity
FROM     Purchase
GROUP BY product
-- what does this mean?
```

Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
Banana	0.5	50
Banana	2	10
Banana	4	10

Product	Max(quantity)
Bagel	20
Banana	50

Product	Quantity
Bagel	20
Banana	??

Everything in SELECT must be either a GROUP-BY attribute, or an aggregate

CAREFUL...

```
SELECT product,
       max(quantity)
FROM   Purchase
GROUP BY product
```

```
SELECT   product, quantity
FROM     Purchase
GROUP BY product
-- what does this mean?
```

Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
Banana	0.5	50
Banana	2	10
Banana	4	10

Product	Max(quantity)
Bagel	20
Banana	50

Product	Quantity
Bagel	20
Banana	??

GROUPING AND AGGREGATION

```
Purchase(product, price, quantity)
```

Find total quantities for all sales over $1, by product.

```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
WHERE    price > 1
GROUP BY product
```

How is this query processed?

GROUPING AND AGGREGATION

```
Purchase(product, price, quantity)
```

Find total quantities for all sales over $1, by product.

```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
WHERE    price > 1
GROUP BY product
```

Do these queries return the same number of rows? Why?

```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
GROUP BY product
```

GROUPING AND AGGREGATION

```
Purchase(product, price, quantity)
```

Find total quantities for all sales over $1, by product.

```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
WHERE    price > 1
GROUP BY product
```

Do these queries return the same number of rows? Why?

```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
GROUP BY product
```

Empty groups are removed, hence first query may return fewer groups

GROUPING AND AGGREGATION

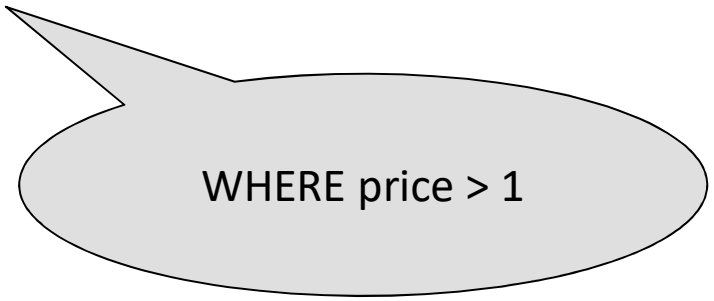
1. Compute the FROM and WHERE clauses.
2. Group by the attributes in the GROUPBY
3. Compute the SELECT clause:
   grouped attributes and aggregates.

FWGS™

1,2: FROM, WHERE

FWGS

Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
Banana	~~0.5~~	~~50~~
Banana	2	10
Banana	4	10

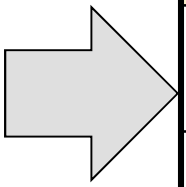



```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
WHERE    price > 1
GROUP BY product
```

3,4. GROUPING, SELECT

FWGS

Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
Banana	~~0.5~~	~~50~~
Banana	2	10
Banana	4	10



Product	TotalSales
Bagel	40
Banana	20

```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
WHERE    price > 1
GROUP BY product
```

Purchase(pid, product, price, quantity, month)

ORDERING RESULTS

```
SELECT product, sum(price*quantity) as rev
FROM    Purchase
GROUP BY product
ORDER BY rev desc
```

FWGOS™

Note: some SQL engines
want you to say `ORDER BY sum(price*quantity) desc`

Purchase(pid, product, price, quantity, month)

HAVING CLAUSE

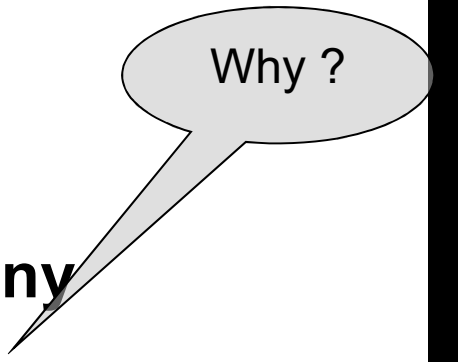
Same query as before, except that we consider only products that had at least 30 sales.

```
SELECT   product, sum(price*quantity)
FROM     Purchase
WHERE    price > 1
GROUP BY product
HAVING   sum(quantity) > 30
```

HAVING clause contains conditions on aggregates.

GENERAL FORM OF GROUPING AND AGGREGATION

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



S = may contain attributes $a_1,\ldots,a_k$ and/or any aggregates but NO OTHER ATTRIBUTES

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

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

SEMANTICS OF SQL WITH GROUP-BY

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

FWGHOS

Evaluation steps:

1. **Evaluate FROM-WHERE using Nested Loop Semantic**
2. **Group by the attributes $a_1,\ldots,a_k$**
3. **Apply condition C2 to each group (may have aggrega**
4. **Compute aggregates in S and return the result**

```
Purchase(pid, product, price, quantity, month)
```

EXERCISE

Compute the total income per month
Show only months with less than 10 items sold
Order by quantity sold and display as “TotalSold”

```
Purchase(pid, product, price, quantity, month)
```

EXERCISE

Compute the total income per month
Show only months with less than 10 items sold
Order by quantity sold and display as “TotalSold”

```
FROM      Purchase
```

Purchase(pid, product, price, quantity, month)

EXERCISE

Compute the total income per month
Show only months with less than 10 items sold
Order by quantity sold and display as “TotalSold”

```
FROM        Purchase
GROUP BY    month
```

Purchase(pid, product, price, quantity, month)

EXERCISE

Compute the total income per month
Show only months with less than 10 items sold
Order by quantity sold and display as “TotalSold”

```
FROM        Purchase
GROUP BY    month
HAVING      sum(quantity) < 10
```

Purchase(pid, product, price, quantity, month)

EXERCISE

Compute the total income per month
Show only months with less than 10 items sold
Order by quantity sold and display as “TotalSold”

```
SELECT   month, sum(price*quantity),
         sum(quantity) as TotalSold
FROM     Purchase
GROUP BY month
HAVING   sum(quantity) < 10
```

Purchase(pid, product, price, quantity, month)

EXERCISE

Compute the total income per month
Show only months with less than 10 items sold
Order by quantity sold and display as “TotalSold”

```
SELECT    month, sum(price*quantity),
          sum(quantity) as TotalSold
FROM      Purchase
GROUP BY  month
HAVING    sum(quantity) < 10
ORDER BY  sum(quantity)
```

WHERE VS HAVING

WHERE condition is applied to individual rows

- The rows may or may not contribute to the aggregate
- No aggregates allowed here
- Occasionally, some groups become empty and are removed

HAVING condition is applied to the entire group

- Entire group is returned, or removed
- May use aggregate functions on the group