Introduction to Database Systems
CSE 414

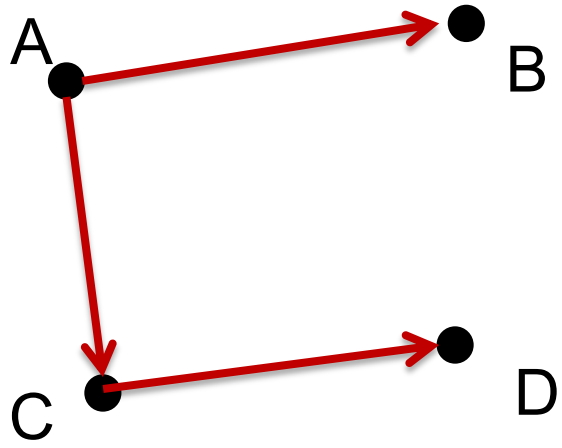
Lecture 5: SQL Aggregates and Grouping

Announcements

- Web quiz 1 due tonight
- HW 2 due Tuesday at midnight

```
Edge(start, end)
```

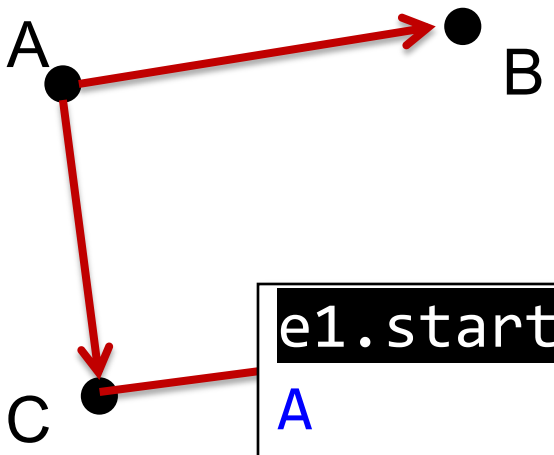
Self Join Example



start	end
A	B
A	C
C	D

Edge(start, end)

Self Join Example



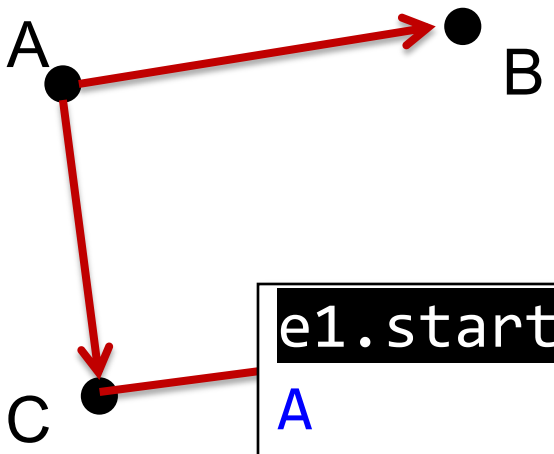

```
SELECT *
FROM   Edge e1, Edge e2
```

start
A
A
C

e1.start	e1.end	e2.start	e2.end
A	B	A	B
A	B	A	C
A	B	C	D
A	C	A	B
A	C	A	C
A	C	C	D
C	D	A	B
C	D	A	C

Edge(start, end)

Self Join Example



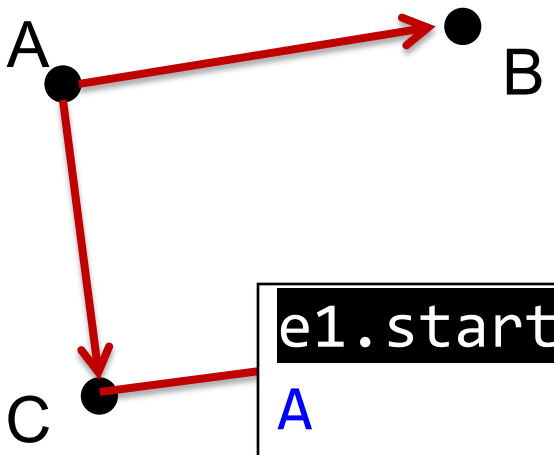

```
SELECT *
FROM   Edge e1, Edge e2
WHERE e1.end = e2.start
```

start
A
A
C

e1.start	e1.end	e2.start	e2.end
A	B	A	B
A	B	A	C
A	B	C	D
A	C	A	B
A	C	A	C
A	C	C	D
C	D	A	B
C	D	A	C

Edge(start, end)

Self Join Example



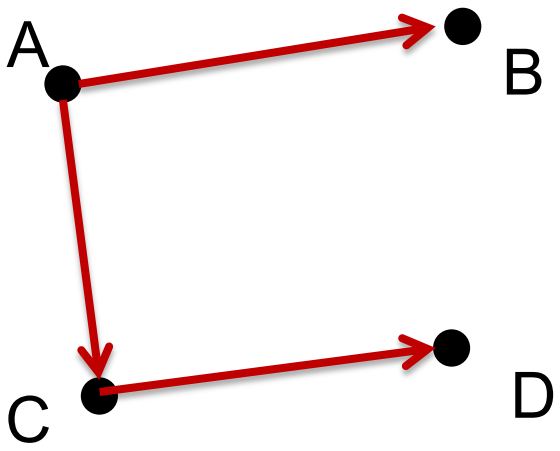

```
SELECT *
FROM   Edge e1, Edge e2
WHERE e1.end = e2.start
```

start
A
A
C

e1.start	e1.end	e2.start	e2.end
A	B	A	B
A	B	A	C
A	B	C	D
A	C	A	B
A	C	A	C
A	C	C	D
C	D	A	B
C	D	A	C

```
Edge(start, end)
```

Self Join Example



start	end
A	B
A	C
C	D

```
SELECT e1.start, e2.end
FROM   Edge e1, Edge e2
WHERE e1.end = e2.start
```

e1.start	e2.end
A	D

Simple Aggregations

Five basic aggregate operations in SQL

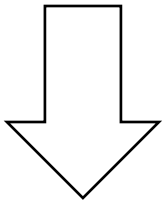
```
select COUNT(*) from Purchase
select SUM(quantity) from Purchase
select AVG(price) from Purchase
select MAX(quantity) from Purchase
select MIN(quantity) from Purchase
```

Except `count`, all aggregations apply to a single attribute

Simple Aggregations

pid	product	price	quantity	month
1	bagel	1.99	20	september
2	bagel	2.5	12	december
3	banana	0.99	9	september
4	banana	1.59	9	february

```
select sum(quantity) from Purchase
```

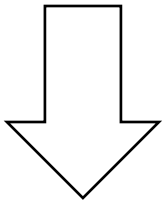


sum(quantity)
50

Simple Aggregations

pid	product	price	quantity	month
1	bagel	1.99	20	september
2	bagel	2.5	12	december
3	banana	0.99	9	september
4	banana	1.59	9	february

```
select avg(price) from Purchase
```

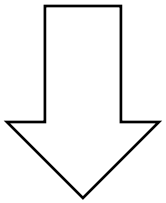


avg(price)
1.7675

Simple Aggregations

pid	product	price	quantity	month
1	bagel	1.99	20	september
2	bagel	2.5	12	december
3	banana	0.99	9	september
4	banana	1.59	9	february

```
select count(*) from Purchase
```

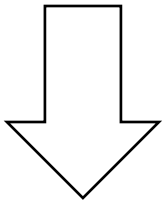


count(*)
4

Simple Aggregations

pid	product	price	quantity	month
1	bagel	1.99	20	september
2	bagel	2.5	12	december
3	banana	0.99	9	september
4	banana	1.59	9	february

```
select count(quantity) from Purchase
```

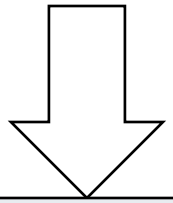


count(quantity)
4

Simple Aggregations

pid	product	price	quantity	month
1	bagel	1.99	20	september
2	bagel	2.5	12	december
3	banana	0.99	9	september
4	banana	1.59	9	february

```
select count(DISTINCT quantity) from Purchase
```

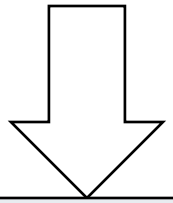


count(DISTINCT quantity)
3

Simple Aggregations

pid	product	price	quantity	month
1	bagel	1.99	20	september
2	bagel	2.5	12	december
3	banana	0.99	9	september
4	banana	1.59	NULL	february

```
select count(quantity) from Purchase
```



count(DISTINCT quantity)
3

Counting Duplicates

`COUNT` applies to duplicates, unless otherwise stated:

```
SELECT count(product)
FROM   Purchase
WHERE  price > 4.99
```

same as `count(*)` if no nulls

We probably want:

```
SELECT count(DISTINCT product)
FROM   Purchase
WHERE  price > 4.99
```

More Examples

What do
they mean ?

```
SELECT  SUM(P.price * P.quantity)
FROM    Purchase AS P
```

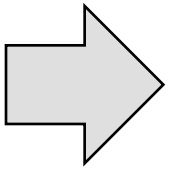
```
SELECT  SUM(P.price * P.quantity)
FROM    Purchase AS P
WHERE   P.product = 'bagel'
```

Grouping and Aggregation

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

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

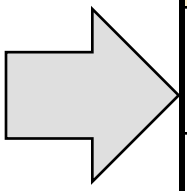
Product	Price	Quantity
Bagel	3	20
Bagel	1.50	20
Banana	0.5	50
Banana	2	10
Banana	4	10



Product	TotalSales
Bagel	40
Banana	70

Grouping and Aggregation

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



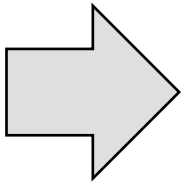
Product	TotalSales
Bagel	40
Banana	70

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


Group by command applies the aggregate commands only to groups that share the given attribute (i.e. product in this case) rather than over the entire table. Returns a table of responses rather than a single number
i.e. creates a table with unique values of given attribute (product)

Grouping and Aggregation

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

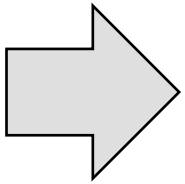


Product
Bagel
Banana

```
SELECT   product
FROM     Purchase
GROUP 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
Bagel
Banana

```
SELECT   product
FROM     Purchase
GROUP BY product
```

Grouping and Aggregation

Product	Price	Quantity
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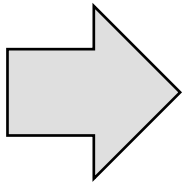
Banana	4	10



Product
Bagel
Banana

Price	Quantity
3	20
1.50	20

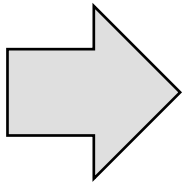
Price	Quantity
0.5	50
2	10
4	10

Intermediate collections

```
SELECT   product, ……
FROM     Purchase
GROUP 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
Bagel
Banana

Price	Quantity
3	20
1.50	20

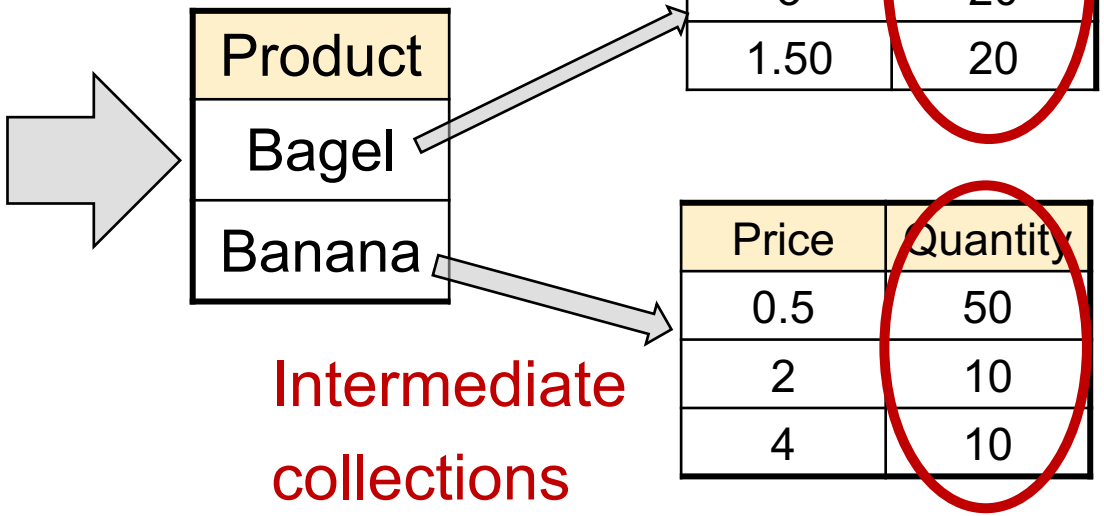
Price	Quantity
0.5	50
2	10
4	10

Intermediate collections

```
SELECT   product, ……
FROM     Purchase
GROUP 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

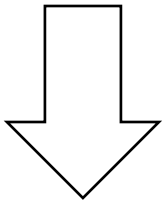



```
SELECT   product, SUM(quantity)
FROM     Purchase
GROUP BY product
```

Remember: Simple Aggregate

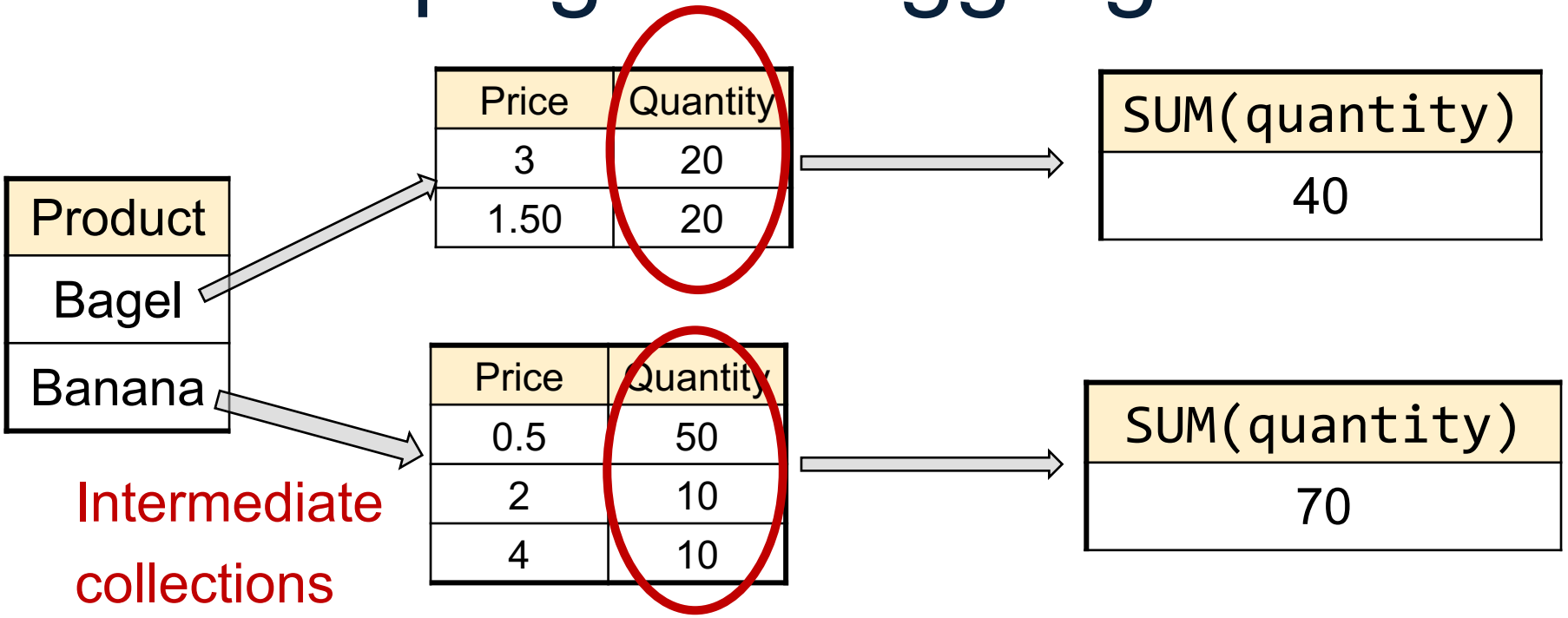
pid	product	price	quantity	month
1	bagel	1.99	20	september
2	bagel	2.5	12	december
3	banana	0.99	9	september
4	banana	1.59	9	february

```
select sum(quantity) from Purchase
```



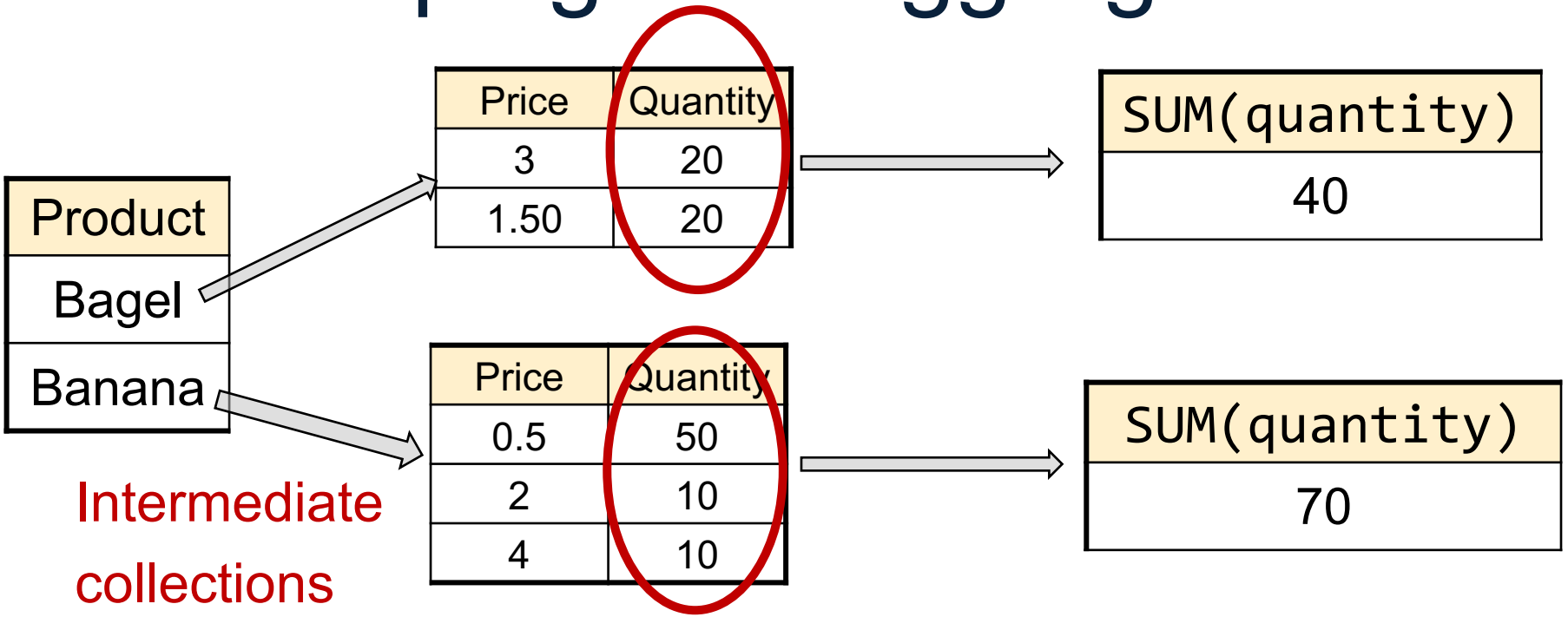
sum(quantity)
50

Grouping and Aggregation




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

Grouping and Aggregation

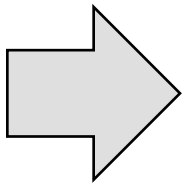



```
SELECT   product, SUM(quantity)
FROM     Purchase
GROUP BY product
```

Product	SUM(quantity)
Bagel	40
Banana	70

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	70

```
SELECT   product, Sum(quantity) AS TotalSales
FROM     Purchase
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
Banana	0.5	50
Banana	2	10
Banana	4	10

Since you are not grouping by quantity, each tuple for each product will have a quantity attribute. Thus, if you have multiple tuples in each group it may be ambiguous what value of quantity ought to be taken on

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
```

NOT FIRST NORMAL FORM!

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

Need to be Careful…

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

```
SELECT   product, quantity
FROM     Purchase
GROUP BY product
```

NOT FIRST NORMAL FORM!

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?

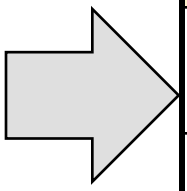
Grouping and Aggregation

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
```

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
```

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
```

Rows where price > 1 are removed, so first query may return fewer groups

Groups with no rows will not be present in final table

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

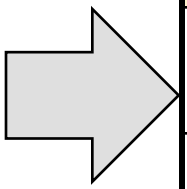
WHERE price > 1

```
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)

Ordering and SQLite LIMIT

Useful keyword:

LIMIT N

constrains output to N tuples

```
SELECT product, sum(price*quantity) as rev
FROM    Purchase
GROUP BY product
ORDER BY rev desc
LIMIT 5
```

Often use for “top 5” type queries

Filtering Groups

FWGOS

If the WHERE filter comes before GROUP BY,
Need some way to filter after forming groups

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
```

otherwise the result would contain a nested table (i.e. not first normal form)

Why ?

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
```

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Evaluation steps:

1. Evaluate FROM-WHERE using Nested Loop Semantics
2. Group by the attributes $a_1,\ldots,a_k$
3. Apply condition C2 to each group (may have aggregates)
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”

```
SELECT P.month, sum(P.quantity * P.price) as TotalIncome
FROM Purchase P
GROUP BY P.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”

```
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

```
Product(pid,pname,manufacturer)
Purchase(id,product_id,price,month)
```

Aggregate + Join

For each manufacturer, compute how many products with price > $100 they sold

```
Product(pid,pname,manufacturer)
Purchase(id,product_id,price,month)
```

Aggregate + Join

For each manufacturer, compute how many products with price > $100 they sold

Problem: manufacturer is in Product, price is in Purchase...

```
Product(pid,pname,manufacturer)
Purchase(id,product_id,price,month)
```

Aggregate + Join

For each manufacturer, compute how many products with price > $100 they sold

Problem: manufacturer is in Product, price is in Purchase...

```
-- step 1: think about their join
SELECT ...
FROM Product x, Purchase y
WHERE x.pid = y.product_id
  and y.price > 100
```

manu facturer	...	price	...
Hitachi		150	
Canon		300	
Hitachi		180	

```
Product(pid,pname,manufacturer)
Purchase(id,product_id,price,month)
```

Aggregate + Join

For each manufacturer, compute how many products with price > $100 they sold

Problem: manufacturer is in Product, price is in Purchase...

```
-- step 1: think about their join
SELECT ...
FROM Product x, Purchase y
WHERE x.pid = y.product_id
  and y.price > 100
```

manu facturer	...	price	...
Hitachi		150	
Canon		300	
Hitachi		180	

```
-- step 2: do the group-by on the join
SELECT x.manufacturer, count(*)
FROM Product x, Purchase y
WHERE x.pid = y.product_id
  and y.price > 100
GROUP BY  x.manufacturer
```

manu facturer	count(*)
Hitachi	2
Canon	1
...	60

```
Product(pid,pname,manufacturer)
Purchase(id,product_id,price,month)
```

Aggregate + Join

Variant:

For each manufacturer, compute how many products with price > $100 they sold in each month

```
SELECT x.manufacturer, y.month, count(*)
FROM Product x, Purchase y
WHERE x.pid = y.product_id
  and y.price > 100
GROUP BY  x.manufacturer, y.month
```

manu facturer	month	count(*)
Hitachi	Jan	2
Hitachi	Feb	1
Canon	Jan	3
...		

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Including Empty Groups

- In the result of a group by query, there is one row per group in the result

Count(*) is never 0

```
SELECT x.manufacturer, count(*)
FROM Product x, Purchase y
WHERE x.pname = y.product
GROUP BY x.manufacturer
```

Including Empty Groups

```
SELECT x.manufacturer, count(*)
FROM Product x, Purchase y
WHERE x.pname = y.product
GROUP BY x.manufacturer
```

Product

pname	manufacturer	…
Gizmo	GizmoWorks	
Camera	Canon	
OneClick	Hitachi	

Purchase

product	price	...
Camera	150	
Camera	300	
OneClick	180	

Join(Product, Purchase)

pname	manu facturer	…	manu facturer	price	…
Camera	Canon		Canon	150	
Camera	Canon		Canon	300	
OneClick	Hitachi		Hitachi	180	

Final results

manufacturer	Count(*)
Canon	2
Hitachi	1

No GizmoWorks!

Including Empty Groups

```
SELECT x.manufacturer, count(y.pid)
FROM Product x LEFT OUTER JOIN Purchase y
ON x.pname = y.product
GROUP BY x.manufacturer
```

Count(pid) is 0 when all pid's in the group are NULL

Including Empty Groups

```
SELECT x.manufacturer, count(y.pid)
FROM Product x LEFT OUTER JOIN Purchase y
ON x.pname = y.product
GROUP BY x.manufacturer
```

Product

pname	manufacturer	…
Gizmo	GizmoWorks	
Camera	Canon	
OneClick	Hitachi	

Purchase

product	price	...
Camera	150	
Camera	300	
OneClick	180	

Left Outer Join(Product, Purchase)

pname	manufacturer	…	product	price	…
Camera	Canon		Camera	150	
Camera	Canon		Camera	300	
OneClick	Hitachi		OneClick	180	
Gizmo	GizmoWorks	…	NULL	NULL	NULL

Why 0 for GizmoWorks?

Final results

manufacturer	Count(y.pid)
Canon	2
Hitachi	1
GizmoWorks	0

GizmoWorks is paired with NULLs

NULL attributes are not counted when you run count(attribute)

Including Empty Groups

```
SELECT x.manufacturer, count(*)
FROM Product x LEFT OUTER JOIN Purchase y
ON x.pname = y.product
GROUP BY x.manufacturer
```

count(*) counts NULL values… all tuples

Product

pname	manufacturer	…
Gizmo	GizmoWorks	
Camera	Canon	
OneClick	Hitachi	

Purchase

product	price	...
Camera	150	
Camera	300	
OneClick	180	

Left Outer Join(Product, Purchase)

pname	manufacturer	…	product	price	…
Camera	Canon		Camera	150	
Camera	Canon		Camera	300	
OneClick	Hitachi		OneClick	180	
Gizmo	GizmoWorks	…	NULL	NULL	NULL

Final results

manufacturer	Count(*)
Canon	2
Hitachi	1
GizmoWorks	1

Probably not what we want!