Database Systems
CSE 414

Lectures 4: Joins & Aggregation
(Ch. 6.1-6.4)

Announcements

- WQ1 is posted to gradebook
  - double check scores
- WQ2 is out – due next Sunday
- HW1 is due Tuesday (tomorrow), 11pm
- HW2 is coming out on Wednesday
- Should now have seats for **all registered**

Outline

- Inner joins (6.2, review)
- Outer joins (6.3.8)
- Aggregations (6.4.3 – 6.4.6)

UNIQUE

- PRIMARY KEY adds implicit "NOT NULL" constraint while UNIQUE does not
  - you would have to add this explicitly for UNIQUE:

```
CREATE TABLE Company(
  name VARCHAR(20) NOT NULL, …
  UNIQUE (name));
```

- You almost always want to do this (in real schemas)
  - SQL Server behaves badly with NULL & UNIQUE
  - otherwise, think through NULL for every query
  - you can remove the NOT NULL constraint later

(Inner) Joins

```
SELECT a1, a2, …, an
FROM   R1, R2, …, Rm
WHERE  Cond
```

(Nested loop semantics)

```
for t1 in R1:
  for t2 in R2:
    ...
      for tm in Rm:
        if Cond(t1.a1, t1.a2, …):
          output(t1.a1, t1.a2, …, tm.an)
```

(Inner) joins

Company(<u>cname</u>, country)
Product(<u>pname</u>, price, category, manufacturer)
– manufacturer is foreign key

```
SELECT DISTINCT cname
FROM    Product, Company
WHERE   country = 'USA' AND category = 'gadget' AND
        manufacturer = cname
```

(Inner) joins

```
SELECT DISTINCT cname
FROM     Product, Company
WHERE    country = 'USA' AND category = 'gadget' AND
         manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

(Inner) joins

```
SELECT DISTINCT cname
FROM     Product, Company
WHERE    country = 'USA' AND category = 'gadget' AND
         manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

pname	category	manufacturer	cname	country
Gizmo	gadget	GizmoWorks	GizmoWorks	USA

(Inner) joins

```
SELECT DISTINCT cname
FROM     Product, Company
WHERE    country = 'USA' AND category = 'gadget' AND
         manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Not output since country != 'USA'
(also cname != manufacturer)

(Inner) joins

```
SELECT DISTINCT cname
FROM     Product, Company
WHERE    country = 'USA' AND category = 'gadget' AND
         manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Not output since country != 'USA'

(Inner) joins

```
SELECT DISTINCT cname
FROM     Product, Company
WHERE    country = 'USA' AND category = 'gadget' AND
         manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Not output since category != 'gadget' (and …)

(Inner) joins

```
SELECT DISTINCT cname
FROM     Product, Company
WHERE    country = 'USA' AND category = 'gadget' AND
         manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Not output since category != 'gadget'

(Inner) joins

```
SELECT DISTINCT cname
FROM    Product, Company
WHERE   country = 'USA' AND category = 'gadget' AND
        manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Not output since category != 'gadget'

(Inner) joins

```
SELECT DISTINCT cname
FROM    Product, Company
WHERE   country = 'USA' AND category = 'gadget' AND
        manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

Not output since category != 'gadget' (with any Company)

(Inner) joins

```
SELECT DISTINCT cname
FROM    Product, Company
WHERE   country = 'USA' AND category = 'gadget' AND
        manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

restrict to category = 'gadget'

(Inner) joins

```
SELECT DISTINCT cname
FROM    Product, Company
WHERE   country = 'USA' AND category = 'gadget' AND
        manufacturer = cname
```

Product (where category = 'gadget')

pname	category	manufacturer
Gizmo	gadget	GizmoWorks

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

restrict to country = 'USA'

(Inner) joins

```
SELECT DISTINCT cname
FROM    Product, Company
WHERE   country = 'USA' AND category = 'gadget' AND
        manufacturer = cname
```

Product (where category = 'gadget')

pname	category	manufacturer
Gizmo	gadget	GizmoWorks

Company (where country = 'USA')

cname	country
GizmoWorks	USA

Now only one combination to consider

(Query optimizers do this too.)

(Inner) joins

```
SELECT DISTINCT cname
FROM    Product, Company
WHERE   country = 'USA' AND category = 'gadget' AND
        manufacturer = cname
```

Alternative syntax:

```
SELECT DISTINCT cname
FROM    Product JOIN Company ON
    country = 'USA' AND category = 'gadget' AND
    manufacturer = cname
```

Emphasizes that the predicate is part of the join.

Self-Joins and Tuple Variables

- **Ex**: find companies that manufacture both products in the 'gadgets' category and in the 'photo' category
- Just joining Company with Product is insufficient: need to join Company with Product with Product

```
FROM Company, Product, Product
```

- When a relation occurs twice in the FROM clause we call it a *self-join*; in that case every column name in Product is ambiguous (why?)
  - are you referring to the tuple in the 2nd or 3rd loop?

Name Conflicts

we used cname / pname to avoid this problem

- When a name is ambiguous, qualify it:

```
WHERE Company.name = Product.name AND …
```

- For self-join, we need to distinguish tables:

```
FROM Product x, Product y, Company
```

- These new names are called "tuple variables"
  - can think of as name for the variable of each loop
  - can also write "`Company AS C`" etc.
  - can make SQL query shorter: `C.name` vs `Company.name`

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 = cname
    AND  y.manufacturer = 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 = cname
    AND  y.manufacturer = cname;
```

Product

	pname	category	manufacturer
x	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 = cname
    AND  y.manufacturer = cname;
```

Product

	pname	category	manufacturer
x y	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 = cname
    AND  y.manufacturer = cname;
```

Product

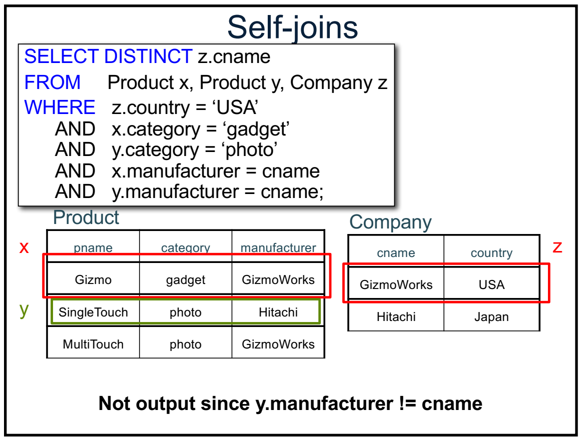
	pname	category	manufacturer
x y	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
	MultiTouch	photo	GizmoWorks

Company

cname	country	
GizmoWorks	USA	z
Hitachi	Japan	

restrict to country = 'USA'

Not output since y.category != 'photo'



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 = cname
    AND   y.manufacturer = cname;
```

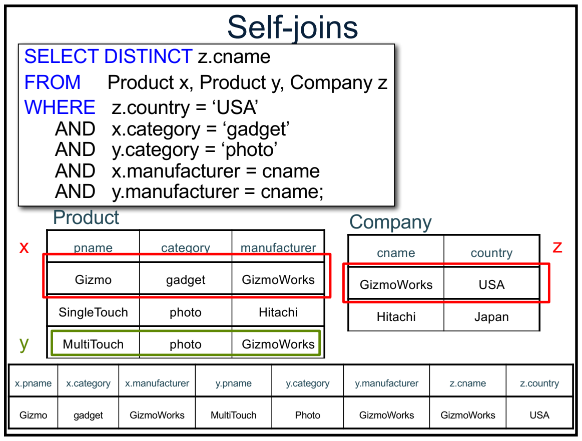
Product

	pname	category	manufacturer
x	Gizmo	gadget	GizmoWorks
y	SingleTouch	photo	Hitachi
	MultiTouch	photo	GizmoWorks

Company

cname	country	
GizmoWorks	USA	z
Hitachi	Japan	

Not output since y.manufacturer != cname



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 = cname
    AND   y.manufacturer = cname;
```

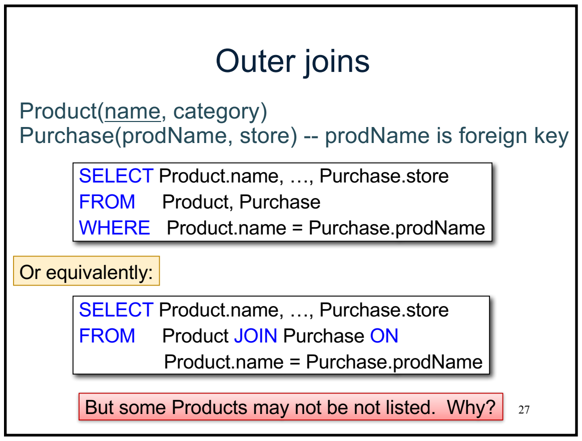
Product

	pname	category	manufacturer
x	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
y	MultiTouch	photo	GizmoWorks

Company

cname	country	
GizmoWorks	USA	z
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

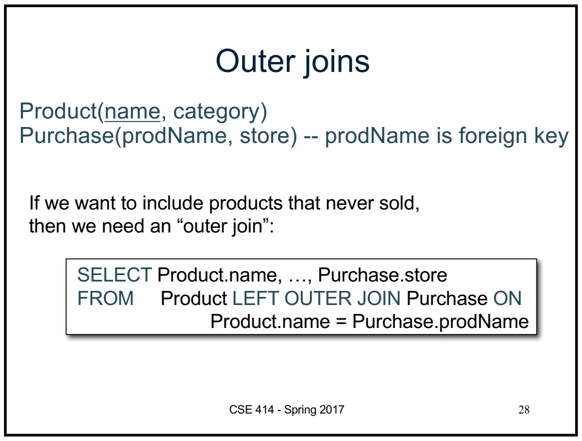
Product(<u>name</u>, category)
Purchase(prodName, store) -- prodName is foreign key

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

Or equivalently:

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

But some Products may not be not listed. Why?

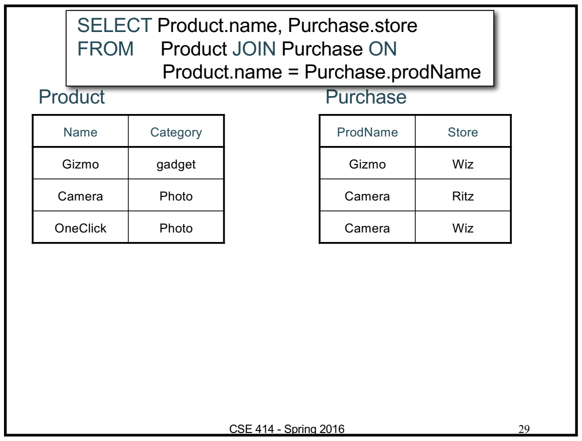


Outer joins

Product(<u>name</u>, category)
Purchase(prodName, store) -- prodName is foreign key

If we want to include products that never sold,
then we need an "outer join":

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



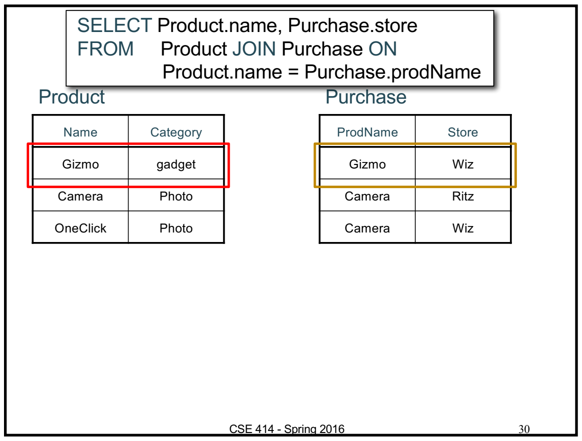
```
SELECT Product.name, Purchase.store
FROM    Product JOIN Purchase ON
          Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz



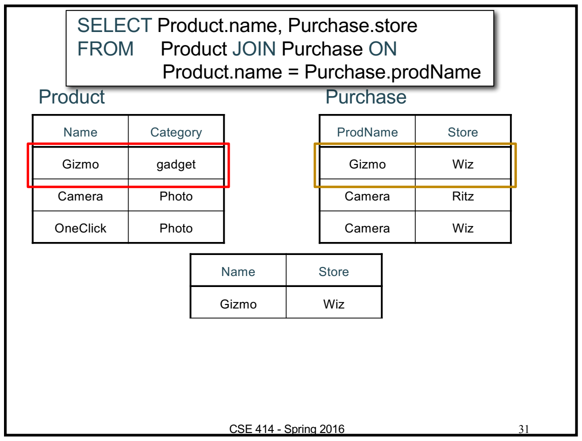
```
SELECT Product.name, Purchase.store
FROM    Product JOIN Purchase ON
          Product.name = Purchase.prodName
```

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

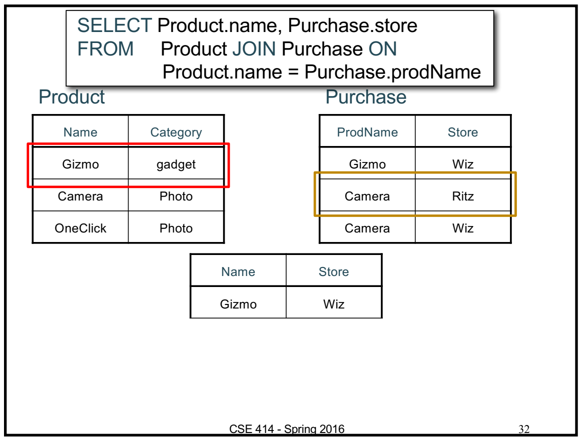
Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Name	Store
Gizmo	Wiz

CSE 414 - Spring 2016 31



```
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

Name	Store
Gizmo	Wiz

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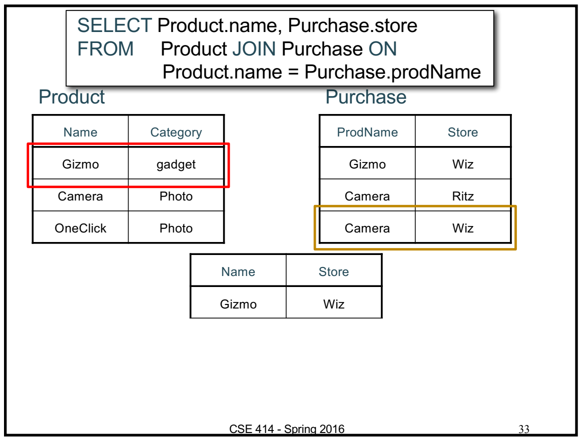

```
SELECT Product.name, Purchase.store
FROM    Product JOIN Purchase ON
        Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Name	Store
Gizmo	Wiz

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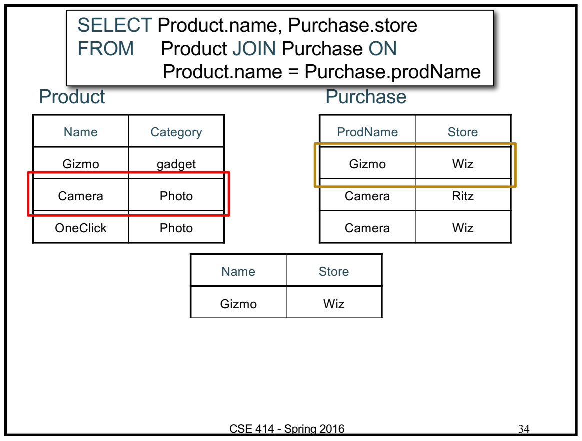

```
SELECT Product.name, Purchase.store
FROM    Product JOIN Purchase ON
        Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Name	Store
Gizmo	Wiz

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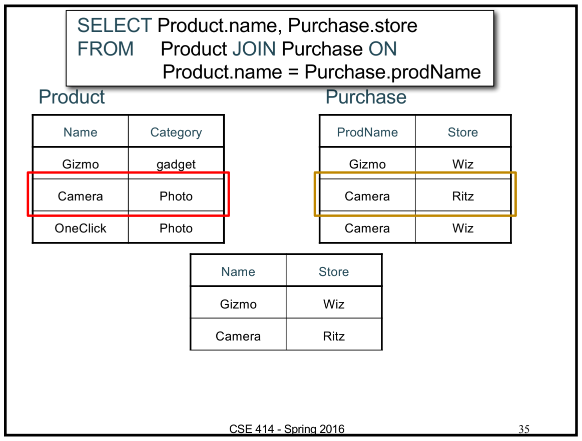


```
SELECT Product.name, Purchase.store
FROM    Product JOIN Purchase ON
        Product.name = Purchase.prodName
```

Product

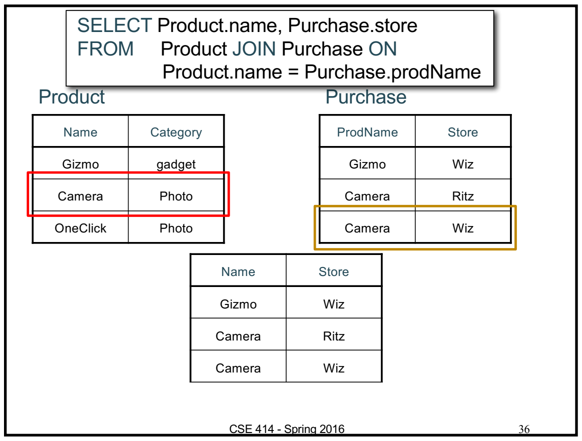
Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Name	Store
Gizmo	Wiz
Camera	Ritz

CSE 414 - Spring 2016 35



```
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

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

CSE 414 - Spring 2016 36

```
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

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

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

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL

```
SELECT Product.name, Purchase.store
FROM   Product RIGHT 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

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
NULL	Foo

```
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

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

Outer Joins

- Left outer join:
  - Include the left tuple even if there's no match
- Right outer join:
  - Include the right tuple even if there's no match
- Full outer join:
  - Include both left and right tuples even if there's no match

- (Also something called a UNION JOIN, though it's rarely used.)
- (Actually, all of these used much more rarely than inner joins.)

Outer Joins Example

See lec04-sql-outer-joins.sql…

Aggregation in SQL

```
>sqlite3 lecture04

sqlite> create table Purchase(
          pid int primary key,
          product text,
          price float,
          quantity int,
          month varchar(15));

sqlite> -- download data.txt
sqlite> .import lec04-data.txt Purchase
```

Other DBMSs have other ways of importing data

Comment about SQLite

- One cannot load NULL values such that they are actually loaded as null values
- So we need to use two steps:
  - Load null values using some type of special value
  - Update the special values to actual null values

```
update Purchase
  set price = null
  where price = ‘null’
```

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 value

Aggregates and NULL Values

Null values are not used in aggregates

```
insert into Purchase
values(12, 'gadget', NULL, NULL, 'april')
```

Let’s try the following

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

select sum(quantity) from Purchase

select sum(quantity)
from Purchase
where quantity is not null;
```

Aggregates and NULL Values

Null values are not used in aggregates

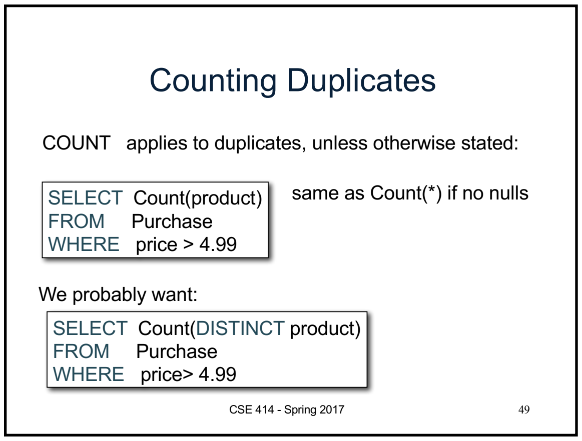
```
insert into Purchase
values(12, 'gadget', NULL, NULL, 'april')
```

Let’s try the following

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

select sum(quantity) from Purchase

select sum(quantity)
from Purchase
where quantity is not null;
```



Counting Duplicates

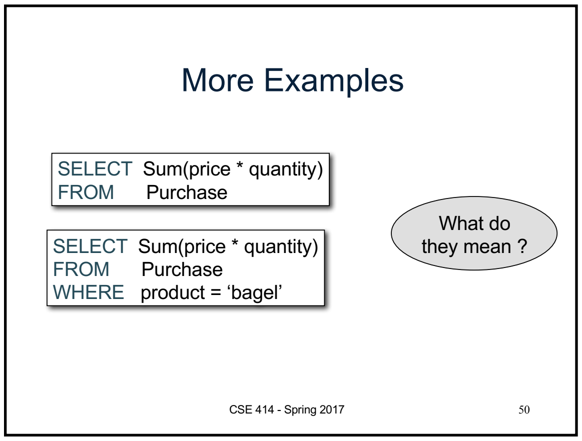
COUNT applies to duplicates, unless otherwise stated:

```
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
```

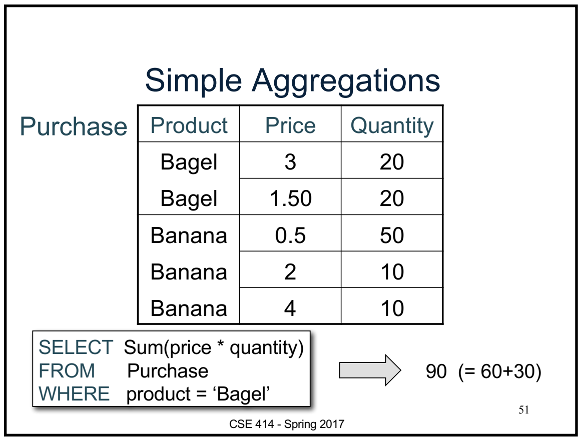


More Examples

```
SELECT  Sum(price * quantity)
FROM    Purchase
```

```
SELECT  Sum(price * quantity)
FROM    Purchase
WHERE   product = 'bagel'
```

What do they mean ?



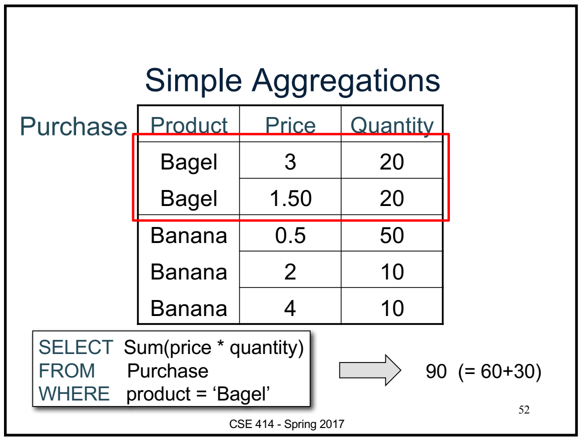
Simple Aggregations

Purchase

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

```
SELECT  Sum(price * quantity)
FROM    Purchase
WHERE   product = 'Bagel'
```

$\Rightarrow$ 90 (= 60+30)



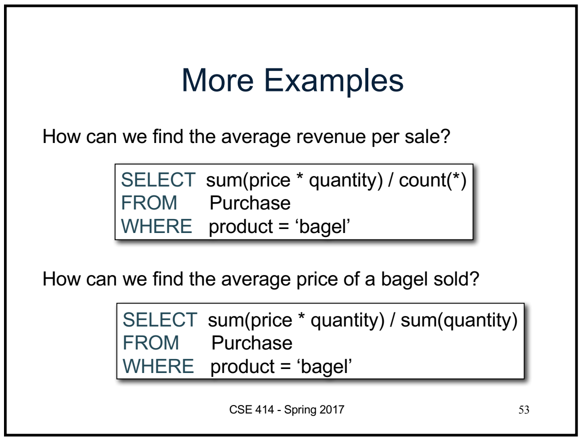
Simple Aggregations

Purchase

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

```
SELECT  Sum(price * quantity)
FROM    Purchase
WHERE   product = 'Bagel'
```

$\Rightarrow$ 90 (= 60+30)



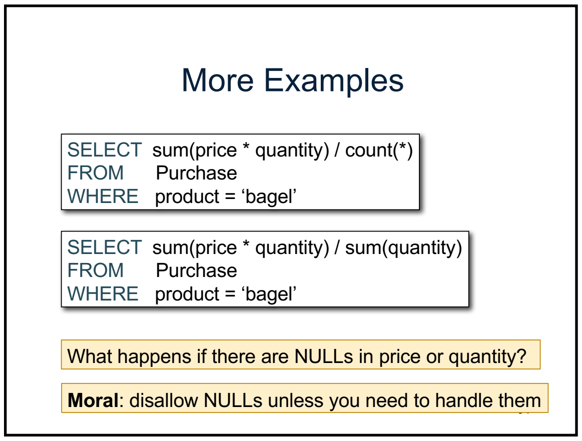
More Examples

How can we find the average revenue per sale?

```
SELECT  sum(price * quantity) / count(*)
FROM    Purchase
WHERE   product = 'bagel'
```

How can we find the average price of a bagel sold?

```
SELECT  sum(price * quantity) / sum(quantity)
FROM    Purchase
WHERE   product = 'bagel'
```



More Examples

```
SELECT  sum(price * quantity) / count(*)
FROM    Purchase
WHERE   product = 'bagel'
```

```
SELECT  sum(price * quantity) / sum(quantity)
FROM    Purchase
WHERE   product = 'bagel'
```

What happens if there are NULLs in price or quantity?

Moral: disallow NULLs unless you need to handle them