

SQL

SQL Introduction

Standard language for querying and manipulating data

Structured Query Language

Many standards out there:

- ANSI SQL, SQL92 (a.k.a. SQL2), SQL99 (a.k.a. SQL3),
- Vendors support various subsets: watch for fun discussions in class !

SQL

- Data Definition Language (DDL)
 - Create/alter/delete tables and their attributes
 - Following lectures...
- Data Manipulation Language (DML)
 - Query one or more tables – discussed next !
 - Insert/delete/modify tuples in tables

Table name

Attribute names

Product

Tables in SQL

PName	Price	Category	Manufacturer
Gizmo	\$19.99	Gadgets	GizmoWorks
Powergizmo	\$29.99	Gadgets	GizmoWorks
SingleTouch	\$149.99	Photography	Canon
MultiTouch	\$203.99	Household	Hitachi

Tuples or rows

Tables Explained

- The *schema* of a table is the table name and its attributes:

Product(PName, Price, Category, Manufacturer)

- A *key* is an attribute whose values are unique; we underline a key

Product(PName, Price, Category, Manufacturer)

Data Types in SQL

- Atomic types:
 - Characters: CHAR(20), VARCHAR(50)
 - Numbers: INT, BIGINT, SMALLINT, FLOAT
 - Others: MONEY, DATETIME, ...
- Every attribute must have an atomic type
 - Hence tables are flat
 - Why ?

Tables Explained

- A tuple = a record
 - Restriction: all attributes are of atomic type
- A table = a set of tuples
 - Like a list...
 - ...but it is unorderd:
no **first()**, no **next()**, no **last()**.

SQL Query

Basic form: (plus many many more bells and whistles)

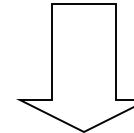
```
SELECT <attributes>
FROM   <one or more relations>
WHERE  <conditions>
```

Simple SQL Query

Product

PName	Price	Category	Manufacturer
Gizmo	\$19.99	Gadgets	GizmoWorks
Powergizmo	\$29.99	Gadgets	GizmoWorks
SingleTouch	\$149.99	Photography	Canon
MultiTouch	\$203.99	Household	Hitachi

```
SELECT *
FROM Product
WHERE category= 'Gadgets'
```



“selection”

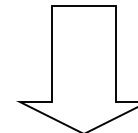
PName	Price	Category	Manufacturer
Gizmo	\$19.99	Gadgets	GizmoWorks
Powergizmo	\$29.99	Gadgets	GizmoWorks

Simple SQL Query

Product

PName	Price	Category	Manufacturer
Gizmo	\$19.99	Gadgets	GizmoWorks
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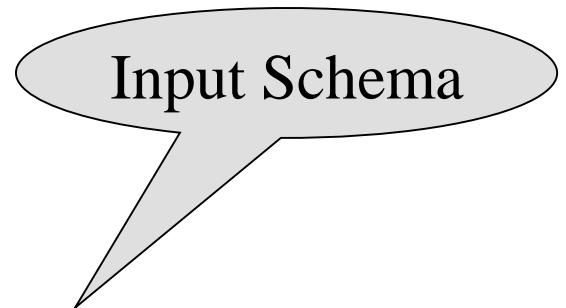
```
SELECT PName, Price, Manufacturer  
FROM Product  
WHERE Price > 100
```



“selection” and
“projection”

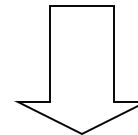
PName	Price	Manufacturer
SingleTouch	\$149.99	Canon
MultiTouch	\$203.99	Hitachi

Notation

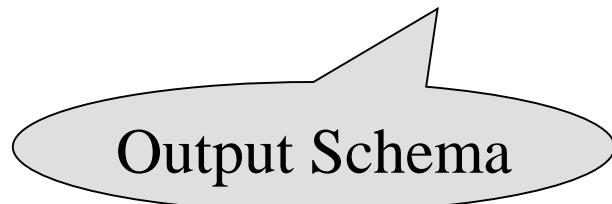


Product(PName, Price, Category, Manufacturer)

```
SELECT PName, Price, Manufacturer  
FROM Product  
WHERE Price > 100
```



Answer(PName, Price, Manfacturer)



Details

- Case insensitive:
 - Same: SELECT Select select
 - Same: Product product
 - Different: ‘Seattle’ ‘seattle’
- Constants:
 - ‘abc’ - yes
 - “abc” - no

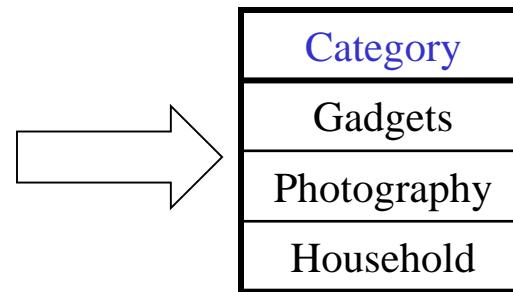
The **LIKE** operator

```
SELECT *
FROM   Products
WHERE  PName LIKE '%gizmo%'
```

- **s LIKE p:** pattern matching on strings
- **p** may contain two special symbols:
 - **%** = any sequence of characters
 - **_** = any single character

Eliminating Duplicates

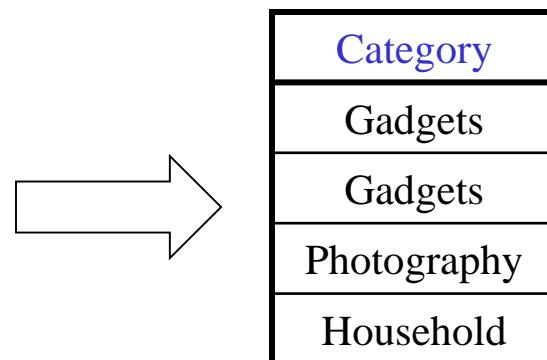
```
SELECT DISTINCT category  
FROM Product
```



Category
Gadgets
Photography
Household

Compare to:

```
SELECT category  
FROM Product
```



Category
Gadgets
Gadgets
Photography
Household

Ordering the Results

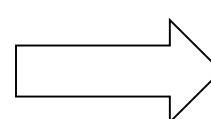
```
SELECT  pname, price, manufacturer  
FROM    Product  
WHERE   category= 'gizmo' AND price > 50  
ORDER BY price, pname
```

Ties are broken by the second attribute on the ORDER BY list, etc.

Ordering is ascending, unless you specify the DESC keyword.

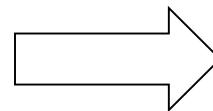
PName	Price	Category	Manufacturer
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Powergizmo	\$29.99	Gadgets	GizmoWorks
SingleTouch	\$149.99	Photography	Canon
MultiTouch	\$203.99	Household	Hitachi

```
SELECT DISTINCT category
FROM Product
ORDER BY category
```



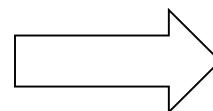
?

```
SELECT Category
FROM Product
ORDER BY PName
```



?

```
SELECT DISTINCT category
FROM Product
ORDER BY PName
```



?

Keys and Foreign Keys

Company

<u>CName</u>	StockPrice	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

Key

Product

<u>PName</u>	Price	Category	Manufacturer
Gizmo	\$19.99	Gadgets	GizmoWorks
Powergizmo	\$29.99	Gadgets	GizmoWorks
SingleTouch	\$149.99	Photography	Canon
MultiTouch	\$203.99	Household	Hitachi

Foreign
key

Joins

Product (pname, price, category, manufacturer)
Company (cname, stockPrice, country)

Find all products under \$200 manufactured in Japan;
return their names and prices.

```
SELECT PName, Price  
FROM Product, Company  
WHERE Manufacturer=CName AND Country='Japan'  
      AND Price <= 200
```

Join
between Product
and Company

Joins

Product

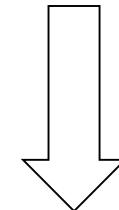
PName	Price	Category	Manufacturer
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Powergizmo	\$29.99	Gadgets	GizmoWorks
SingleTouch	\$149.99	Photography	Canon
MultiTouch	\$203.99	Household	Hitachi

Company

Cname	StockPrice	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

```

SELECT PName, Price
FROM Product, Company
WHERE Manufacturer=CName AND Country= 'Japan'
AND Price <= 200
    
```



PName	Price
SingleTouch	\$149.99

More Joins

Product (pname, price, category, manufacturer)
Company (cname, stockPrice, country)

Find all Chinese companies that manufacture products
both in the ‘electronic’ and ‘toy’ categories

SELECT cname

FROM

WHERE

A Subtlety about Joins

Product (pname, price, category, manufacturer)
Company (cname, stockPrice, country)

Find all countries that manufacture some product in the
'Gadgets' category.

```
SELECT Country
FROM Product, Company
WHERE Manufacturer=CName AND Category= 'Gadgets'
```

Unexpected duplicates

A Subtlety about Joins

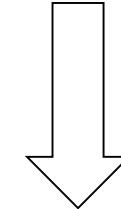
Product

Name	Price	Category	Manufacturer
Gizmo	\$19.99	Gadgets	GizmoWorks
Powergizmo	\$29.99	Gadgets	GizmoWorks
SingleTouch	\$149.99	Photography	Canon
MultiTouch	\$203.99	Household	Hitachi

Company

Cname	StockPrice	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

```
SELECT Country  
FROM Product, Company  
WHERE Manufacturer=CName AND Category='Gadgets'
```



What is
the problem ?
What's the
solution ?

Country
??
??

Tuple Variables

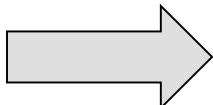
Person(pname, address, worksfor)

Company(cname, address)

```
SELECT DISTINCT pname, address  
FROM Person, Company  
WHERE worksfor = cname
```

Which
address ?

```
SELECT DISTINCT Person.pname, Company.address  
FROM Person, Company  
WHERE Person.worksfor = Company.cname
```



```
SELECT DISTINCT x.pname, y.address  
FROM Person AS x, Company AS y  
WHERE x.worksfor = y.cname
```

Meaning (Semantics) of SQL Queries

```
SELECT a1, a2, ..., ak  
FROM R1 AS x1, R2 AS x2, ..., Rn AS xn  
WHERE Conditions
```

```
Answer = {}  
for x1 in R1 do  
  for x2 in R2 do  
    ....  
    for xn in Rn do  
      if Conditions  
        then Answer = Answer  $\cup$  {(a1,...,ak)}  
return Answer
```

An Unintuitive Query

```
SELECT DISTINCT R.A  
FROM R, S, T  
WHERE R.A=S.A OR R.A=T.A
```

What does it compute ?

Computes $R \cap (S \cup T)$

But what if $S = \emptyset$?

Subqueries Returning Relations

Company(name, city)

Product(pname, maker)

Purchase(id, product, buyer)

Return cities where one can find companies that manufacture products bought by Joe Blow

```
SELECT Company.city
FROM Company
WHERE Company.name IN
    (SELECT Product.maker
     FROM Purchase , Product
     WHERE Product.pname=Purchase.product
           AND Purchase .buyer = 'Joe Blow');
```

Subqueries Returning Relations

Is it equivalent to this ?

```
SELECT Company.city
FROM Company, Product, Purchase
WHERE Company.name= Product.maker
      AND Product.pname = Purchase.product
      AND Purchase.buyer = 'Joe Blow'
```

Beware of duplicates !

Removing Duplicates

```
SELECT DISTINCT Company.city  
FROM Company  
WHERE Company.name IN  
    (SELECT Product.maker  
     FROM Purchase , Product  
     WHERE Product.pname=Purchase.product  
           AND Purchase .buyer = 'Joe Blow ');
```

```
SELECT DISTINCT Company.city  
FROM Company, Product, Purchase  
WHERE Company.name= Product.maker  
      AND Product.pname = Purchase.product  
      AND Purchase.buyer = 'Joe Blow'
```

Now
they are
equivalent

Subqueries Returning Relations

You can also use:

- s > ALL R
- s > ANY R
- EXISTS R

Product (pname, price, category, maker)

Find products that are more expensive than all those produced
By “Gizmo-Works”

```
SELECT name
  FROM Product
 WHERE price > ALL (SELECT price
                      FROM Purchase
                     WHERE maker= 'Gizmo-Works' )
```

Question for Database Fans and their Friends

- Can we express this query as a single SELECT-FROM-WHERE query, without subqueries ?

Question for Database Fans and their Friends

- Answer: all SFW queries are **monotone** (figure out what this means). A query with **ALL** is not monotone

Correlated Queries

Movie (title, year, director, length)

Find movies whose title appears more than once.

```
SELECT DISTINCT title  
FROM Movie AS x  
WHERE year <> ANY  
      (SELECT year  
       FROM Movie  
      WHERE title = x.title);
```

correlation

Note (1) scope of variables (2) this can still be expressed as single SFW

Complex Correlated Query

Product (pname, price, category, maker, year)

- Find products (and their manufacturers) that are more expensive than all products made by the same manufacturer before 1972

```
SELECT DISTINCT pname, maker
FROM Product AS x
WHERE price > ALL (SELECT price
                     FROM Product AS y
                     WHERE x.maker = y.maker AND y.year < 1972);
```

Very powerful ! Also much harder to optimize.

Aggregation

```
SELECT avg(price)  
FROM Product  
WHERE maker="Toyota"
```

```
SELECT count(*)  
FROM Product  
WHERE year > 1995
```

SQL supports several aggregation operations:

sum, count, min, max, avg

Except count, all aggregations apply to a single attribute

Aggregation: Count

COUNT applies to duplicates, unless otherwise stated:

```
SELECT Count(category)  
FROM Product  
WHERE year > 1995
```

same as Count(*)

We probably want:

```
SELECT Count(DISTINCT category)  
FROM Product  
WHERE year > 1995
```

More Examples

Purchase(product, date, price, quantity)

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

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

What do
they mean ?

Purchase

Simple Aggregations

Product	Date	Price	Quantity
Bagel	10/21	1	20
Banana	10/3	0.5	10
Banana	10/10	1	10
Bagel	10/25	1.50	20

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



50 (= 20+30)

Grouping and Aggregation

Purchase(product, date, price, quantity)

Find total sales after 10/1/2005 per product.

```
SELECT      product, Sum(price*quantity) AS TotalSales  
FROM        Purchase  
WHERE       date > '10/1/2005'  
GROUP BY    product
```

Let's see what this means...

Grouping and Aggregation

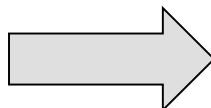
1. Compute the **FROM** and **WHERE** clauses.
2. Group by the attributes in the **GROUPBY**
3. Compute the **SELECT** clause: grouped attributes and aggregates.

1&2. FROM-WHERE-GROUPBY

Product	Date	Price	Quantity
Bagel	10/21	1	20
	10/25	1.50	20
Banana	10/3	0.5	10
	10/10	1	10

3. SELECT

Product	Date	Price	Quantity
Bagel	10/21	1	20
	10/25	1.50	20
Banana	10/3	0.5	10
	10/10	1	10



Product	TotalSales
Bagel	50
Banana	15

```
SELECT product, Sum(price*quantity) AS TotalSales  
FROM Purchase  
WHERE date > '10/1/2005'  
GROUP BY product
```

GROUP BY v.s. Nested Quereis

```
SELECT      product, Sum(price*quantity) AS TotalSales  
FROM        Purchase  
WHERE       date > '10/1/2005'  
GROUP BY    product
```

```
SELECT DISTINCT x.product, (SELECT Sum(y.price*y.quantity)  
                           FROM   Purchase y  
                           WHERE  x.product = y.product  
                                 AND y.date > '10/1/2005')  
                           AS TotalSales  
FROM        Purchase x  
WHERE       x.date > '10/1/2005'
```

Another Example

What does
it mean ?

```
SELECT      product,  
            sum(price * quantity) AS SumSales  
            max(quantity) AS MaxQuantity  
FROM        Purchase  
GROUP BY    product
```

HAVING Clause

Same query, except that we consider only products that had at least 100 buyers.

```
SELECT      product, Sum(price * quantity)
FROM        Purchase
WHERE       date > '10/1/2005'
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 a₁,...,a_k and/or any aggregates but NO OTHER ATTRIBUTES

C1 = is any condition on the attributes in R₁,...,R_n

C2 = is any condition on aggregate expressions

General form of Grouping and Aggregation

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

Evaluation steps:

1. Evaluate FROM-WHERE, apply condition C1
2. Group by the attributes a₁,...,a_k
3. Apply condition C2 to each group (may have aggregates)
4. Compute aggregates in S and return the result

Advanced SQLizing

1. Getting around INTERSECT and EXCEPT
2. Quantifiers
3. Aggregation v.s. subqueries

INTERSECT and EXCEPT: not in SQL Server

1. INTERSECT and EXCEPT:

```
(SELECT R.A, R.B  
FROM R)  
INTERSECT  
(SELECT S.A, S.B  
FROM S)
```



```
SELECT R.A, R.B  
FROM R  
WHERE  
EXISTS(SELECT *  
FROM S  
WHERE R.A=S.A and R.B=S.B)
```

If R, S have no
duplicates, then can
write without
subqueries
(HOW?)

```
(SELECT R.A, R.B  
FROM R)  
EXCEPT  
(SELECT S.A, S.B  
FROM S)
```



```
SELECT R.A, R.B  
FROM R  
WHERE  
NOT EXISTS(SELECT *  
FROM S  
WHERE R.A=S.A and R.B=S.B)
```

2. Quantifiers

Product (pname, price, company)

Company(cname, city)

Find all companies that make some products with price < 100

```
SELECT DISTINCT Company.cname  
FROM Company, Product  
WHERE Company.cname = Product.company and Product.price < 100
```

Existential: easy ! 😊

2. Quantifiers

Product (pname, price, company)

Company(cname, city)

Find all companies that make only products with price < 100

same as:

Find all companies s.t. all of their products have price < 100

Universal: hard ! ☹

2. Quantifiers

1. Find *the other* companies: i.e. s.t. some product ≥ 100

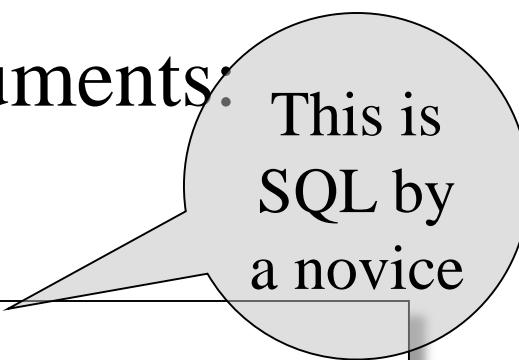
2. Find all companies s.t. all their products have price < 100

3. Group-by v.s. Nested Query

Author(login,name)

Wrote(login,url)

- Find authors who wrote ≥ 10 documents:
- Attempt 1: with nested queries



This is
SQL by
a novice

```
SELECT DISTINCT Author.name
FROM      Author
WHERE      count(SELECT Wrote.url
                  FROM Wrote
                  WHERE Author.login=Wrote.login)
                > 10
```

3. Group-by v.s. Nested Query

- Find all authors who wrote at least 10 documents:
- Attempt 2: SQL style (with GROUP BY)

```
SELECT      Author.name
FROM        Author, Wrote
WHERE        Author.login=Wrote.login
GROUP BY    Author.name
HAVING      count(wrote.url) > 10
```

This is
SQL by
an expert

No need for **DISTINCT**: automatically from **GROUP BY**

3. Group-by v.s. Nested Query

Author(login,name)

Wrote(login,url)

Mentions(url,word)

Find authors with vocabulary ≥ 10000 words:

```
SELECT      Author.name
FROM        Author, Wrote, Mentions
WHERE        Author.login=Wrote.login AND Wrote.url=Mentions.url
GROUP BY    Author.name
HAVING      count(distinct Mentions.word) > 10000
```

Two Examples

Store(sid, sname)

Product(pid, pname, price, sid)

Find all stores that sell *only* products with price > 100

same as:

Find all stores s.t. all their products have price > 100)

```
SELECT Store.name  
FROM Store, Product  
WHERE Store.sid = Product.sid  
GROUP BY Store.sid, Store.name  
HAVING 100 < min(Product.price)
```

Why both ?

Almost equivalent...

```
SELECT Store.name  
FROM Store  
WHERE  
    100 < ALL (SELECT Product.price  
                FROM product  
                WHERE Store.sid = Product.sid)
```

```
SELECT Store.name  
FROM Store  
WHERE Store.sid NOT IN  
    (SELECT Product.sid  
        FROM Product  
        WHERE Product.price <= 100)
```

Two Examples

Store(sid, sname)

Product(pid, pname, price, sid)

For each store,
find its most expensive product

Two Examples

This is easy but doesn't do what we want:

```
SELECT Store.sname, max(Product.price)
FROM   Store, Product
WHERE  Store.sid = Product.sid
GROUP BY Store.sid, Store.sname
```

Better:

But may
return
multiple
product names
per store

```
SELECT Store.sname, x.pname
FROM   Store, Product x
WHERE  Store.sid = x.sid and
       x.price >=
              ALL (SELECT y.price
                   FROM Product y
                   WHERE Store.sid = y.sid)
```

Two Examples

Finally, choose some pid arbitrarily, if there are many with highest price:

```
SELECT Store.sname, max(x.pname)
FROM   Store, Product x
WHERE  Store.sid = x.sid and
       x.price >=
           ALL (SELECT y.price
                 FROM Product y
                 WHERE Store.sid = y.sid)
GROUP BY Store.sname
```

NULLS in SQL

- Whenever we don't have a value, we can put a NULL
- Can mean many things:
 - Value does not exists
 - Value exists but is unknown
 - Value not applicable
 - Etc.
- The schema specifies for each attribute if can be null (*nullable* attribute) or not
- How does SQL cope with tables that have NULLs ?

Null Values

- If $x = \text{NULL}$ then $4*(3-x)/7$ is still NULL
- If $x = \text{NULL}$ then $x = \text{"Joe"}$ is UNKNOWN
- In SQL there are three boolean values:

FALSE = 0

UNKNOWN = 0.5

TRUE = 1

Null Values

- C1 AND C2 = min(C1, C2)
- C1 OR C2 = max(C1, C2)
- NOT C1 = 1 – C1

```
SELECT *
FROM Person
WHERE (age < 25) AND
      (height > 6 OR weight > 190)
```

E.g.
age=20
height=NULL
weight=200

Null Values

Unexpected behavior:

```
SELECT *
FROM Person
WHERE age < 25 OR age >= 25
```

Some Persons are not included !

Null Values

Can test for NULL explicitly:

- x IS NULL
- x IS NOT NULL

```
SELECT *
FROM Person
WHERE age < 25 OR age >= 25 OR age IS NULL
```

Now it includes all Persons

Outerjoins

Explicit joins in SQL = “inner joins”:

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

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

Same as:

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

But Products that never sold will be lost !

Outerjoins

Left outer joins in SQL:

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

```
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

Application

Compute, for each product, the total number of sales in ‘September’

Product(name, category)

Purchase(prodName, month, store)

```
SELECT Product.name, count(*)  
FROM Product, Purchase  
WHERE Product.name = Purchase.prodName  
      and Purchase.month = 'September'  
GROUP BY Product.name
```

What's wrong ?

Application

Compute, for each product, the total number of sales in ‘September’

Product(name, category)

Purchase(prodName, month, store)

```
SELECT Product.name, count(*)  
FROM Product LEFT OUTER JOIN Purchase ON  
    Product.name = Purchase.prodName  
    and Purchase.month = 'September'  
GROUP BY Product.name
```

Now we also get the products who sold in 0 quantity

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 the both left and right tuples even if there's no match

Modifying the Database

Three kinds of modifications

- Insertions
- Deletions
- Updates

Sometimes they are all called “updates”

Insertions

General form:

```
INSERT INTO R(A1,...,An) VALUES (v1,...,vn)
```

Example: Insert a new purchase to the database:

```
INSERT INTO Purchase(buyer, seller, product, store)  
VALUES ('Joe', 'Fred', 'wakeup-clock-espresso-machine',  
       'The Sharper Image')
```

Missing attribute → NULL.

May drop attribute names if give them in order.

Insertions

```
INSERT INTO PRODUCT(name)  
  
SELECT DISTINCT Purchase.product  
FROM Purchase  
WHERE Purchase.date > "10/26/01"
```

The query replaces the VALUES keyword.
Here we insert *many* tuples into PRODUCT

Insertion: an Example

Product(name, listPrice, category)
Purchase(prodName, buyerName, price)

prodName is foreign key in Product.name

Suppose database got corrupted and we need to fix it:

Product

name	listPrice	category
gizmo	100	gadgets

Purchase

prodName	buyerName	price
camera	John	200
gizmo	Smith	80
camera	Smith	225

Task: insert in Product all prodNames from Purchase

Insertion: an Example

```
INSERT INTO Product(name)
```

```
SELECT DISTINCT prodName  
FROM Purchase  
WHERE prodName NOT IN (SELECT name FROM Product)
```

name	listPrice	category
gizmo	100	Gadgets
camera	-	-

Insertion: an Example

```
INSERT INTO Product(name, listPrice)
```

```
SELECT DISTINCT prodName, price  
FROM Purchase  
WHERE prodName NOT IN (SELECT name FROM Product)
```

name	listPrice	category
gizmo	100	Gadgets
camera	200	-
camera ??	225 ??	-

← Depends on the implementation

Deletions

Example:

```
DELETE FROM PURCHASE  
WHERE seller = 'Joe' AND  
      product = 'Brooklyn Bridge'
```

Factoid about SQL: there is no way to delete only a single occurrence of a tuple that appears twice in a relation.

Updates

Example:

```
UPDATE PRODUCT
SET price = price/2
WHERE Product.name IN
    (SELECT product
     FROM Purchase
     WHERE Date = 'Oct, 25, 1999');
```