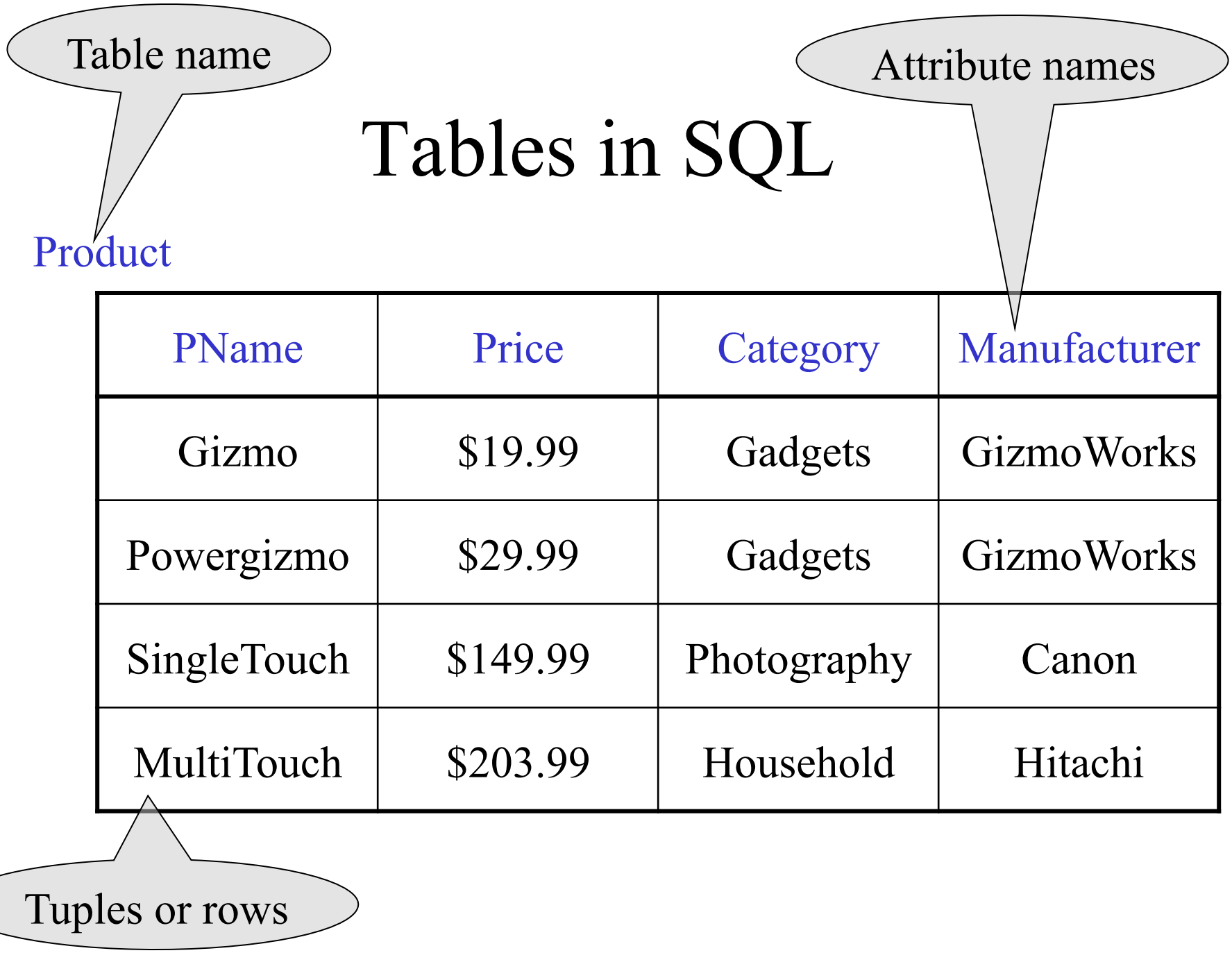
SQL

Structured Query Language

SQL

- Data Definition Language (DDL)
  - Create/alter/delete tables and their attributes
  - We won't cover this ...
- Data Manipulation Language (DML)
  - Query one or more tables – discussed next !
  - Insert/delete/modify tuples in tables

Tables in SQL



Tables Explained

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

Product(PName, Price, Category, Manfacturer)

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

Product(<u>PName</u>, Price, Category, Manfacturer)

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)

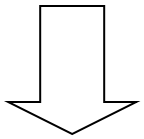
```
SELECT  <attributes>
FROM    <one or more relations>
WHERE   <conditions>
```

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'
```



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

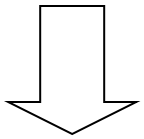
"selection"

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

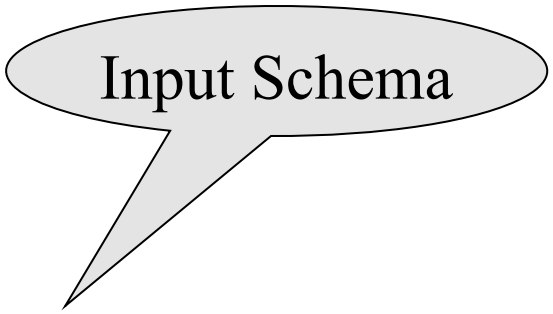
```
SELECT  PName, Price, Manufacturer
FROM    Product
WHERE   Price > 100
```



"selection" and "projection"

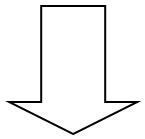
PName	Price	Manufacturer
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

Notation

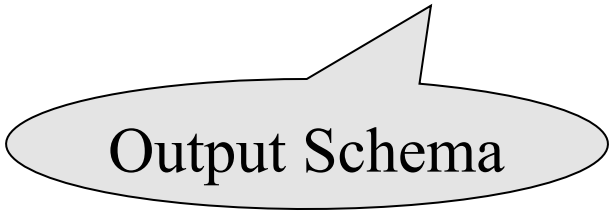


Product(PName, Price, Category, Manfacturer)

```
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

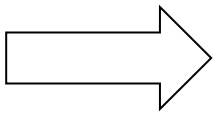
The **LIKE** operator

```
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

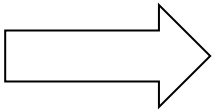
```
SELECT  DISTINCT category
FROM    Product
```



Category
Gadgets
Photography
Household

Compare to:

```
SELECT  category
FROM    Product
```



Category
Gadgets
Gadgets
Photography
Household

Ordering the Results

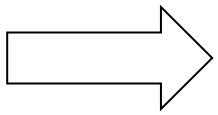
```
SELECT   pname, price, manufacturer
FROM     Product
WHERE    category='gizmo' AND price > 50
ORDER BY  price, pname
```

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

Ordering is ascending, unless you specify the DESC keyword.

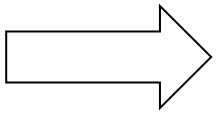
PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

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



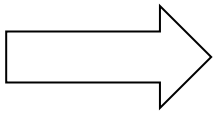
?

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



?

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



?

Keys and Foreign Keys

Company

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

Key

Product

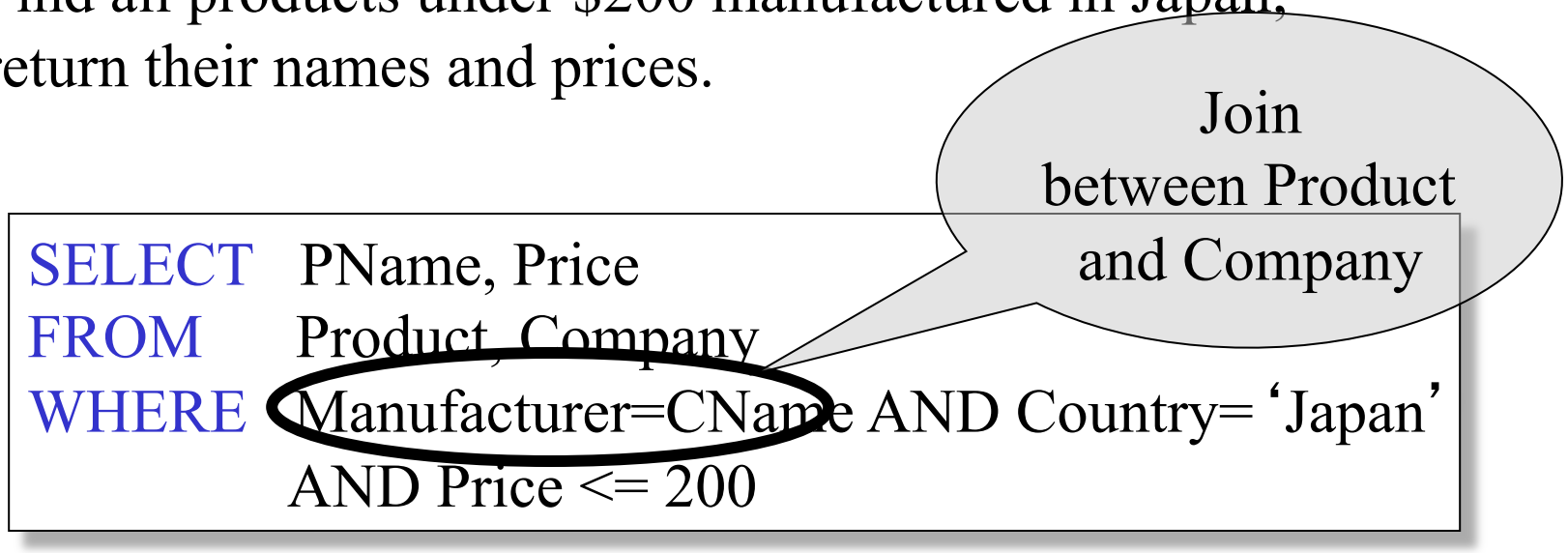
PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

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.



Joins

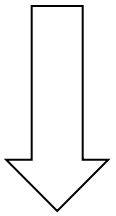
Product

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

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

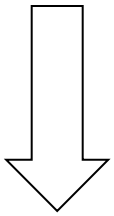
Product

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'
```



Country
??
??

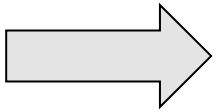
What is the problem ? What's the solution ?

Tuple Variables

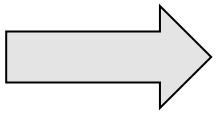
Person(pname, address, worksfor)
Company(cname, address)

```
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 $a_1, a_2, \ldots, a_k$
FROM R_1 AS x_1, R_2 AS x_2, …, R_n AS x_n
WHERE Conditions

Answer = {}
for x_1 **in** R_1 **do**
  for x_2 **in** R_2 **do**
    …..
      for x_n **in** R_n **do**
        if Conditions
          then Answer = Answer ∪ $\{(a_1,\ldots,a_k)\}$
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 $S = \phi$?

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 ?

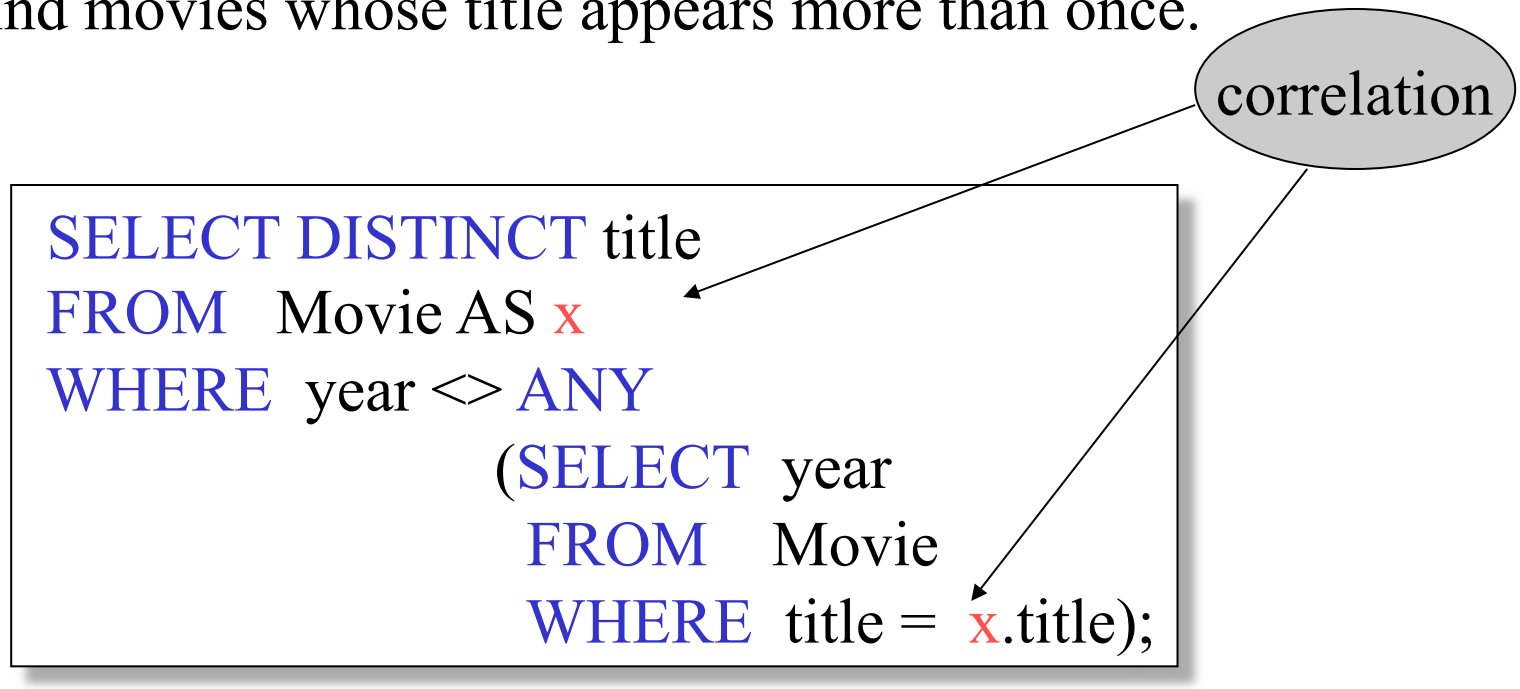
Question for Database Fans and their Friends

- 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.



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'
```

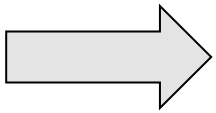
What do they mean ?

Simple Aggregations

Purchase

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

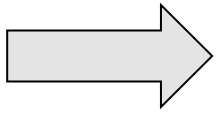
3. Compute the SELECT clause: grouped attributes and aggregates.

1&2. FROM-WHERE-GROUPBY

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

3. SELECT

Product	Date	Price	Quantity
Bagel	10/21	1	20
Bagel	10/25	1.50	20
Banana	10/3	0.5	10
Banana	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 $R_1,\ldots,R_n$
WHERE C1
GROUP BY $a_1,\ldots,a_k$
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

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 $a_1,\ldots,a_k$
3. Apply condition C2 to each group (may have aggregates)
4. Compute aggregates in S and return the result