Introduction to SQL

SELECT-FROM-WHERE STATEMENTS

MULTIRELATION QUERIES

SUBQUERIES

SQL

SQL is a standard language for accessing databases.

SQL stands for Structured Query Language.

SQL lecture's material will teach you how to use SQL to access and manipulate data in: Postgresql, MySQL, SQL Server, Access, Oracle, Sybase, IBM DB2, and other database systems.

Why SQL?

SQL is a very-high-level language.

- Say “what to do” rather than “how to do it.”
- Avoid a lot of data-manipulation details needed in procedural languages like C++ or Java.

Database management system figures out “best” way to execute query.

- Called “query optimization.”

Select-From-Where Statements

SELECT desired attributes

FROM one or more tables

WHERE condition about tuples of

the tables

Our Running Example

All our SQL queries will be based on the following database schema.

Beers(name, manf)

Bars(name, addr, license)

Drinkers(name, addr, phone)

Likes(drinker, beer)

Sells(bar, beer, price)

Frequents(drinker, bar)

Example

Using Beers(name, manf), what beers are made by Anheuser-Busch?

```
SELECT name
FROM Beers
WHERE manf = 'Anheuser-Busch';
```

Result of Query

name
Bud
Bud Lite
Michelob
. . .

The answer is a relation with a single attribute, name, and tuples with the name of each beer by Anheuser-Busch, such as Bud.

Meaning of Single-Relation Query

Begin with the relation in the FROM clause.

Apply the selection indicated by the WHERE clause.

Apply the extended projection indicated by the SELECT clause.

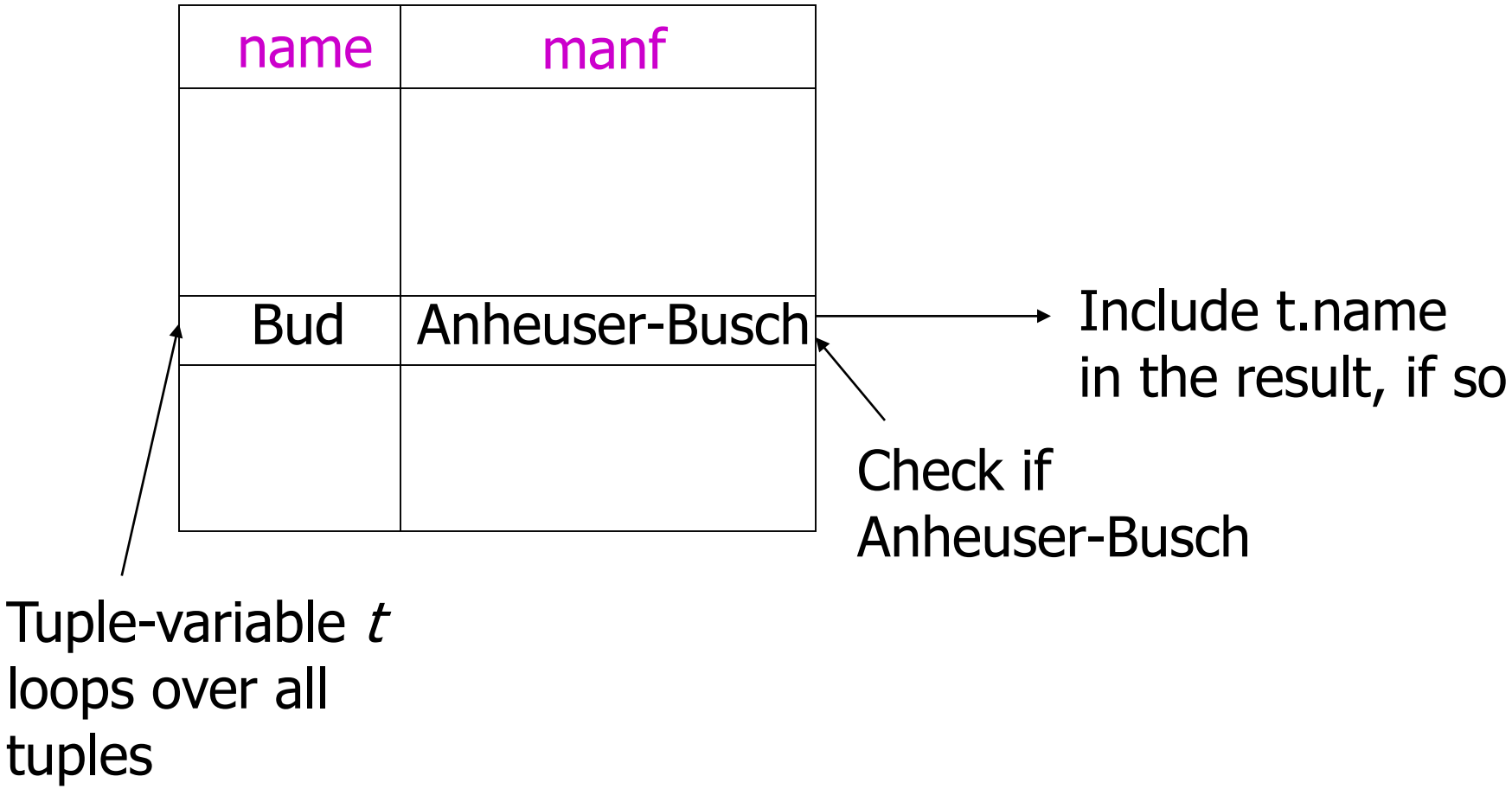
Operational Semantics --- General

Think of a *tuple variable* visiting each tuple of the relation mentioned in FROM.

Check if the “current” tuple satisfies the WHERE clause.

If so, compute the attributes or expressions of the SELECT clause using the components of this tuple.

Operational Semantics



* In SELECT clauses

When there is one relation in the FROM clause, * in the SELECT clause stands for "all attributes of this relation."

Example: Using Beers(name, manf):

```
SELECT *
FROM Beers
WHERE manf = 'Anheuser-Busch';
```

Result of Query:

name	manf
Bud	Anheuser-Busch
Bud Lite	Anheuser-Busch
Michelob	Anheuser-Busch
. . .	. . .

Now, the result has each of the attributes of Beers.

Renaming Attributes

If you want the result to have different attribute names, use “AS <new name>” to rename an attribute.

Example: Using Beers(name, manf):

```
SELECT name AS beer, manf
FROM Beers
WHERE manf = 'Anheuser-Busch'
```

Result of Query:

beer	manf
Bud	Anheuser-Busch
Bud Lite	Anheuser-Busch
Michelob	Anheuser-Busch
. . .	. . .

Exercise

1. Copy query below into local Word doc or Google doc (create your own)

```
SELECT name AS beer, manf
      FROM Beers
      WHERE manf = 'Anheuser-Busch'
```

2. Rewrite the query by Renaming the attribute manf to manufacturer

3. Present how the result of the query looks like (as in Slide 14)

Expressions in SELECT Clauses

Any expression that makes sense can appear as an element of a SELECT clause.

Example: Using Sells(bar, beer, price):

```
SELECT bar, beer,
           price*114 AS priceInYen
FROM Sells;
```

Result of Query

bar	beer	priceInYen
Joe's	Bud	285
Sue's	Miller	342
…	…	…

Exercise

1. Copy query into Google doc

```
SELECT bar, beer,
       price
FROM Sells;
```

2. Assume price is in CAD dollars
3. Rewrite the query, so there is additional column price in american dollars.
4. Name calculated column as priceInAmerDoll
5. Present how the result of the query looks like

Example: Constants as Expressions

Using Likes(drinker, beer):

```
SELECT drinker,
           'likes Bud' AS whoLikesBud
FROM Likes
WHERE beer = 'Bud';
```

Result of Query

drinker	whoLikesBud
Sally	likes Bud
Fred	likes Bud
…	…

Example: Information Integration

We often build “data warehouses” from the data at many “sources.”

Suppose each bar has its own relation Menu(beer, price) .

To contribute to Sells(bar, beer, price) we need to query each bar and insert the name of the bar.

Information Integration --- (2)

For instance, at Joe's Bar we can issue the query:

```
SELECT 'Joe''s Bar', beer, price
FROM Menu;
```

Complex Conditions in WHERE Clause

Boolean operators AND, OR, NOT.

Comparisons =, <>, <, >, <=, >=.

- And many other operators that produce boolean-valued results.

Example: Complex Condition

Using Sells(bar, beer, price), find the price Joe's Bar charges for Bud:

```
SELECT price
FROM Sells
WHERE bar = 'Joe''s Bar' AND
      beer = 'Bud';
```

Exercise

1. …

2. Using Sells(bar, beer, price), find the price Joe's Bar charges for Bud and Millller.

Patterns

A condition can compare a string to a pattern by:

- <Attribute> LIKE <pattern> or <Attribute> NOT LIKE <pattern>

Pattern is a quoted string with % = “any string”; _ = “any character.”

Example: LIKE

Using Drinkers(name, addr, phone) find the drinkers with exchange 555:

```
SELECT name
FROM Drinkers
WHERE phone LIKE '%555-_ _ _ _';
```

Exercise

1. …

2. Using Drinkers(name, addr, phone) find the drinkers with exchange 555 and country code 1 and name starting with „Jo” (eg., Johnson, Jacobsen etc.)

NULL Values

Tuples in SQL relations can have NULL as a value for one or more components.

Meaning depends on context. Two common cases:

- *Missing value* : e.g., we know Joe's Bar has some address, but we don't know what it is.
- *Inapplicable* : e.g., the value of attribute spouse for an unmarried person.

Comparing NULL's to Values

The logic of conditions in SQL is really 3-valued logic: TRUE, FALSE, UNKNOWN.

Comparing any value (including NULL itself) with NULL yields UNKNOWN.

A tuple is in a query answer iff the WHERE clause is TRUE (not FALSE or UNKNOWN).

Three-Valued Logic

To understand how AND, OR, and NOT work in 3-valued logic, think of TRUE = 1, FALSE = 0, and UNKNOWN = ½.

AND = MIN; OR = MAX, NOT(*x*) = 1-*x*.

Example:

TRUE AND (FALSE OR NOT(UNKNOWN)) =

MIN(1, MAX(0, (1 - ½))) =

MIN(1, MAX(0, ½)) =

MIN(1, ½) = ½.

Surprising Example

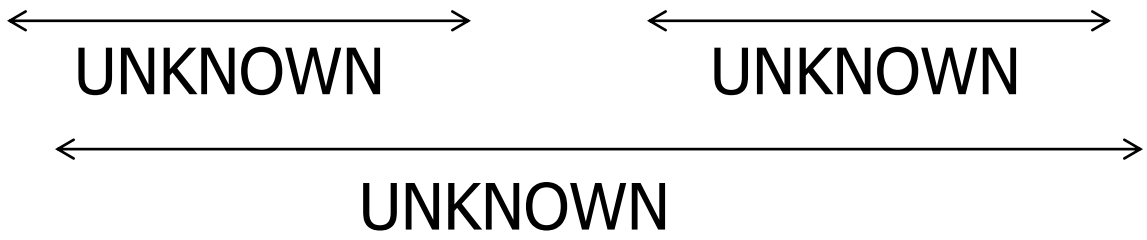
From the following Sells relation:

bar	beer	price
Joe's Bar	Bud	NULL

SELECT bar

FROM Sells

WHERE price < 2.00 OR price >= 2.00;



Reason: 2-Valued Laws != 3-Valued Laws

Some common laws, like commutativity of AND, hold in 3-valued logic.

But not others, e.g., the *law of the excluded middle* : *p* OR NOT *p* = TRUE.

- When *p* = UNKNOWN, the left side is MAX(½, (1 – ½)) = ½ != 1.

Multirelation Queries

Interesting queries often combine data from more than one relation.

We can address several relations in one query by listing them all in the FROM clause.

Distinguish attributes of the same name by “<relation>.<attribute>” .

Example: Joining Two Relations

Using relations Likes(drinker, beer) and Frequents(drinker, bar), find the beers liked by at least one person who frequents Joe's Bar.

```
SELECT beer

FROM Likes, Frequents

WHERE bar = 'Joe''s Bar' AND

     Frequents.drinker =
Likes.drinker;
```

Formal Semantics

Almost the same as for single-relation queries:

1. Start with the *product* of all the relations in the FROM clause.
2. Apply the selection *condition* from the WHERE clause.
3. *Project* onto the list of attributes and expressions in the SELECT clause.

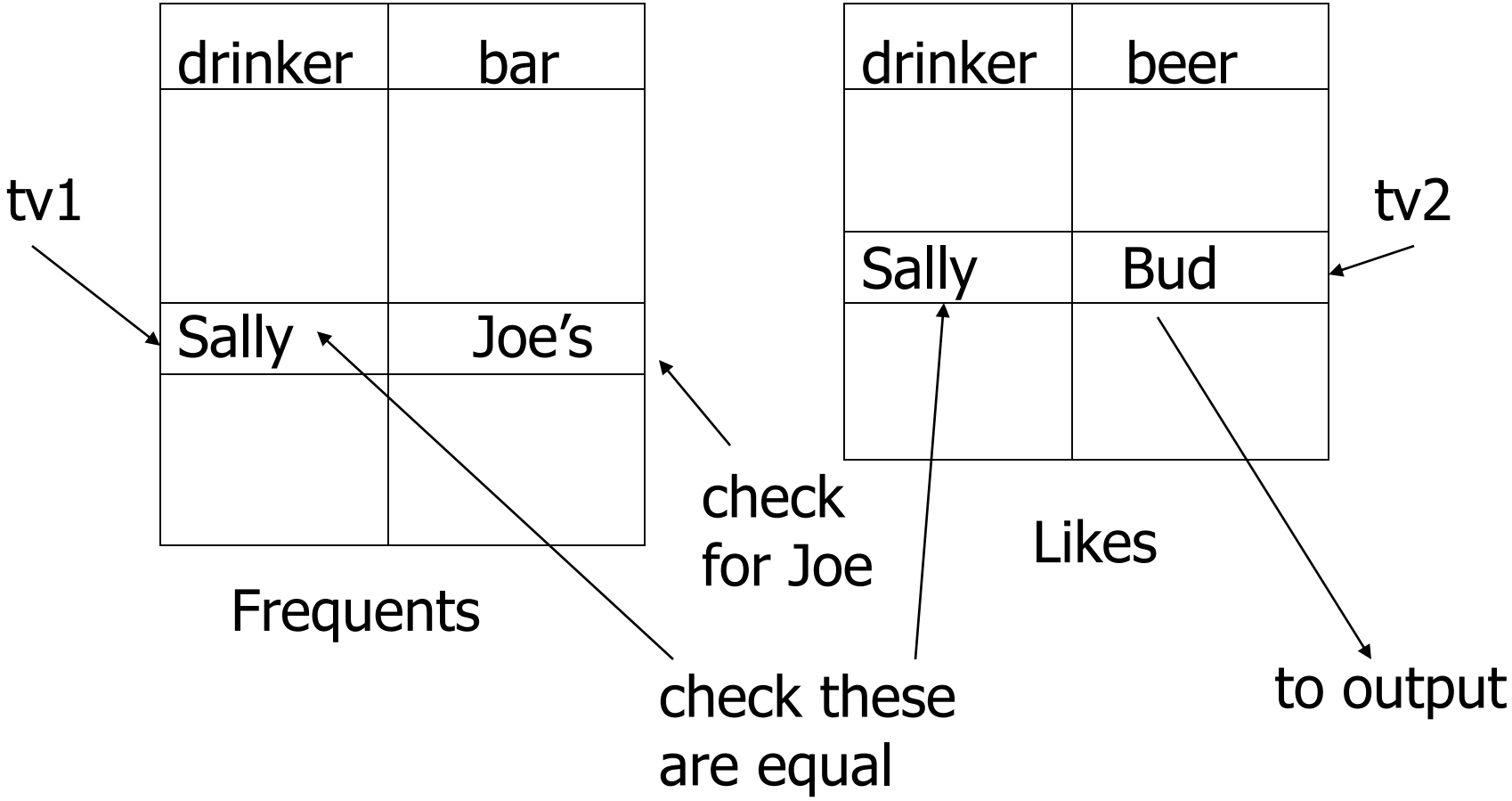
Operational Semantics

Imagine one tuple-variable for each relation in the FROM clause.

- These tuple-variables visit each combination of tuples, one from each relation.

If the tuple-variables are pointing to tuples that satisfy the WHERE clause, send these tuples to the SELECT clause.

Example


drinker
bar
Sally
Joe's
Frequents
tv1
drinker
beer
Sally
Bud
Likes
tv2
check
for Joe
check these
are equal
to output

Explicit Tuple-Variables

Sometimes, a query needs to use two copies of the same relation.

Distinguish copies by following the relation name by the name of a tuple-variable, in the FROM clause.

It is always an option to rename relations this way, even when not essential.

Example: Self-Join

From Beers(name, manf), find all pairs of beers by the same manufacturer.

- Do not produce pairs like (Bud, Bud).
- Produce pairs in alphabetic order, e.g. (Bud, Miller), not (Miller, Bud).

```
SELECT b1.name, b2.name
FROM Beers b1, Beers b2
WHERE b1.manf = b2.manf AND
      b1.name < b2.name;
```

Example: Self-Join

From Beers(name, manf), find all pairs of beers by the same manufacturer.

- Do not produce pairs like (Bud, Bud).
- Produce pairs in reverse alphabetic order, e.g. (Miller, Bud), not (Bud, Miller).

```
SELECT ...
```

Subqueries

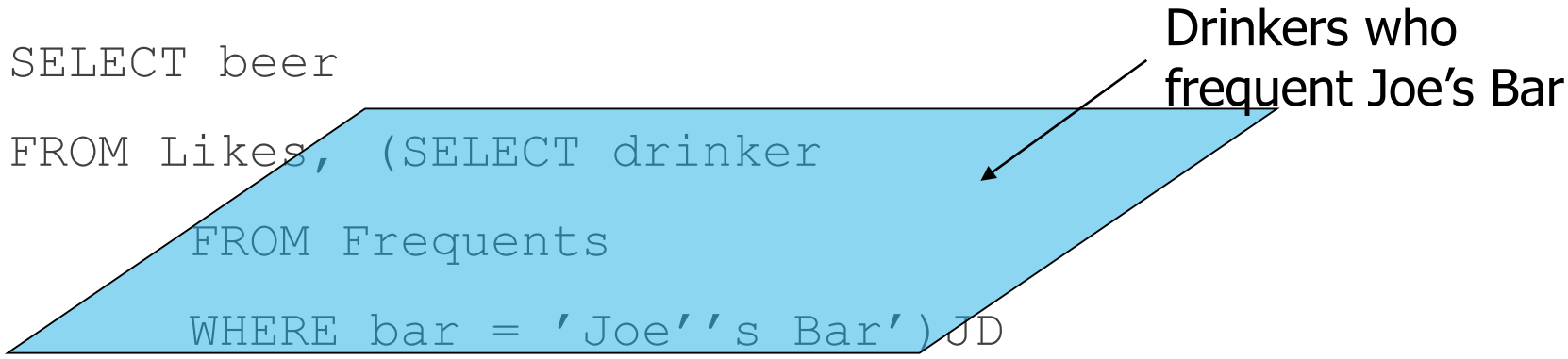
A parenthesized SELECT-FROM-WHERE statement (*subquery*) can be used as a value in a number of places, including FROM and WHERE clauses.

Example: in place of a relation in the FROM clause, we can use a subquery and then query its result.

- Must use a tuple-variable to name tuples of the result.

Example: Subquery in FROM

Find the beers liked by at least one person who frequents Joe's Bar.




```
SELECT beer
FROM Likes, (SELECT drinker
      FROM Frequents
      WHERE bar = 'Joe''s Bar')JD
WHERE Likes.drinker = JD.drinker;
```

Subqueries That Return One Tuple

If a subquery is guaranteed to produce one tuple, then the subquery can be used as a value.

- Usually, the tuple has one component.
- A run-time error occurs if there is no tuple or more than one tuple.

Example: Single-Tuple Subquery

Using Sells(bar, beer, price), find the bars that serve Miller for the same price Joe charges for Bud.

Two queries would surely work:

1. Find the price Joe charges for Bud.
2. Find the bars that serve Miller at that price.

Query + Subquery Solution

```
SELECT bar
FROM Sells
WHERE beer = 'Miller' AND
        price = (SELECT price
                 FROM Sells
                 WHERE bar = 'Joe''s Bar'
                       AND beer = 'Bud');
```

The price at which Joe sells Bud

The IN Operator

<tuple> IN (<subquery>) is true if and only if the tuple is a member of the relation produced by the subquery.

- Opposite: <tuple> NOT IN (<subquery>).

IN-expressions can appear in WHERE clauses.

Example: IN

Using Beers(name, manf) and Likes(drinker, beer), find the name and manufacturer of each beer that Fred likes.

```
SELECT *
FROM Beers
WHERE name IN (SELECT beer
               FROM Likes
               WHERE drinker = 'Fred');
```

The set of beers Fred likes

Remember These From Lecture #1?

```
SELECT a
FROM R, S
WHERE R.b = S.b;


SELECT a
FROM R
WHERE b IN (SELECT b FROM S);
```

IN is a Predicate About R's Tuples

```
SELECT a
FROM R
WHERE b IN (SELECT b FROM S);
```

Two 2's

One loop, over the tuples of R

a	b
1	2
3	4

R

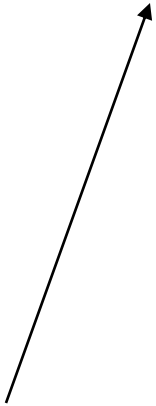
b	c
2	5
2	6

S

(1,2) satisfies the condition; 1 is output once.

This Query Pairs Tuples from R, S

```
SELECT a
FROM R, S
WHERE R.b = S.b;
```



Double loop, over the tuples of R and S

a	b
1	2
3	4

R

b	c
2	5
2	6

S

(1,2) with (2,5) and (1,2) with (2,6) both satisfy the condition;
1 is output twice.

The Exists Operator

EXISTS(<subquery>) is true if and only if the subquery result is not empty.

We can also use NOT EXSISTS

Example: From Beers(name, manf) , find those beers that are the unique beer by their manufacturer.

Example: EXISTS

```
SELECT name
FROM Beers b1
WHERE NOT EXISTS (
        SELECT *
        FROM Beers b2
        WHERE b2.manf = b1.manf AND
                b2.name <> b1.name);
```

Set of beers with the same manf as b1, but not the same beer

Notice the SQL "not equals" operator

The Operator ANY

x = ANY(<subquery>) is a boolean condition that is true iff *x* equals at least one tuple in the subquery result.

- = could be any comparison operator.

Example: *x* >= ANY(<subquery>) means *x* is not the uniquely smallest tuple produced by the subquery.

- Note tuples must have one component only.

The Operator ALL

x <> ALL(<subquery>) is true iff for every tuple *t* in the relation, *x* is not equal to *t*.

- That is, *x* is not in the subquery result.

<> can be any comparison operator.

Example: *x* >= ALL(<subquery>) means there is no tuple larger than *x* in the subquery result.

Example: ALL

From Sells(bar, beer, price), find the beer(s) sold for the highest price.

```
SELECT beer
FROM Sells
WHERE price >= ALL(
        SELECT price
        FROM Sells);
```

price from the outer Sells must not be less than any price.

Union, Intersection, and Difference

Union, intersection, and difference of relations are expressed by the following forms, each involving subqueries:

- (<subquery>) UNION (<subquery>)
- (<subquery>) INTERSECT (<subquery>)
- (<subquery>) EXCEPT (<subquery>)

Example: Intersection

Using Likes(drinker, beer), Sells(bar, beer, price), and Frequents(drinker, bar), find the drinkers and beers such that:

1. The drinker likes the beer, and
2. The drinker frequents at least one bar that sells the beer.

Notice trick: subquery is really a stored table.

Solution

```
(SELECT * FROM Likes)
INTERSECT
(SELECT drinker, beer
 FROM Sells, Frequents
 WHERE Frequents.bar = Sells.bar
);
```

The drinker frequents a bar that sells the beer.

Bag/Set Semantics

Although the SELECT-FROM-WHERE statement uses bag semantics, the default for union, intersection, and difference is set semantics!!

- That is, duplicates are eliminated as the operation is applied.

Motivation: Efficiency

When doing projection, it is easier to avoid eliminating duplicates.

- Just work tuple-at-a-time.

For intersection or difference, it is most efficient to sort the relations first.

- At that point you may as well eliminate the duplicates anyway.

Controlling Duplicate Elimination

Force the result to be a set by SELECT DISTINCT . . .

Force the result to be a bag (i.e., don't eliminate duplicates) by ALL, as in . . . UNION ALL . . .

Example: DISTINCT

From Sells(bar, beer, price), find all the different prices charged for beers:

```
SELECT DISTINCT price
FROM Sells;
```

Notice that without DISTINCT, each price would be listed as many times as there were bar/beer pairs at that price.

Example: ALL

Using relations Frequents(drinker, bar) and Likes(drinker, beer):

```
(SELECT drinker FROM Frequents)
    EXCEPT ALL
(SELECT drinker FROM Likes);
```

Lists drinkers who frequent more bars than they like beers, and does so as many times as the difference of those counts.

Join Expressions

SQL provides several versions of (bag) joins.

These expressions can be stand-alone queries or used in place of relations in a FROM clause.

Products and Natural Joins

Natural join:

R NATURAL JOIN S;

Product:

R CROSS JOIN S;

Example:

```
Likes NATURAL JOIN Sells;
```

Relations can be parenthesized subqueries, as well.

Theta Join

R JOIN S ON <condition>

Example: using Drinkers(name, addr) and Frequents(drinker, bar):

```
Drinkers JOIN Frequents ON
        name = drinker;
```

gives us all (*d, a, d, b*) quadruples such that drinker *d* lives at address *a* and frequents bar *b*.

Actions

Review slides.

Read chapter about SQL (Chapters 6.1-3 in 2nd Edition of course book).

Next class: SQL Advanced.

Play with SQL: http://www.w3schools.com/sql/default.asp