Introduction to SQL

Select-From-Where Statements

Multirelation Queries

Subqueries

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.
  - Underline indicates key attributes.

Lemonades(name, manf)

Bars(name, addr, license)

Drinkers(name, addr, phone)

Likes(drinker, lemonade)

Sells(bar, lemonade, price)

Frequents(drinker, bar)

Example

- Using Lemonades(name, manf), what lemonades are made by Anheuser-Busch?

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

Result of Query

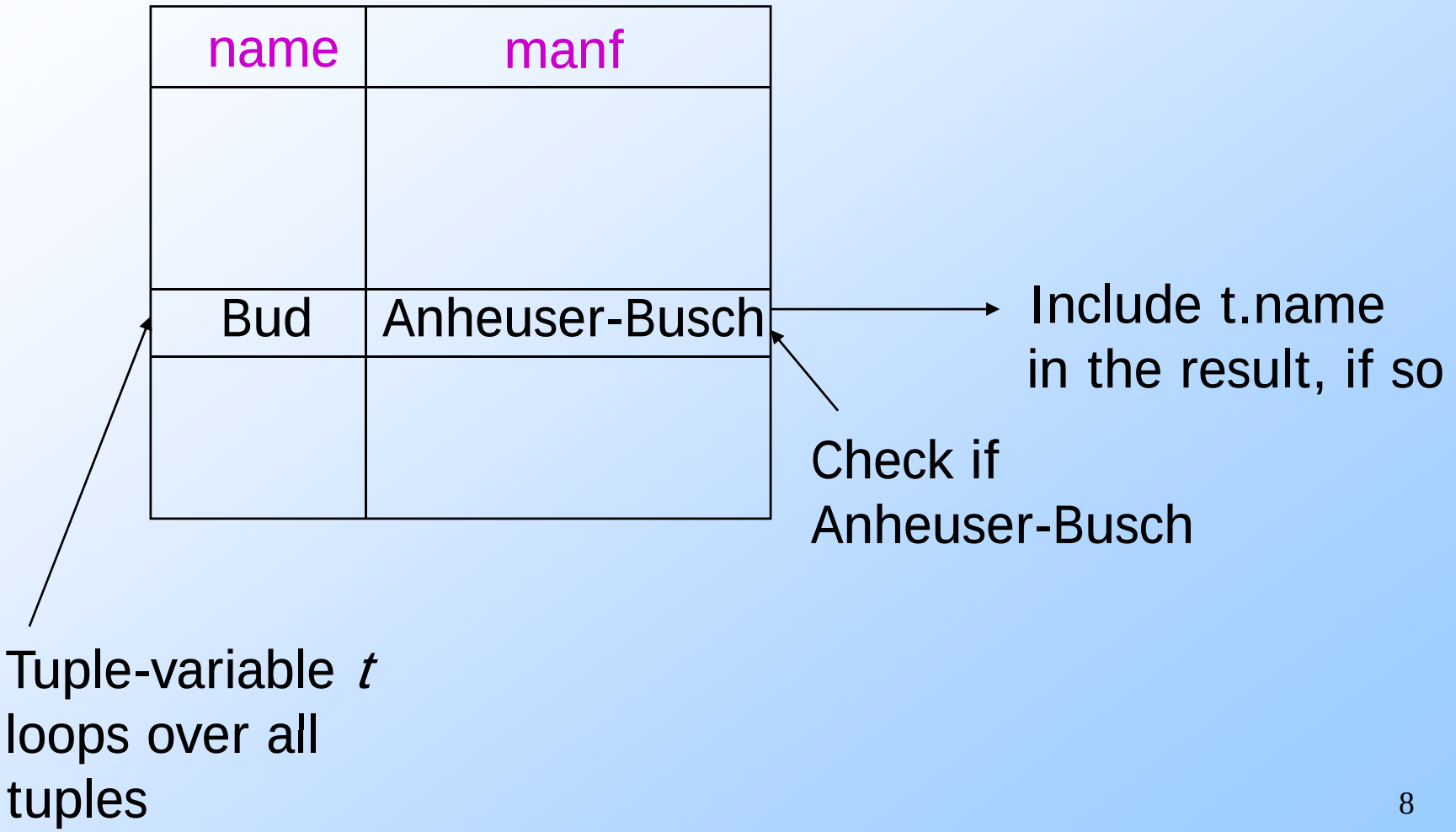
name
Bud
Bud Lite
Michelob
. . .

The answer is a relation with a single attribute, name, and tuples with the name of each lemonade 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



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.

* 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 Lemonades(name, manf):

```
SELECT *
FROM Lemonades
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 Lemonades.

Renaming Attributes

- If you want the result to have different attribute names, use “AS <new name>” to rename an attribute.
- Example: Using Lemonades(name, manf):

```
SELECT name AS lemonade, manf
FROM Lemonades
WHERE manf = 'Anheuser-Busch'
```

Result of Query:

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

Expressions in SELECT Clauses

- Any expression that makes sense can appear as an element of a SELECT clause.
- Example: Using Sells(bar, lemonade, price):

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

Result of Query

bar	lemonade	priceInYen
Joe's	Bud	285
Sue's	Miller	342
...	...	...

Example: Constants as Expressions

- Using Likes(drinker, lemonade):

```
SELECT drinker,
       'likes Bud' AS whoLikesBud
FROM Likes
WHERE lemonade = '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(lemonade, price) .
- To contribute to Sells(bar, lemonade, 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', lemonade,
  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, lemonade, price), find the price Joe's Bar charges for Bud:

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

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-_ _ _ _';
```

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	lemonade	price
Joe's Bar	Bud	NULL

```
SELECT bar
FROM Sells
WHERE price < 2.00 OR price >= 2.00;
```

UNKNOWN UNKNOWN

UNKNOWN

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, lemonade) and Frequents(drinker, bar), find the lemonades liked by at least one person who frequents Joe's Bar.

```
SELECT lemonade
FROM Likes, Frequents
WHERE bar = 'Joe''s Bar' AND
   Frequents.drinker =
       Likes.drinker;
```

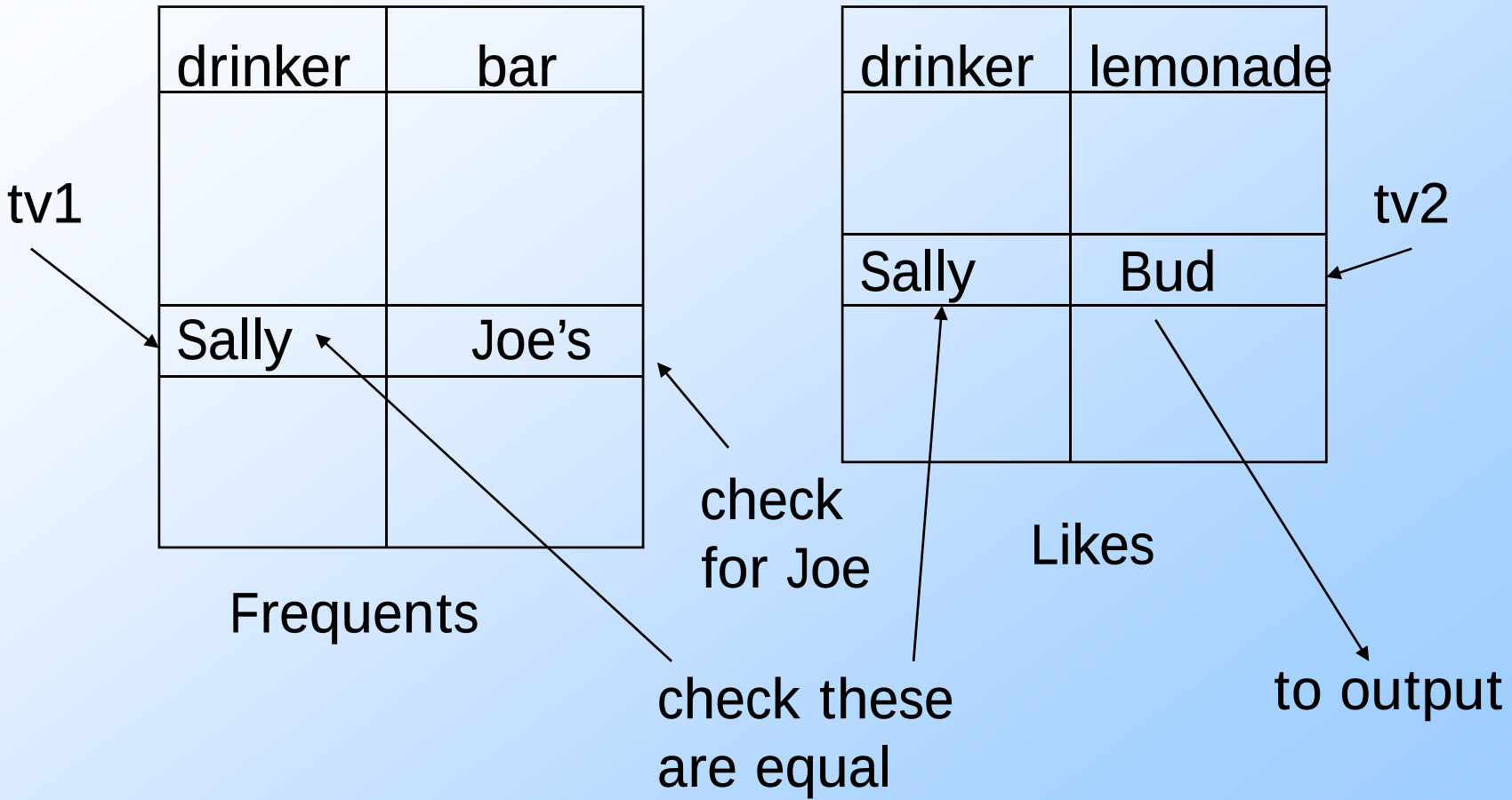
Formal Semantics

- 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
lemonade
Sally
Bud
tv2
Likes
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's always an option to rename relations this way, even when not essential.

Example: Self-Join

- From Lemonades(name, manf), find all pairs of lemonades by the same manufacturer.
  - Do not produce pairs like (Bud, Bud).
  - Produce pairs in alphabetic order, e.g. (Bud, Miller), not (Miller, Bud).

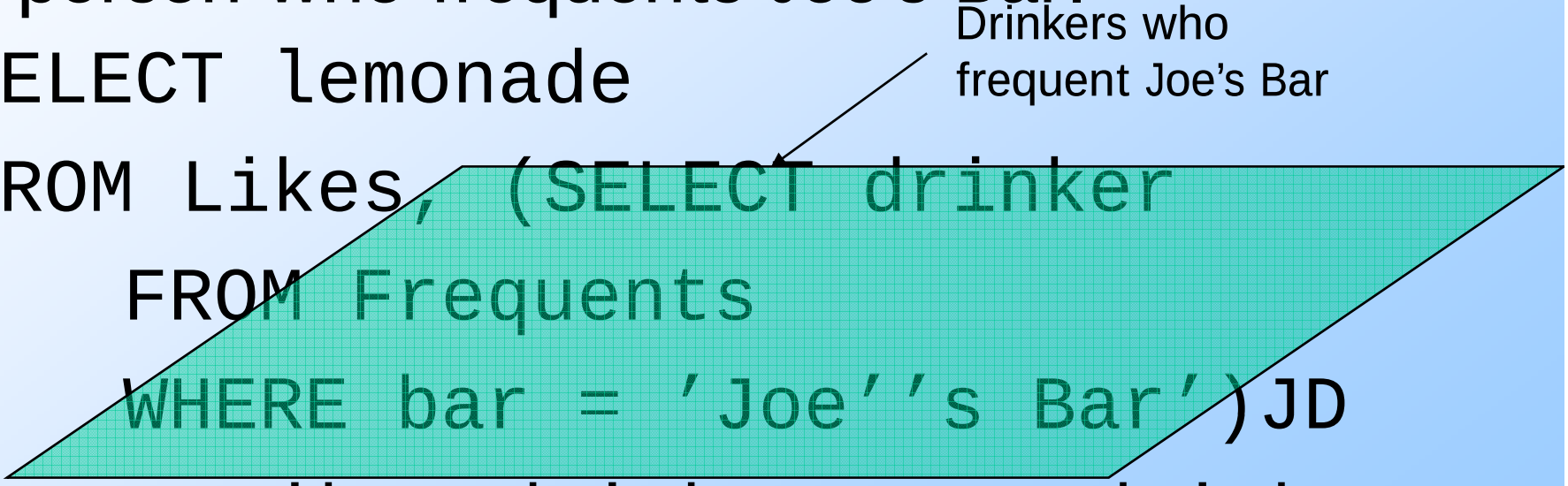
```
SELECT b1.name, b2.name
FROM Lemonades b1, Lemonades b2
WHERE b1.manf = b2.manf AND
   b1.name < b2.name;
```

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 lemonades liked by at least one person who frequents Joe's Bar.




```
SELECT lemonade
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.

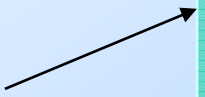
Example: Single-Tuple Subquery

- Using Sells(bar, lemonade, 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 lemonade = 'Miller' AND
    price = (SELECT price
             FROM Sells
             WHERE bar = 'Joe''s Bar'
               AND lemonade = '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 Lemonades(name, manf) and Likes(drinker, lemonade), find the name and manufacturer of each lemonade that Fred likes.

```
SELECT *
FROM Lemonades
WHERE name IN (SELECT lemonade
               FROM Likes
               WHERE drinker = 'Fred');
```

The set of lemonades 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

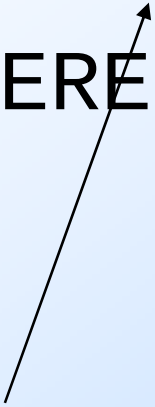
b	c
2	5
2	6

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.
- Example: From Lemonedes(name, manf) , find those lemonades that are the unique lemonade by their manufacturer.

Example: EXISTS

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

Notice scope rule: manf refers to closest nested FROM with a relation having that attribute.

Set of lemonades with the same manf as b1, but not the same lemonade

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, lemonade, price), find the lemonade(s) sold for the highest price.

```
SELECT lemonade
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, lemonade), Sells(bar, lemonade, price), and Frequents(drinker, bar), find the drinkers and lemonades such that:
  1. The drinker likes the lemonade, and
  2. The drinker frequents at least one bar that sells the lemonade.

Solution

Notice trick: subquery is really a stored table.

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

The drinker frequents a bar that sells the lemonade.

Bag 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, lemonade, price), find all the different prices charged for lemonades:

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

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

Example: ALL

- Using relations Frequents(drinker, bar) and Likes(drinker, lemonade):

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

- Lists drinkers who frequent more bars than they like lemonades, 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:

```
SELECT * FROM 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):

```
SELECT * FROM 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*.