

# Chapter 3: SQL

# Chapter 3: SQL

- ❑ Data Definition
- ❑ Basic Query Structure
- ❑ Set Operations
- ❑ Aggregate Functions
- ❑ Null Values
- ❑ Nested Subqueries
- ❑ Complex Queries
- ❑ Views
- ❑ Modification of the Database

# History

- ❑ IBM Sequel language developed as part of System R project at the IBM San Jose Research Laboratory
- ❑ Renamed Structured Query Language (SQL)
- ❑ ANSI and ISO standard SQL:
  - SQL-86
  - SQL-89
  - SQL-92
  - SQL:1999 (language name became Y2K compliant!)
  - SQL:2003
  - SQL:2006
  - SQL:2008
- ❑ Commercial systems offer most, if not all, SQL-92 features, plus varying feature sets from later standards and special proprietary features.
  - Not all examples here may work on your particular system.

# Data Definition Language

- ❑ The set of relations in a database must be specified to the system by means of a data-definition language (DDL)
- ❑ Allows the specification of not only a set of relations but also information about each relation, including:
  - The schema for each relation.
  - The domain of values associated with each attribute.
  - Integrity constraints
  - The set of indices to be maintained for each relations.
  - Security and authorization information for each relation.
  - The physical storage structure of each relation on disk.

# Domain Types in SQL

- ❑ **char(*n*)**. Fixed length character string, with user-specified length *n*.
- ❑ **varchar(*n*)**. Variable length character strings, with user-specified maximum length *n*.
- ❑ **int**. Integer (a finite subset of the integers that is machine-dependent).
- ❑ **smallint**. Small integer (a machine-dependent subset of the integer domain type).
- ❑ **numeric(*p*,*d*)**. Fixed point number, with user-specified precision of *p* digits, with *d* digits to the right of decimal point.
  - numeric(3,1) allows 44.5 to be stored exactly, but neither 444.5 or 0.32 can be stored exactly.
- ❑ **real, double precision**. Floating point and double-precision floating point numbers, with machine-dependent precision.
- ❑ **float(*n*)**. Floating point number, with user-specified precision of at least *n* digits.
- ❑ More are covered in Chapter 4.

# Create Table Construct

- ❑ An SQL relation is defined using the **create table** command:

```
create table  $r$  ( $A_1$   $D_1$ ,  $A_2$   $D_2$ , ...,  $A_n$   $D_n$ ,  
                (integrity-constraint1),  
                ...,  
                (integrity-constraintk))
```

- $r$  is the name of the relation
- each  $A_i$  is an attribute name in the schema of relation  $r$
- $D_i$  is the data type of values in the domain of attribute  $A_i$

- ❑ Example:

```
create table branch  
  (branch_name  char(15) not null,  
   branch_city char(30),  
   assets       integer)
```

# Integrity Constraints in Create Table

- ❑ not null
- ❑ primary key ( $A_1, \dots, A_n$ )

Example: Declare *branch\_name* as the primary key for *branch*.

```
create table branch
    (branch_name char(15),
     branch_city   char(30),
     assets         integer,
     primary key (branch_name))
```

**primary key** declaration on an attribute automatically ensures  
**not null**

# Drop and Alter Table Constructs

- ❑ **drop table** command: deletes all information about the dropped relation from the database.

**drop table**  $r$

- ❑ **alter table** command: add attributes to an **existing** relation:

**alter table**  $r$  **add**  $A$   $D$

where  $A$  is the name of the attribute to be added to relation  $r$  and  $D$  is the domain of  $A$ .

- All tuples in the relation are assigned *null* as the value for the new attribute.

- ❑ The **alter table** command can also be used to drop **attributes** of a relation:

**alter table**  $r$  **drop**  $A$

where  $A$  is the name of an attribute of relation  $r$

- Dropping of attributes not supported by many databases



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# Basic Query Structure

- ❑ SQL is based on set and relational operations with certain modifications and enhancements
- ❑ A typical SQL query has the form:

**select**  $A_1, A_2, \dots, A_n$   
**from**  $r_1, r_2, \dots, r_m$   
**where**  $P$

- $A_i$  represents an attribute
  - $r_i$  represents a relation
  - $P$  is a predicate.
- ❑ This query is equivalent to the relational algebra expression.

$$\Pi_{A_1, A_2, \dots, A_n} (\sigma_P (r_1 \times r_2 \times \dots \times r_m))$$

- ❑ The result of an SQL query is a **relation**.

# The select Clause

- ❑ The **select** clause list the attributes desired in the result of a query
  - corresponds to the **projection** operation of the relational algebra

- ❑ Example: find the names of all branches in the *loan* relation:

**select** *branch\_name*  
**from** *loan*

- ❑ In the relational algebra, the query would be:

$\Pi_{branch\_name}(loan)$

- ❑ NOTE: SQL names are **case insensitive** (i.e., you may use upper- or lower-case letters.)
  - E.g. *Branch\_Name*  $\equiv$  *BRANCH\_NAME*  $\equiv$  *branch\_name*
  - Some people use upper case wherever we use bold font.

# SQL Example 1

<i>customer-id</i>	<i>customer-name</i>	<i>customer-street</i>	<i>customer-city</i>
019-28-3746	Smith	North	Rye
182-73-6091	Turner	Putnam	Stamford
192-83-7465	Johnson	Alma	Palo Alto
244-66-8800	Curry	North	Rye
321-12-3123	Jones	Main	Harrison
335-57-7991	Adams	Spring	Pittsfield
336-66-9999	Lindsay	Park	Pittsfield
677-89-9011	Hayes	Main	Harrison
963-96-3963	Williams	Nassau	Princeton

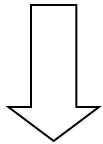
❑ SELECT *customer-id*  
FROM CUST

❑ The result on the right will be  
shown on screen.

<i>customer-id</i>
019-28-3746
182-73-6091
192-83-7465
244-66-8800
321-12-3123
335-57-7991
336-66-9999
677-89-9011
963-96-3963

# SQL Example 1

<i>customer-id</i>	<i>customer-name</i>	<i>customer-street</i>	<i>customer-city</i>
019-28-3746	Smith	North	Rye
182-73-6091	Turner	Putnam	Stamford
192-83-7465	Johnson	Alma	Palo Alto
244-66-8800	Curry	North	Rye
321-12-3123	Jones	Main	Harrison
335-57-7991	Adams	Spring	Pittsfield
336-66-9999	Lindsay	Park	Pittsfield
677-89-9011	Hayes	Main	Harrison
963-96-3963	Williams	Nassau	Princeton



019-28-3746
182-73-6091
192-83-7465
244-66-8800
321-12-3123
335-57-7991
336-66-9999
677-89-9011
963-96-3963

❑ SELECT *customer-id*  
FROM CUST

❑ This is called a **projection**.

# The select Clause (Cont.)

- ❑ SQL allows duplicates in relations as well as in query results.
- ❑ To force the elimination of duplicates, insert the keyword **distinct** after select.
- ❑ Find the names of all branches in the *loan* relations, and remove duplicates

```
select distinct branch_name  
from loan
```

- ❑ The keyword **all** specifies that duplicates not be removed.

```
select all branch_name  
from loan
```

# SQL example 2

<i>customer-id</i>	<i>customer-name</i>	<i>customer-street</i>	<i>customer-city</i>
019-28-3746	Smith	North	Rye
182-73-6091	Turner	Putnam	Stamford
192-83-7465	Johnson	Alma	Palo Alto
244-66-8800	Curry	North	Rye
321-12-3123	Jones	Main	Harrison
335-57-7991	Adams	Spring	Pittsfield
336-66-9999	Lindsay	Park	Pittsfield
677-89-9011	Hayes	Main	Harrison
963-96-3963	Williams	Nassau	Princeton

<i>customer-city</i>
Rye
Stamford
Palo Alto
Rye
Harrison
Pittsfield
Pittsfield
Harrison
Princeton

❑ SELECT *customer-city*  
FROM CUST

❑ SELECT **DISTINCT** *customer-city*  
FROM CUST

<i>customer-city</i>
Rye
Stamford
Palo Alto
<del>Rye</del>
Harrison
Pittsfield
<del>Pittsfield</del>
<del>Harrison</del>
Princeton

# The select Clause (Cont.)

- ❑ An **asterisk** in the select clause denotes “all attributes”

```
select *  
from loan
```

- ❑ The **select** clause can contain arithmetic expressions involving the operation, +, −, \*, and /, and operating on constants or attributes of tuples.
- ❑ The query:

```
select loan_number, branch_name, amount * 100  
from loan
```

would return a relation that is the same as the *loan* relation, except that the value of the attribute *amount* is multiplied by 100.



# The where Clause

- ❑ The **where** clause specifies conditions that the result must satisfy
  - Corresponds to the selection predicate of the relational algebra.
- ❑ To find all loan number for loans made at the Perryridge branch with loan amounts greater than \$1200.

```
select loan_number  
from loan  
where branch_name = 'Perryridge' and amount > 1200
```

- ❑ Comparison results can be combined using the logical connectives **and**, **or**, and **not**.
- ❑ Comparisons can be applied to results of arithmetic expressions.

# The where Clause (Cont.)

- ❑ SQL includes a **between** comparison operator
- ❑ Example: Find the loan number of those loans with loan amounts between \$90,000 and \$100,000 (that is,  $\geq$  \$90,000 and  $\leq$  \$100,000)

```
select loan_number  
from loan  
where amount between 90000 and 100000
```

# The from Clause

- ❑ The **from** clause lists the relations involved in the query
  - Corresponds to the Cartesian product operation of the relational algebra.
- ❑ Find the Cartesian product *borrower X loan*

```
select *  
from borrower, loan
```

- ❑ Find the name, loan number and loan amount of all customers having a loan at the Perryridge branch.

```
select customer_name, borrower.loan_number, amount  
from borrower, loan  
where borrower.loan_number = loan.loan_number and  
branch_name = 'Perryridge'
```

# SQL example 3

<i>cust-id</i>	<i>name</i>
1	John
2	Smith
3	Joan

<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A2	1	5k
A3	2	35k
A4	3	100k

- ❑ Write an SQL query to display, for each account, its id and the name of its owner.
- ❑ Obviously, we cannot answer this query using only one table.
- ❑ We need to do filtering and projection on the cartesian product.
- ❑ Answer:  
SELECT ACC.*acc-id*, CUST.*name*  
FROM CUST, ACC  
WHERE CUST.*cust-id* = ACC.*cust-id*
- ❑ Let us understand the query step-by-step.

# SQL example 3 (cont.)

CUST

<i>cust-id</i>	<i>name</i>
1	John
2	Smith
3	Joan

ACC

<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A2	1	5k
A3	2	35k
A4	3	100k

- SELECT ACC.*acc-id*, CUST.*name*  
FROM CUST, ACC  
WHERE  
CUST.*cust-id* = ACC.*cust-id*

- First, compute the cartesian product.

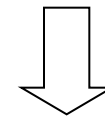
CUST. <i>cust-id</i>	CUST. <i>name</i>	ACC. <i>acc-id</i>	ACC. <i>cust-id</i>	ACC. <i>balance</i>
1	John	A1	1	20k
1	John	A2	1	5k
1	John	A3	2	35k
1	John	A4	3	100k
2	Smith	A1	1	20k
2	Smith	A2	1	5k
2	Smith	A3	2	35k
2	Smith	A4	3	100k
3	Joan	A1	1	20k
3	Joan	A2	1	5k
3	Joan	A3	2	35k
3	Joan	A4	3	100k

# SQL example 3 (cont.)

CUST. <i>cust-id</i>	CUST. <i>name</i>	ACC. <i>acc-id</i>	ACC. <i>cust-id</i>	ACC. <i>balance</i>
1	John	A1	1	20k
1	John	A2	1	5k
1	John	A3	2	35k
1	John	A4	3	100k
2	Smith	A1	1	20k
2	Smith	A2	1	5k
2	Smith	A3	2	35k
2	Smith	A4	3	100k
3	Joan	A1	1	20k
3	Joan	A2	1	5k
3	Joan	A3	2	35k
3	Joan	A4	3	100k

❑ SELECT ACC.*acc-id*, CUST.*name*  
FROM CUST, ACC  
WHERE  
*CUST.cust-id = ACC.cust-id*

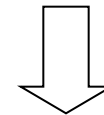
❑ Then, on the cartesian product,  
perform filtering.



CUST. <i>cust-id</i>	CUST. <i>name</i>	ACC. <i>acc-id</i>	ACC. <i>cust-id</i>	ACC. <i>balance</i>
1	John	A1	1	20k
1	John	A2	1	5k
2	Smith	A3	2	35k
3	Joan	A4	3	100k

## SQL example 3 (cont.)

CUST. <i>cust-id</i>	CUST. <i>name</i>	ACC. <i>acc-id</i>	ACC. <i>cust-id</i>	ACC. <i>balance</i>
1	John	A1	1	20k
1	John	A2	1	5k
2	Smith	A3	2	35k
3	Joan	A4	3	100k

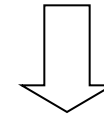


ACC. <i>acc-id</i>	CUST. <i>name</i>
A1	John
A2	John
A3	Smith
A4	Joan

- ❑ **SELECT** ACC.*acc-id*, CUST.*name*  
FROM CUST, ACC  
WHERE CUST.*cust-id* = ACC.*cust-id*
- ❑ Finally, apply projection.
- ❑ In general, if a query involves two (or more) relations, we call it a **join**.

## SQL example 3 (cont.)

CUST. <i>cust-id</i>	CUST. <i>name</i>	ACC. <i>acc-id</i>	ACC. <i>cust-id</i>	ACC. <i>balance</i>
1	John	A1	1	20k
1	John	A2	1	5k
2	Smith	A3	2	35k
3	Joan	A4	3	100k



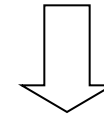
ACC. <i>acc-id</i>	CUST. <i>name</i>
A1	John
A2	John
A3	Smith
A4	Joan

- ❑ SELECT *ACC.acc-id*, *CUST.name*  
FROM CUST, ACC  
WHERE CUST.*cust-id* = ACC.*cust-id*
- ❑ The above query can be simplified as:
- ❑ SELECT *acc-id*, *name*  
FROM CUST, ACC  
WHERE CUST.*cust-id* = ACC.*cust-id*
- ❑ No ambiguity can arise because CUST doesn't have 'acc-id' and ACC doesn't have 'name'.



## SQL example 3 (cont.)

CUST. <i>cust-id</i>	CUST. <i>name</i>	ACC. <i>acc-id</i>	ACC. <i>cust-id</i>	ACC. <i>balance</i>
1	John	A1	1	20k
1	John	A2	1	5k
2	Smith	A3	2	35k
3	Joan	A4	3	100k



ACC. <i>acc-id</i>	CUST. <i>name</i>
A1	John
A2	John
A3	Smith
A4	Joan

- ❑ SELECT *acc-id, name*  
FROM CUST, ACC  
WHERE CUST.*cust-id* = ACC.*cust-id*
- ❑ The above query can be further written as:  
SELECT *acc-id, name*  
FROM CUST T1, ACC T2  
WHERE T1.*cust-id* = T2.*cust-id*
- ❑ T1 and T2 are used to rename the input tables.

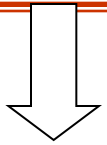
# The Rename Operation

- ❑ The SQL allows **renaming** relations and attributes using the **as** clause:  
*old-name as new-name*
- ❑ Find the name, loan number and loan amount of all customers; rename the column name *loan\_number* as *loan\_id*.

```
select customer_name, borrower.loan_number as loan_id, amount  
from borrower, loan  
where borrower.loan_number = loan.loan_number
```

# SQL example 4

<i>customer-id</i>	<i>customer-name</i>	<i>customer-street</i>	<i>customer-city</i>
019-28-3746	Smith	North	Rye
182-73-6091	Turner	Putnam	Stamford
192-83-7465	Johnson	Alma	Palo Alto
244-66-8800	Curry	North	Rye
321-12-3123	Jones	Main	Harrison
335-57-7991	Adams	Spring	Pittsfield
336-66-9999	Lindsay	Park	Pittsfield
677-89-9011	Hayes	Main	Harrison
963-96-3963	Williams	Nassau	Princeton



cid
019-28-3746
182-73-6091
192-83-7465
244-66-8800
321-12-3123
335-57-7991
336-66-9999
677-89-9011
963-96-3963

- ❑ `SELECT customer-id AS cid`  
`FROM CUST`
- ❑ Use **AS** in SELECT clause to rename output columns

# SQL example 4

<i>customer-id</i>	<i>customer-name</i>	<i>customer-street</i>	<i>customer-city</i>
019-28-3746	Smith	North	Rye
182-73-6091	Turner	Putnam	Stamford
192-83-7465	Johnson	Alma	Palo Alto
244-66-8800	Curry	North	Rye
321-12-3123	Jones	Main	Harrison
335-57-7991	Adams	Spring	Pittsfield
336-66-9999	Lindsay	Park	Pittsfield
677-89-9011	Hayes	Main	Harrison
963-96-3963	Williams	Nassau	Princeton

- ❑ SELECT *customer-id*, *customer-city*  
FROM CUST
- ❑ Projection onto 2 columns.

<i>customer-id</i>	<i>customer-city</i>
019-28-3746	Rye
182-73-6091	Stamford
192-83-7465	Palo Alto
244-66-8800	Rye
321-12-3123	Harrison
335-57-7991	Pittsfield
336-66-9999	Pittsfield
677-89-9011	Harrison
963-96-3963	Princeton

# Tuple Variables

- ❑ Tuple variables are defined in the **from** clause via the use of the **as** clause.
- ❑ Find the customer names and their loan numbers for all customers having a loan at some branch.

```
select customer_name, T.loan_number, S.amount  
from borrower as T, loan as S  
where T.loan_number = S.loan_number
```

- ❑ Find the names of all branches that have greater assets than some branch located in Brooklyn.

```
select distinct T.branch_name  
from branch as T, branch as S  
where T.assets > S.assets and S.branch_city = 'Brooklyn'
```

- ❑ Keyword **as** is optional and may be omitted

```
borrower as T  $\equiv$  borrower T
```

# String Operations

- ❑ SQL includes a string-matching operator for comparisons on character strings. The operator “like” uses patterns that are described using two special characters:
  - percent (%): The % character matches any substring.
  - underscore (\_) The \_ character matches any character.
- ❑ Find the names of all customers whose street includes the substring “Main”.

```
select customer_name  
from customer  
where customer_street like '% Main%'
```

- ❑ Match all strings beginning with “ab%cd”  
**like** 'ab\%cd%' **escape** '\'

- ❑ SQL supports a variety of string operations such as
  - concatenation (using “||”)
  - converting from upper to lower case (and vice versa)
  - finding string length, extracting substrings, etc.

# Ordering the Display of Tuples

- ❑ List in alphabetic order the names of all customers having a loan in Perryridge branch

```
select distinct customer_name  
from    borrower, loan  
where borrower loan_number = loan.loan_number and  
        branch_name = 'Perryridge'  
order by customer_name
```

- ❑ We may specify **desc** for descending order or **asc** for ascending order, for each attribute; ascending order is the default.
  - Example: **order by** *customer\_name* **desc**

# SQL example 4

- ❑ The previous queries do not have any ordering requirements.

- ❑ We can request ordered results using 'ORDER BY'.

- ❑ 

```
SELECT *  
FROM ACC  
WHERE balance > 10000  
ORDER BY balance
```

- ❑ 

```
SELECT *  
FROM ACC  
WHERE balance > 10000  
ORDER BY balance DESC
```

ACC

<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A2	1	5k
A3	2	35k
A4	3	100k

<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A3	2	35k
A4	3	100k

<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A4	3	100k
A3	2	35k
A1	1	20k



# Duplicates

- ❑ In relations with duplicates, SQL can define how many copies of tuples appear in the result.
- ❑ **Multiset**: set with repetitions
- ❑ **Multiset** versions of some of the relational algebra operators – given multiset relations  $r_1$  and  $r_2$ :
  1.  $\sigma_{\theta}(r_1)$ : If there are  $c_1$  copies of tuple  $t_1$  in  $r_1$ , and  $t_1$  satisfies selections  $\sigma_{\theta}$ , then there are  $c_1$  copies of  $t_1$  in  $\sigma_{\theta}(r_1)$ .
  2.  $\Pi_A(r)$ : For each copy of tuple  $t_1$  in  $r_1$ , there is a copy of tuple  $\Pi_A(t_1)$  in  $\Pi_A(r_1)$  where  $\Pi_A(t_1)$  denotes the projection of the single tuple  $t_1$ .
  3.  $r_1 \times r_2$ : If there are  $c_1$  copies of tuple  $t_1$  in  $r_1$  and  $c_2$  copies of tuple  $t_2$  in  $r_2$ , there are  $c_1 \times c_2$  copies of the tuple  $t_1 \cdot t_2$  in  $r_1 \times r_2$

# Duplicates (Cont.)

- Example: Suppose multiset relations  $r_1(A, B)$  and  $r_2(C)$  are as follows:

$$r_1 = \{(1, a), (2, a)\} \quad r_2 = \{(2), (3), (3)\}$$

- Then  $\Pi_B(r_1)$  would be  $\{(a), (a)\}$ , while  $\Pi_B(r_1) \times r_2$  would be

$$\{(a, 2), (a, 2), (a, 3), (a, 3), (a, 3), (a, 3)\}$$

- SQL duplicate semantics:

**select**  $A_1, A_2, \dots, A_n$   
**from**  $r_1, r_2, \dots, r_m$   
**where**  $P$

is equivalent to the *multiset* version of the expression:

$$\Pi_{A_1, A_2, \dots, A_n} (\sigma_P(r_1 \times r_2 \times \dots \times r_m))$$

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- ❑ Modification of the Database

# Set Operations

- ❑ The set operations **union**, **intersect**, and **except** operate on relations and correspond to the relational algebra operations  $\cup$ ,  $\cap$ ,  $-$ .
- ❑ Each of the above operations automatically eliminates duplicates; to retain all duplicates use the corresponding multiset versions **union all**, **intersect all** and **except all**.
- ❑ Suppose a tuple occurs  $m$  times in  $r$  and  $n$  times in  $s$ , then, it occurs:
  - $m + n$  times in  $r$  **union all**  $s$
  - $\min(m, n)$  times in  $r$  **intersect all**  $s$
  - $\max(0, m - n)$  times in  $r$  **except all**  $s$

# Set Operations

- ❑ Find all customers who have a loan, an account, or both:

**(select *customer\_name* from *depositor*)**

**union**

**(select *customer\_name* from *borrower*)**

- ❑ Find all customers who have both a loan and an account.

**(select *customer\_name* from *depositor*)**

**intersect**

**(select *customer\_name* from *borrower*)**

- ❑ Find all customers who have an account but no loan.

**(select *customer\_name* from *depositor*)**

**except**

**(select *customer\_name* from *borrower*)**

# Chapter 3: SQL

- ❑ Data Definition
- ❑ Basic Query Structure
- ❑ Set Operations
- ❑ **Aggregate Functions**
- ❑ Null Values
- ❑ Nested Subqueries
- ❑ Complex Queries
- ❑ Views
- ❑ Modification of the Database
- ❑ Joined Relations\*\*

# Aggregate Functions

- ❑ These functions operate on a collection (a set or multiset) of values of a column of a relation, and return a single value

**avg:** average value

**min:** minimum value

**max:** maximum value

**sum:** sum of values

**count:** number of values

- ❑ Note: An aggregate function *cannot* be used directly in *where* clause

# Aggregate Function Example

- ❑ Find the total amount of money ever deposited into account A1.

❑ `SELECT SUM(amount)`  
`FROM DEPOSIT`  
`WHERE acc-id = 'A1'`

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k

- ❑ Find the total number of times that account A1 has been deposited into.

❑ `SELECT COUNT(*)`  
`FROM DEPOSIT`  
`WHERE acc-id = 'A1'`



# Aggregate Function Example

- Find the number of **distinct** customers that ever deposited into account A1.

- SELECT **COUNT**(**DISTINCT** *cust-id*)  
FROM DEPOSIT  
WHERE *acc-id* = 'A1'

- Answer: 1

- Repeat the above query with respect to 'A3', the answer is 2.

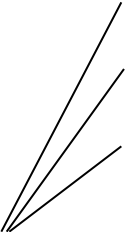
<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k

# Aggregate Functions – Group By

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k


❑ SELECT *acc-id*, SUM(*amount*)  
FROM DEPOSIT  
GROUP BY *acc-id*



<i>acc-id</i>	
A1	55k
A2	5k
A3	135k

3 groups

❑ SELECT *acc-id*, *cust-id*, SUM(*amount*)  
FROM DEPOSIT  
GROUP BY *acc-id*, *cust-id*



<i>acc-id</i>	<i>cust-id</i>	
A1	1	55k
A2	1	5k
A3	2	35k
A3	3	100k

4 groups

# Aggregate Functions – Group By

- ❑ In a group-by query, the SELECT clause can involve i) **attribute names** and ii) aggregate functions
  - **attribute name** must be some attribute appeared in the GROUP BY clause
  - aggregate function can take any attribute as argument
  - *have a single value per group!*

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k

- ❑ For example  
SELECT *acc-id*, *cust-id*, SUM(*amount*)  
FROM DEPOSIT  
**GROUP BY** *acc-id*

is wrong, due to the presence of *cust-id*.

# Aggregate Functions – Having Clause

*branch (branch\_name, branch\_city, assets)*

*customer (customer\_name, customer\_street, customer\_city)*

*account (account\_number, branch\_name, balance)*

*loan (loan\_number, branch\_name, amount)*

*depositor (customer\_name, account\_number)*

*borrower (customer\_name, loan\_number)*

- ❑ Find the names of all branches where the average account balance is more than \$1,200.

```
select branch_name, avg (balance)
from account
group by branch_name
having avg (balance) > 1200
```

- Note: predicates in the **having** clause are applied after the formation of groups whereas predicates in the **where** clause are applied before forming groups

# Aggregate Functions – Having

- Find the total amount of money ever deposited into each account, provided that the account has been deposited at least twice.

```
SELECT acc-id, SUM(amount)  
FROM DEPOSIT  
GROUP BY acc-id  
HAVING COUNT(*) >= 2
```

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k

- HAVING applies only to groups, and hence, can be used with GROUP BY only.
- HAVING usually contains only aggregate functions.
- Let us see how the above query is executed.

# Aggregate Functions – Having

❑ SELECT *acc-id*, SUM(*amount*)  
FROM DEPOSIT  
GROUP BY *acc-id*  
HAVING COUNT(\*) >= 2

❑ First, process GROUP BY.

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k

DEPOSIT

GROUP 1 {

GROUP 2

GROUP 3 {

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A1	1	35k
A2	1	5k
A3	2	35k
A3	3	100k

# Aggregate Functions – Having

- ❑ SELECT *acc-id*, SUM(*amount*)  
FROM DEPOSIT  
GROUP BY *acc-id*  
HAVING COUNT(\*) >= 2
- ❑ Then, process HAVING to eliminate the groups that do not qualify the HAVING condition.

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A1	1	35k
A3	2	35k
A3	3	100k

GROUP 1 {

GROUP 3 {

# Aggregate Functions – Having

❑ **SELECT** *acc-id*, SUM(*amount*)  
FROM DEPOSIT  
GROUP BY *acc-id*  
HAVING COUNT(\*) >= 2

❑ Finally, process SELECT.

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k

<i>acc-id</i>	
A1	55k
A3	135k



# A common mistake

- ❑ Find the total amount of money ever deposited into each account, provided that the account has been deposited at least twice.

❑ `SELECT acc-id, SUM(amount)  
FROM DEPOSIT  
WHERE COUNT(*) >= 2  
GROUP BY acc-id`

- ❑ The above query is **wrong**!
- ❑ There can be no aggregate function in WHERE.

- ❑ Remember: WHERE filters tuples, while an aggregate function applies to a group. So they are incompatible.

DEPOSIT		
<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	20k
A2	1	5k
A3	2	35k
A3	3	100k
A1	1	35k

# Chapter 3: SQL

- ❑ Data Definition
- ❑ Basic Query Structure
- ❑ Set Operations
- ❑ Aggregate Functions
- ❑ Null Values
- ❑ Nested Subqueries
- ❑ Complex Queries
- ❑ Views
- ❑ Modification of the Database
- ❑ Joined Relations\*\*

# Null Values

- ❑ It is possible for tuples to have a null value, denoted by *null*, for some of their attributes
- ❑ *null* signifies an unknown value or that a value does not exist.
- ❑ The predicate **is null** can be used to check for null values.
  - Example: Find all loan number which appear in the *loan* relation with null values for *amount*.

```
select loan_number  
from loan  
where amount is null
```

- ❑ The result of any arithmetic expression involving *null* is *null*
  - Example:  $5 + \text{null}$  returns null
- ❑ However, aggregate functions simply ignore nulls
  - More on next slide

# Null Values and Three Valued Logic

- ❑ Any comparison with *null* returns *unknown*
  - Example:  $5 < \text{null}$  or  $\text{null} \diamond \text{null}$  or  $\text{null} = \text{null}$
- ❑ Three-valued logic using the truth value *unknown*:
  - OR:  $(\text{unknown} \text{ or } \text{true}) = \text{true}$ ,  
 $(\text{unknown} \text{ or } \text{false}) = \text{unknown}$   
 $(\text{unknown} \text{ or } \text{unknown}) = \text{unknown}$
  - AND:  $(\text{true} \text{ and } \text{unknown}) = \text{unknown}$ ,  
 $(\text{false} \text{ and } \text{unknown}) = \text{false}$ ,  
 $(\text{unknown} \text{ and } \text{unknown}) = \text{unknown}$
  - NOT:  $(\text{not } \text{unknown}) = \text{unknown}$
  - “*P* is unknown” evaluates to true if predicate *P* evaluates to *unknown*
- ❑ Result of **where** clause predicate is treated as *false* if it evaluates to *unknown*

# Null Values and Aggregates

- ❑ Total all loan amounts

```
select sum (amount )  
from loan
```

- Above statement ignores null amounts
- Result is *null* if there is no non-null amount
- ❑ All aggregate operations except **count(\*)** ignore tuples with null values on the aggregated attributes.

# Chapter 3: SQL

- ❑ Data Definition
- ❑ Basic Query Structure
- ❑ Set Operations
- ❑ Aggregate Functions
- ❑ Null Values
- ❑ **Nested Subqueries**
- ❑ Complex Queries
- ❑ Views
- ❑ Modification of the Database
- ❑ Joined Relations\*\*

# Nested Subqueries

- ❑ SQL provides a mechanism for the nesting of subqueries.
- ❑ A **subquery** is a **select-from-where** expression that is nested within another query.
- ❑ A common use of subqueries is to perform tests for set membership, set comparisons, and set cardinality.

# Example Query

*branch (branch\_name, branch\_city, assets)*

*customer (customer\_name, customer\_street, customer\_city)*

*account (account\_number, branch\_name, balance)*

*loan (loan\_number, branch\_name, amount)*

*depositor (customer\_name, account\_number)*

*borrower (customer\_name, loan\_number)*

- ❑ Find all customers who have both an account and a loan at the bank.

```
select distinct customer_name
from borrower
where customer_name in (select customer_name
                           from depositor )
```

- ❑ Find all customers who have a loan at the bank but do not have an account at the bank

```
select distinct customer_name
from borrower
where customer_name not in (select customer_name
                                   from depositor )
```



# Example Query

*branch (branch\_name, branch\_city, assets)*

*customer (customer\_name, customer\_street, customer\_city)*

*account (account\_number, branch\_name, balance)*

*loan (loan\_number, branch\_name, amount)*

*depositor (customer\_name, account\_number)*

*borrower (customer\_name, loan\_number)*

- ❑ Find all customers who have both an account and a loan at the Perryridge branch

**select distinct** *customer\_name*

**from** *borrower, loan*

**where** *borrower.loan\_number = loan.loan\_number and*

*branch\_name = 'Perryridge' and*

*(branch\_name, customer\_name) in*

**(select** *branch\_name, customer\_name*

**from** *depositor, account*

**where** *depositor.account\_number =*

*account.account\_number)*

- ❑ **Note:** Above query can be written in a much simpler manner. The formulation above is simply to illustrate SQL features.

# Set Comparison

*branch (branch\_name, branch\_city, assets)*

*customer (customer\_name, customer\_street, customer\_city)*

*account (account\_number, branch\_name, balance)*

*loan (loan\_number, branch\_name, amount)*

*depositor (customer\_name, account\_number)*

*borrower (customer\_name, loan\_number)*

- ❑ Find all branches that have greater assets than **some** branch located in Brooklyn.

```
select distinct T.branch_name
from branch as T, branch as S
where T.assets > S.assets and
      S.branch_city = 'Brooklyn'
```

- ❑ Same query using > **some** clause

```
select branch_name
from branch
where assets > some
      (select assets
       from branch
       where branch_city = 'Brooklyn')
```

# Definition of Some Clause

□  $F \text{ <comp> some } r \Leftrightarrow \exists t \in r \text{ such that } (F \text{ <comp> } t)$

Where <comp> can be: <, ≤, >, =, ≠

$(5 < \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline 6 \\ \hline \end{array}) = \text{true}$  (read: 5 < some tuple in the relation)

$(5 < \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline \end{array}) = \text{false}$

$(5 = \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline \end{array}) = \text{true}$

$(5 \neq \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline \end{array}) = \text{true (since } 0 \neq 5)$

$(= \text{some}) \equiv \text{in}$

However,  $(\neq \text{some}) \not\equiv \text{not in}$

# Example Query

*branch (branch\_name, branch\_city, assets)*

*customer (customer\_name, customer\_street, customer\_city)*

*account (account\_number, branch\_name, balance)*

*loan (loan\_number, branch\_name, amount)*

*depositor (customer\_name, account\_number)*

*borrower (customer\_name, loan\_number)*

- ❑ Find the names of all branches that have greater assets than **all** branches located in Brooklyn.

```
select branch_name
from branch
where assets > all
      (select assets
       from branch
       where branch_city = 'Brooklyn')
```

# Definition of all Clause

□  $F \text{ <comp> all } r \Leftrightarrow \forall t \in r (F \text{ <comp> } t)$

$(5 \text{ < all } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline 6 \\ \hline \end{array}) = \text{false}$

$(5 \text{ < all } \begin{array}{|c|} \hline 6 \\ \hline 10 \\ \hline \end{array}) = \text{true}$

$(5 \text{ = all } \begin{array}{|c|} \hline 4 \\ \hline 5 \\ \hline \end{array}) = \text{false}$

$(5 \neq \text{all } \begin{array}{|c|} \hline 4 \\ \hline 6 \\ \hline \end{array}) = \text{true (since } 5 \neq 4 \text{ and } 5 \neq 6)$

$(\neq \text{ all}) \equiv \text{not in}$

However,  $(= \text{ all}) \not\equiv \text{in}$

# Test for Empty Relations

- ❑ The **exists** construct returns the value **true** if the argument subquery is nonempty.
- ❑ **exists**  $r \Leftrightarrow r \neq \emptyset$
- ❑ **not exists**  $r \Leftrightarrow r = \emptyset$

# Example (exists)

ACC

<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A2	1	5k
A3	2	15k
A4	3	100k

- ❑ Find the ids of the accounts whose balances are **not** the largest.

- ❑ 

```
SELECT acc-id
FROM ACC T1
WHERE EXISTS (SELECT *
               FROM ACC T2
               WHERE T1.balance < T2.balance)
```

- ❑ Note that this nested query is different from the previous nested queries we have seen: It **depends on** the outside query.
  - T1 in the nested query **references** the table in the outside query.
- ❑ Lets see how it is executed.

# Example (exists)

- ❑ `SELECT acc-id`  
`FROM ACC T1`  
`WHERE EXISTS (SELECT *`  
`FROM ACC T2`  
`WHERE T1.balance < T2.balance)`

ACC		
<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A2	1	5k
A3	2	15k
A4	3	100k

- ❑ Lets go over every tuple in T1 one by one. For each tuple, get its balance, and place it at the position of `T1.balance` to make the nested query complete.
- ❑ Specifically, when we are looking at the first tuple in T1, the nested query becomes:  
`SELECT *`  
`FROM ACC T2`  
`WHERE 20k < T2.balance`
- ❑ Execute it – does it return any tuples?
- ❑ Yes, so `EXISTS evaluates to true`, and the *acc-id* of the tuple in T1 we are looking at is displayed.



# Example (exists)

❑ `SELECT acc-id`  
`FROM ACC T1`  
`WHERE EXISTS (SELECT *`  
`FROM ACC T2`  
`WHERE T1.balance < T2.balance)`

ACC		
<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A2	1	5k
A3	2	15k
A4	3	100k

- ❑ Repeat the above process for all tuples in T1.
- ❑ The *acc-ids* of all tuples are displayed, until we come to the last tuple, for which the nested query has the form:
- `SELECT *`  
`FROM ACC T2`  
`WHERE 100k < T2.balance`
- ❑ Execute it – does it return any tuples?
- ❑ No, so **EXISTS evaluates to false**, and the *acc-id* of the last tuple in T1 is **not** displayed.

# Example (not exists)

- Find the id of the account whose balance is the largest.

ACC		
<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A2	1	5k
A3	2	15k
A4	3	100k

- SELECT *acc-id*  
FROM ACC T1  
WHERE NOT EXISTS (SELECT \*  
FROM ACC T2  
WHERE T1.*balance* < T2.*balance*)

# Example (not exists)

- Find the ids of the customers who have deposited into all accounts with balances larger than 15k.
- SELECT DISTINCT *cust-id*  
FROM DEPOSIT T1  
WHERE NOT EXISTS (  
    (SELECT DISTINCT *acc-id*  
    FROM ACC  
    WHERE *balance* > 15000)  
    EXCEPT  
    (SELECT DISTINCT *acc-id*  
    FROM DEPOSIT T2  
    WHERE T1.*cust-id* = T2.*cust-id*))

ACC

<i>acc-id</i>	<i>balance</i>
A1	20k
A2	18k
A3	10k

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	2k
A1	1	1k
A2	1	1k
A2	2	3k
A3	3	2k
A3	2	5k

- Answer: 1
- What an inscrutable query! Lets understand it step-by-step.

# Example (not exists)

- ❑ SELECT DISTINCT ~~*cust-id*~~ FROM DEPOSIT T1  
WHERE NOT EXISTS (  
    (SELECT DISTINCT *acc-id*  
    FROM ACC  
    WHERE *balance* > 15000)  
    EXCEPT  
    (SELECT DISTINCT *acc-id*  
    FROM DEPOSIT T2  
    WHERE **T1.*cust-id*** = T2.*cust-id*))

ACC

<i>acc-id</i>	<i>balance</i>
A1	20k
A2	18k
A3	10k

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	2k
A1	1	1k
A2	1	1k
A2	2	3k
A3	3	2k
A3	2	5k

- ❑ The nested query depends on the outside query.
- ❑ So, we look at each tuple in T1, and use its *cust-id* to complete the nested query.
- ❑ Lets start with the first tuple in T1.

# Example (not exists)

ACC

<i>acc-id</i>	<i>balance</i>
A1	20k
A2	18k
A3	10k

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	2k
A1	1	1k
A2	1	1k
A2	2	3k
A3	3	2k
A3	2	5k

- ❑ SELECT DISTINCT *cust-id* FROM DEPOSIT T1  
WHERE NOT EXISTS (  
(SELECT DISTINCT *acc-id*  
FROM ACC  
WHERE *balance* > 15000)  
EXCEPT  
(SELECT DISTINCT *acc-id*  
FROM DEPOSIT T2  
WHERE T1.*cust-id* = T2.*cust-id*))

- ❑ Lets start with the first tuple in T1. The nested query becomes:

- ❑ (SELECT DISTINCT *acc-id*  
FROM ACC  
WHERE *balance* > 15000)  
EXCEPT  
(SELECT DISTINCT *acc-id*  
FROM DEPOSIT T2  
WHERE 1 = T2.*cust-id*))

returns {A1, A2}

returns {A1, A2}

- ❑ The above query returns empty. So NOT EXIST evaluates to true, and *cust-id* 1 is displayed.

# Example (not exists)

ACC

<i>acc-id</i>	<i>balance</i>
A1	20k
A2	18k
A3	10k

DEPOSIT

<i>acc-id</i>	<i>cust-id</i>	<i>amount</i>
A1	1	2k
A1	1	1k
A2	1	1k
A2	2	3k
A3	3	2k
A3	2	5k

- ❑ SELECT DISTINCT *cust-id* FROM DEPOSIT T1  
WHERE NOT EXISTS (  
(SELECT DISTINCT *acc-id*  
FROM ACC  
WHERE *balance* > 15000)  
EXCEPT  
(SELECT DISTINCT *acc-id*  
FROM DEPOSIT T2  
WHERE T1.*cust-id* = T2.*cust-id*))

- ❑ Lets look at the 4th tuple in T1. The nested query becomes:

- ❑ (SELECT DISTINCT *acc-id*  
FROM ACC  
WHERE *balance* > 15000)  
EXCEPT  
(SELECT DISTINCT *acc-id*  
FROM DEPOSIT T2  
WHERE 2 = T2.*cust-id*))

returns {A1, A2}

returns {A2, A3}

- ❑ The above query returns {A1}. So NOT EXIST evaluates to false, and *cust-id* 2 is not displayed.

# Test for Absence of Duplicate Tuples

*branch (branch\_name, branch\_city, assets)*

*customer (customer\_name, customer\_street, customer\_city)*

*account (account\_number, branch\_name, balance)*

*loan (loan\_number, branch\_name, amount)*

*depositor (customer\_name, account\_number)*

*borrower (customer\_name, loan\_number)*

- ❑ The **unique** construct tests whether a subquery has any duplicate tuples in its result.
- ❑ Find all customers who have **at most one** account at the Perryridge branch.

```
select T.customer_name
from depositor as T
where unique (
```

```
    select R.customer_name
    from account, depositor as R
    where T.customer_name = R.customer_name and
           R.account_number = account.account_number and
           account.branch_name = 'Perryridge')
```

# Example Query

*branch (branch\_name, branch\_city, assets)*

*customer (customer\_name, customer\_street, customer\_city)*

*account (account\_number, branch\_name, balance)*

*loan (loan\_number, branch\_name, amount)*

*depositor (customer\_name, account\_number)*

*borrower (customer\_name, loan\_number)*

- ❑ Find all customers who have **at least two** accounts at the Perryridge branch.

```
select distinct T.customer_name
from depositor as T
where not unique (
    select R.customer_name
    from account, depositor as R
    where T.customer_name = R.customer_name and
        R.account_number = account.account_number and
        account.branch_name = 'Perryridge')
```

- ❑ Variable from outer level is known as a **correlation variable**



# Chapter 3: SQL

- ❑ Data Definition
- ❑ Basic Query Structure
- ❑ Set Operations
- ❑ Aggregate Functions
- ❑ Null Values
- ❑ Nested Subqueries
- ❑ **Complex Queries**
- ❑ Views
- ❑ Modification of the Database
- ❑ Joined Relations\*\*

# Derived Relations

- ❑ SQL allows a subquery expression to be used in the **from** clause
- ❑ Find the average account balance of those branches where the average account balance is greater than \$1200.

```
select branch_name, avg_balance
from (select branch_name, avg (balance)
      from account
      group by branch_name )
as branch_avg ( branch_name, avg_balance )
where avg_balance > 1200
```

Note that we do not need to use the **having** clause, since we compute the temporary (view) relation *branch\_avg* in the **from** clause, and the attributes of *branch\_avg* can be used directly in the **where** clause.

# With Clause

- ❑ The **with** clause provides a way of defining a **temporary view** whose definition is available only to the query in which the **with** clause occurs.
- ❑ Find all accounts with the maximum balance

```
with max_balance (value) as  
    select max (balance)  
    from account  
select account_number  
from account, max_balance  
where account.balance = max_balance.value
```

# Complex Queries using With Clause

- Find all branches where the total account deposit is greater than the average of the total account deposits at all branches.

```
with branch_total (branch_name, value) as  
    select branch_name, sum (balance)  
    from account  
    group by branch_name  
with branch_total_avg (value) as  
    select avg (value)  
    from branch_total  
select branch_name  
from branch_total, branch_total_avg  
where branch_total.value >= branch_total_avg.value
```

# Chapter 3: SQL

- ❑ Data Definition
- ❑ Basic Query Structure
- ❑ Set Operations
- ❑ Aggregate Functions
- ❑ Null Values
- ❑ Nested Subqueries
- ❑ Complex Queries
- ❑ **Views**
- ❑ Modification of the Database
- ❑ Joined Relations\*\*

# Views

- ❑ In some cases, it is not desirable for all users to see the entire logical model (that is, all the actual relations stored in the database.)
- ❑ Consider a person who needs to know a customer's name, loan number and branch name, but has no need to see the loan amount. This person should see a relation described, in SQL, by

```
(select customer_name, borrower.loan_number, branch_name  
      from borrower, loan  
      where borrower.loan_number = loan.loan_number )
```

- ❑ A **view** provides a mechanism to hide certain data from the view of certain users.
- ❑ Any relation that is not of the conceptual model but is made visible to a user as a “**virtual relation**” is called a **view**.

# View Definition

- ❑ A view is defined using the **create view** statement which has the form

**create view v as** <query expression >

where <query expression> is any legal SQL expression. The view name is represented by v.

- ❑ Once a view is defined, the view name can be used to refer to the virtual relation that the view generates.
- ❑ When a view is created, the query expression is stored in the database; the expression is substituted into queries using the view.

# Example Queries

- ❑ A view consisting of branches and their customers

```
create view all_customer as  
    (select branch_name, customer_name  
     from depositor, account  
     where depositor.account_number =  
           account.account_number )  
  
    union  
    (select branch_name, customer_name  
     from borrower, loan  
     where borrower.loan_number = loan.loan_number )
```

- ❑ Find all customers of the Perryridge branch

```
select customer_name  
      from all_customer  
      where branch_name = 'Perryridge'
```



# Views Defined Using Other Views

- ❑ One view may be used in the expression defining another view
- ❑ A view relation  $v_1$  is said to *depend directly* on a view relation  $v_2$  if  $v_2$  is used in the expression defining  $v_1$
- ❑ A view relation  $v_1$  is said to *depend on* view relation  $v_2$  if either  $v_1$  depends directly to  $v_2$  or there is a path of dependencies from  $v_1$  to  $v_2$