

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

CUST

<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

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
Rye
Harrison
Pittsfield
Pittsfield
Harrison
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 $borrower \times loan$

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

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.

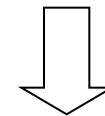
CUST. <i>cust-id</i>	CUST. <i>name</i>	ACC. <i>acc-id</i>	ACC. <i>cust-id</i>	ACC. <i>balance</i>
1	John	A1	1	20k
1	John	A2	1	5k
1	John	A3	2	35k
1	John	A4	3	100k
2	Smith	A1	1	20k
2	Smith	A2	1	5k
2	Smith	A3	2	35k
2	Smith	A4	3	100k
3	Joan	A1	1	20k
3	Joan	A2	1	5k
3	Joan	A3	2	35k
3	Joan	A4	3	100k

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*

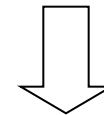
❑ Then, on the cartesian product,
perform filtering.



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

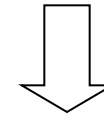


ACC. <i>acc-id</i>	CUST. <i>name</i>
A1	John
A2	John
A3	Smith
A4	Joan

- ❑ **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

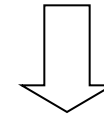


ACC. <i>acc-id</i>	CUST. <i>name</i>
A1	John
A2	John
A3	Smith
A4	Joan

- ❑ 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.

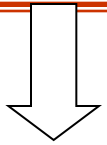
The Rename Operation

- ❑ 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



<i>cid</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

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

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 σ_{θ} , then there are c_1 copies of t_1 in $\sigma_{\theta}(r_1)$.
 2. $\Pi_A(r_1)$: 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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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

SQL example 5 (intersection)


CUST

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

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 *cust-id*
FROM CUST)
INTERSECT
(SELECT *cust-id*
FROM ACC)



<i>cust-id</i>
1
2
3

- ❑ INTERSECT automatically removes duplicates.

SQL example 5 (cont.)

CUST

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

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 *cust-id*, *name*
FROM CUST)
INTERSECT
(SELECT *cust-id*
FROM ACC)
- ❑ The above query is **wrong**!
- ❑ Because the two SELECT clauses return **different** sets of columns. Hence, intersection cannot be performed.

SQL example 6 (union)


CUST

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

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 *cust-id*
FROM CUST)
UNION
(SELECT *cust-id*
FROM ACC)



<i>cust-id</i>
1
2
3
4

- ❑ UNION automatically removes duplicates.
- ❑ As with INTERSECT, the two SELECT queries must return the same columns, too.

SQL example 7 (except: set difference)


CUST

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

ACC

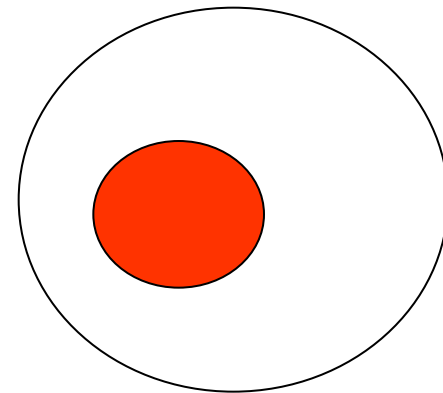
<i>acc-id</i>	<i>cust-id</i>	<i>balance</i>
A1	1	20k
A2	1	5k
A3	2	35k
A4	3	100k

- ❑ (SELECT *cust-id*
FROM CUST)
EXCEPT
(SELECT *cust-id*
FROM ACC)



<i>cust-id</i>
4

- ❑ Returns the id that is in CUST but not in ACC.
- ❑ EXCEPT removes duplicates.
- ❑ The two SELECT must return the same columns.



SQL example 7 (except: set difference)

CUST

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

ACC

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

- ❑ Another example:
- ❑ (SELECT *cust-id*
FROM ACC)
EXCEPT
(SELECT *cust-id*
FROM CUST)
- ❑ Returns the id that is in ACC but not in CUST.
- ❑ There is no such id. So, the query result is **empty**.

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

- 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.
 - The **having** clause is applied after GROUP BY
 - Predicates in the **where** clause are applied before GROUP BY
- 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

GROUP 1 {

GROUP 3 {

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

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
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- ❑ 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

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**
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- ❑ 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 )
```

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: $<$, \leq , $>$, \geq , $=$, \neq

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

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

● <comp> : <, ≤, >, ≥, =, ≠

(5 < all

0
5
6

) = false

(5 < all

6
10

) = true

(5 = all

4
5

) = false

(5 ≠ all

4
6

) = true (since $5 \neq 4$ and $5 \neq 6$)

(≠ all) ≡ not in

However, (= all) ≠ in

Test for Empty Relations

- ❑ The **exists** construct returns the value **true** if the result of 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
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- ❑ 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
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- ❑ Nested Subqueries
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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

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**

Modification of the Database – Deletion

- ❑ Delete all account tuples at the Perryridge branch

```
delete from account  
where branch_name = 'Perryridge'
```

- ❑ Delete all accounts at every branch located in the city 'Needham'.

```
delete from account  
where branch_name in (select branch_name  
                        from branch  
                        where branch_city = 'Needham')
```

Example Query

- ❑ Delete the record of all accounts with balances below the average at the bank.

```
delete from account  
  where balance < (select avg (balance)  
                    from account)
```

- Problem: as we delete tuples from deposit, the average balance changes
- Solution used in SQL:
 1. First, compute **avg** balance and find all tuples to delete
 2. Next, delete all tuples found above (without recomputing **avg** or retesting the tuples)

Modification of the Database – Insertion

- ❑ Add a new tuple to *account*

```
insert into account  
values ('A-9732', 'Perryridge', 1200)
```

or equivalently

```
insert into account (branch_name, balance, account_number)  
values ('Perryridge', 1200, 'A-9732')
```

- ❑ Add a new tuple to *account* with *balance* set to null

```
insert into account  
values ('A-777', 'Perryridge', null)
```

Modification of the Database – Insertion

- ❑ Insert tuples on the basis of the result of a query.
- ❑ Make each student in the Music department who has earned more than 144 credit hours, an instructor in the Music department, with a salary of \$18,000.

insert into instructor

select ID, name, dept name, 18000

from student

where dept name = 'Music' and tot cred > 144;

- SQL evaluates the select statement first, giving a set of tuples
 - Then inserted into the instructor relation.
 - Each tuple has an ID, a name, a dept name (Music), and an salary of \$18,000.
- ❑ The **select from where** statement is evaluated fully before any of its results are inserted into the relation (otherwise queries like
insert into table1 select * from table1
would cause problems)

Modification of the Database – Updates

- ❑ Increase all accounts with balances over \$10,000 by 6%, all other accounts receive 5%.

- Write two **update** statements:

```
update account  
set balance = balance * 1.06  
where balance > 10000
```

```
update account  
set balance = balance * 1.05  
where balance ≤ 10000
```

- The order is important
- Can be done better using the **case** statement (next slide)

Case Statement for Conditional Updates

- ❑ Same query as before: Increase all accounts with balances over \$10,000 by 6%, all other accounts receive 5%.

```
update account
set balance = case
                when balance <= 10000 then
                    balance * 1.05
                else balance * 1.06
end
```


Update of a View

- ❑ Create a view of all loan data in the *loan* relation, hiding the *amount* attribute

```
create view loan_branch as  
    select loan_number, branch_name  
    from loan
```

- ❑ Add a new tuple to *loan_branch*

```
insert into loan_branch  
    values ('L-37', 'Perryridge')
```

This insertion must be represented by the insertion of the tuple

('L-37', 'Perryridge', *null*)

into the *loan* relation

Updates Through Views (Cont.)

- ❑ Some updates through views are impossible to appear in the inserted view, for example

- **create view *v* as**

```
select loan_number, branch_name, amount  
from loan  
where branch_name = 'Perryridge'
```

```
insert into v values ( 'L-99', 'Downtown', '23')
```

- ❑ Others cannot be translated uniquely

- **insert into *all_customer* values** ('Perryridge', 'John')

- ▶ *All_customer* is derived from relations *loan* and *account*
- ▶ Have to choose *loan* or *account*, and create a new *loan/account* number!

- ❑ Most SQL implementations allow updates only on simple views (without aggregates) defined on a single relation

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**

Joined Relations

- ❑ **Join operations** take two relations and return as a result another relation.
- ❑ A join operation is a Cartesian product which requires that tuples in the two relations match (under some condition). It also specifies the attributes that are present in the result of the join
- ❑ The join operations are typically used as subquery expressions in the **from** clause

Join operations – Example

❑ Relation *course*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

❑ Relation *prereq*

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

❑ Observe that

prereq information is missing for CS-315 and
course information is missing for CS-437

Joined Relations

- ❑ **Join operations** take two relations and return as a result another relation.
- ❑ These additional operations are typically used as subquery expressions in the **from** clause
- ❑ **Join condition** – defines which tuples in the two relations match, and what attributes are present in the result of the join.
- ❑ **Join type** – defines how tuples in each relation that do not match any tuple in the other relation (based on the join condition) are treated.

<i>Join types</i>	<i>Join Conditions</i>
inner join left outer join right outer join full outer join	natural on <predicate> using (A_1, A_1, \dots, A_n)

Outer Join

- ❑ An extension of the join operation that avoids loss of information.
- ❑ Computes the join and then adds tuples from one relation that does not match tuples in the other relation to the result of the join.
- ❑ Uses *null* values.

Left Outer Join

■ *course* **natural left outer join** *prereq*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prere_id</i>
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	<i>null</i>

Right Outer Join

■ *course* **natural right outer join** *prereq*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prere_id</i>
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	<i>null</i>	<i>null</i>	<i>null</i>	CS-101

Full Outer Join

■ *course* **natural full outer join** *prereq*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prere_id</i>
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	<i>null</i>
CS-347	<i>null</i>	<i>null</i>	<i>null</i>	CS-101

Joined Relations in SQL – Examples

- ❑ *course* **inner join** *prereq* on
course.course_id = prereq.course_id

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prereq_id</i>	<i>course_id</i>
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190

- ❑ What is the difference between the above and a natural join?

Joined Relations in SQL – Examples

- *course* **left outer join** *prereq* on
course.course_id = prereq.course_id

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prere_id</i>	<i>course_id</i>
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190
CS-315	Robotics	Comp. Sci.	3	<i>null</i>	<i>null</i>

Joined Relations – Examples

- *course* **natural right outer join** *prereq*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prereq_id</i>
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	<i>null</i>	<i>null</i>	<i>null</i>	CS-101

- *course* **full outer join** *prereq* **using** (*course_id*)

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prereq_id</i>
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	<i>null</i>
CS-347	<i>null</i>	<i>null</i>	<i>null</i>	CS-101

End of Chapter 3