



Database System (Relational Model - SQL)

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SQL

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


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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
- 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.

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Data Definition Language

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.


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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.
- **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 next session.

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Create Table Construct

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


```
create table r(A1 D1, A2 D2, ..., An Dn,
              (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)
```

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Integrity Constraints in Create Table

- not null
- primary key (A_1, \dots, A_n)
- check(P)
- unique($A_{j_1}, A_{j_2}, \dots, A_{j_m}$)

Example: Declare *branch_name* as the primary key for *branch* and ensure that the values of *assets* are non-negative.

```
create table branch
(branch_name char(15),
 branch_city char(30),
 assets integer,
 primary key (branch_name),
 check (assets >= 0))
```

primary key declaration on an attribute automatically ensures not null in SQL-92 onwards, needs to be explicitly stated in SQL-89

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Drop and Alter Table Constructs

- The **drop table** command deletes all information about the dropped relation from the database.
- The **alter table** command is used to 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 A1, A2, ..., An
from R1, R2, ..., Rm
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.

$$\prod_{A_1, A_2, \dots, A_n} (\sigma_P (R_1 \times R_2 \times \dots \times R_m))$$
- The result of an SQL query is a relation.

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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:

$$\prod_{branch_name} (loan)$$
- NOTE: SQL names are case insensitive (i.e., you may use upper- or lower-case letters.)
 - Some people use upper case wherever we use bold font.

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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.


```
select distinct branch_name
from loan
```
- Find the names of all branches in the *loan* relations, and remove duplicates


```
select all branch_name
from loan
```
- The keyword **all** specifies that duplicates not be removed.

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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.

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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.

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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
```

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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'
```

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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
```

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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'
```

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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 the name "Main%"


```
like 'Main%' 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.

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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**

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Duplicates

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

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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 A1, A2, ..., An
from r1, r2, ..., rm
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

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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)
```

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Aggregate Functions

- These functions operate on the multiset of values of a column of a relation, and return a value
 - avg**: average value
 - min**: minimum value
 - max**: maximum value
 - sum**: sum of values
 - count**: number of values

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Aggregate Functions (Cont.)


- Find the average account balance at the Perryridge branch.


```
select avg (balance)
  from account
  where branch_name = 'Perryridge'
```
- Find the number of tuples in the *customer* relation.


```
select count (*)
  from customer
```
- Find the number of depositors in the bank.


```
select count (distinct customer_name)
  from depositor
```

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Aggregate Functions – Group By

- Find the number of depositors for each branch.


```
select branch_name, count (distinct customer_name)
  from depositor, account
  where depositor.account_number = account.account_number
  group by branch_name
```

Note: Attributes in **select** clause outside of aggregate functions must appear in **group by** list

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Aggregate Functions – Having Clause

- 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

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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


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Null Values and Three Valued Logic

- Any comparison with *null* returns *unknown*
 - Example: $5 < \text{null}$ or $\text{null} <> \text{null}$ or $\text{null} = \text{null}$
- Three-valued logic using the truth value *unknown*:
 - OR: $(\text{unknown or true}) = \text{true}$, $(\text{unknown or false}) = \text{unknown}$, $(\text{unknown or unknown}) = \text{unknown}$
 - AND: $(\text{true and unknown}) = \text{unknown}$, $(\text{false and unknown}) = \text{false}$, $(\text{unknown and unknown}) = \text{unknown}$
 - NOT: $(\text{not unknown}) = \text{unknown}$
 - "*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*

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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.


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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.

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Example Query

- 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 )

```

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Example Query

- 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.

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Set Comparison

- 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')

```

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Definition of Some Clause

- $F \langle \text{comp} \rangle \text{ some } r \Leftrightarrow \exists t \in r \text{ such that } (F \langle \text{comp} \rangle t)$
Where $\langle \text{comp} \rangle$ can be: $<, \leq, >, =, \neq$

(5 < **some**

0
5
6

) = true (read: 5 < some tuple in the relation)

(5 < **some**

0
5

) = false

(5 = **some**

0
5

) = true


(5 \neq **some**

0
5

) = true (since $0 \neq 5$)

(= **some**) \equiv in
However, (\neq **some**) \neq not in

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Example Query

- 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')

```

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Definition of all Clause

- $F \langle \text{comp} \rangle \text{all } r \Leftrightarrow \forall t \in r (F \langle \text{comp} \rangle t)$

$(5 < \text{all } \begin{matrix} 0 \\ 5 \\ 6 \end{matrix}) = \text{false}$
 $(5 < \text{all } \begin{matrix} 6 \\ 10 \end{matrix}) = \text{true}$
 $(5 = \text{all } \begin{matrix} 4 \\ 5 \end{matrix}) = \text{false}$
 $(5 \neq \text{all } \begin{matrix} 4 \\ 6 \end{matrix}) = \text{true}$ (since $5 \neq 4$ and $5 \neq 6$)

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

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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** $r \Leftrightarrow r = \emptyset$

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Example Query

- Find all customers who have an account at all branches located in Brooklyn.

```

select distinct S.customer_name
  from depositor as S
  where not exists (
    (select branch_name
     from branch
     where branch_city = 'Brooklyn')
    except
    (select R.branch_name
     from depositor as T, account as R
     where T.account_number = R.account_number and
           S.customer_name = T.customer_name ))
  
```

- Note that $X - Y = \emptyset \Leftrightarrow X \subseteq Y$
- Note: Cannot write this query using = all and its variants

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Test for Absence of Duplicate Tuples

- 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' )
  
```

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Example Query

- 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' )
  
```

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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.

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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

```

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Complex Query 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

```

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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 loan number but has no need to see the loan amount. This person should see a relation described, in SQL, by


```

(select customer_name, loan_number
  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**.

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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.
- View definition is not the same as creating a new relation by evaluating the query expression
 - Rather, a view definition causes the saving of an expression; the expression is substituted into queries using the view.

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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'

```


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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
- A view relation v is said to be *recursive* if it depends on itself.


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View Expansion

- A way to define the meaning of views defined in terms of other views.
- Let view v_i be defined by an expression e_i that may itself contain uses of view relations.
- View expansion of an expression repeats the following replacement step:
 - repeat**
 - Find any view relation v_i in e_i
 - Replace the view relation v_i by the expression defining v_i
 - until** no more view relations are present in e_i
- As long as the view definitions are not recursive, this loop will terminate

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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')
```

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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)

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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)
```

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Modification of the Database – Insertion

- Provide as a gift for all loan customers of the Perryridge branch, a \$200 savings account. Let the loan number serve as the account number for the new savings account


```
insert into account
select loan_number, branch_name, 200
from loan
where branch_name = 'Perryridge'
```

```
insert into depositor
select customer_name, loan_number
from loan, borrower
where branch_name = 'Perryridge'
and loan.account_number = borrower.account_number
```
- 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)

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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)

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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
    
```

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Update of a View

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

```

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

- Add a new tuple to *branch_loan*

```

insert into branch_loan
values ('Perryridge', 'L-307')
    
```

This insertion must be represented by the insertion of the tuple ('L-307', 'Perryridge', null) into the *loan* relation

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Updates Through Views (Cont.)

- Some updates through views are impossible to translate into updates on the database relations
 - create view *v* as


```

select branch_name from account
                    
```

 insert into *v* values ('L-99', 'Downtown', 23)
- Others cannot be translated uniquely
 - insert into *all_customer* values ('Perryridge', 'John')
 - 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

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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.

Join types	Join Conditions
inner join	natural
left outer join	on <predicate>
right outer join	using (A ₁ , A ₁ , ..., A _n)
full outer join	

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Joined Relations – Datasets for Examples

- Relation *loan*
- Relation *borrower*

loan_number	branch_name	amount	customer_name	loan_number
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230
L-260	Perryridge	1700	Hayes	L-155

Note: borrower information missing for L-260 and loan information missing for L-155

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Joined Relations – Examples

- loan* inner join *borrower* on *loan.loan_number = borrower.loan_number*

loan_number	branch_name	amount	customer_name	loan_number
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230

- loan* left outer join *borrower* on *loan.loan_number = borrower.loan_number*

loan_number	branch_name	amount	customer_name	loan_number
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230
L-260	Perryridge	1700	null	null

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Joined Relations – Examples

- loan natural inner join borrower

loan_number	branch_name	amount	customer_name	loan_number
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230

- loan natural right outer join borrower

loan_number	branch_name	amount	customer_name
L-170	Downtown	3000	Jones
L-230	Redwood	4000	Smith
L-155	null	null	Hayes

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Joined Relations – Examples

- loan full outer join borrower using (loan_number)

loan_number	branch_name	amount	customer_name
L-170	Downtown	3000	Jones
L-230	Redwood	4000	Smith
L-260	Perryridge	1700	null
L-155	null	null	Hayes

- Find all customers who have either an account or a loan (but not both) at the bank.

```
select customer_name
  from (depositor natural full outer join borrower)
 where account_number is null or loan_number is null
```

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End of Chapter 3

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Figure 3.1: Database Schema

branch (branch_name, branch_city, assets)
 customer (customer_name, customer_street, customer_city)
 loan (loan_number, branch_name, amount)
 borrower (customer_name, loan_number)
 account (account_number, branch_name, balance)
 depositor (customer_name, account_number)

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Figure 3.3: Tuples inserted into loan and borrower

loan_number	branch_name	amount	customer_name	loan_number
L-11	Round Hill	900	Adams	L-16
L-14	Downtown	1500	Curry	L-93
L-15	Perryridge	1500	Hayes	L-15
L-16	Perryridge	1300	Jackson	L-14
L-17	Downtown	1000	Jones	L-17
L-23	Redwood	2000	Smith	L-11
L-93	Mianus	500	Smith	L-23
null	null	1900	Williams	L-17
			Johnson	null

loan borrower

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Figure 3.4: The loan and borrower relations

loan_number	branch_name	amount	customer_name	loan_number
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230
L-260	Perryridge	1700	Hayes	L-155

loan borrower

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