

## The SQL Standard

- **SQL – Structured Query Language**  
An international standard (ANSI, ISO) that specifies how
  - a relational schema is created
  - data is inserted / updated in the relations
  - data is queried
  - transactions are started and stopped
  - programs access data in the relations
  - and a host of other things are done
- Every relational database management system (RDBMS) is required to support / implement the SQL standard.
  - RDBMS vendors may give additional features
  - Downside of using vendor-specific features - portability

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## History of SQL

### SEQUEL

- developed by IBM in early 70's
- relational query language as part of System-R project at IBM San Jose Research Lab.
- the earliest version of SQL

### SQL evolution

- SQL- 86/89
- SQL- 92 - SQL2
- SQL- 99/03 - SQL3  
(includes object relational features)

And the evolution continues .....

Disclaimer: This module covers only important principles of SQL

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## Components of SQL Standard(1/2)

- **Data Definition Language (DDL)**  
Specifies constructs for schema definition, relation definition, integrity constraints, views and schema modification.
- **Data Manipulation Language (DML)**  
Specifies constructs for inserting, updating and querying the data in the relational instances ( or tables ).
- **Embedded SQL and Dynamic SQL**  
Specifies how SQL commands can be embedded in a high-level host language such as C, C++ or Java for programmatic access to the data.

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### Components of SQL Standard(2/2)

- **Transaction Control**  
Specifies how transactions can be started / stopped, how a set of concurrently executing transactions can be managed.
- **Authorization**  
Specifies how to restrict a user / set of users to access only certain parts of data, perform only certain types of queries etc.

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### Data Definition in SQL

Defining the schema of a relation

create table *r* ( attributeDefinition-1, attributeDefinition-2,...,  
name of the relation attributeDefinition-n, [integrityConstraints-1],  
 [integrityConstraints-2],...,[integrityConstraints-m])

Attribute Definition –

attribute-name domain-type [NOT NULL] [DEFAULT v]

E.g.:

create table *example1* ( A char(6) not null default “000000”,  
 B int, C char(1) default “F” );

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### Domain Types in SQL-92 (1/2)

- **Numeric data types**
  - integers of various sizes – INT, SMALLINT
  - real numbers of various precision – REAL, FLOAT, DOUBLE PRECISION
  - formatted numbers – DECIMAL ( i, j ) or NUMERIC ( i, j )
    - i – total number of digits ( precision )
    - j – number of digits after the decimal point ( scale )
- **Character string data types**
  - fixed length – CHAR(n) – n: no. of characters
  - varying length – VARCHAR(n) – n: max.no. of characters
- **Bit string data types**
  - fixed length – BIT(n)
  - varying length – BIT VARYING(n)

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### Domain Types in SQL-92 (2/2)

- *Date data type*  
DATE type has 10 position format – YYYY-MM-DD
- *Time data type*  
TIME type has 8 position format – HH : MM : SS
- *Others*  
There are several more data types whose details are available in SQL reference books

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### Specifying Integrity Constraints in SQL

Also called Table Constraints  
Included in the definition of a table

#### Key constraints

PRIMARY KEY ( $A_1, A_2, \dots, A_k$ )  
specifies that  $\{A_1, A_2, \dots, A_k\}$  is the primary key of the table

UNIQUE ( $B_1, B_2, \dots, B_k$ )  
specifies that  $\{B_1, B_2, \dots, B_k\}$  is a candidate key for the table

There can be more than one UNIQUE constraint but only one PRIMARY KEY constraint for a table.

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### Specifying Referential Integrity Constraints

FOREIGN KEY ( $A_1$ ) REFERENCES  $r_2$  ( $B_1$ )

- specifies that attribute  $A_1$  of the table being defined, say  $r_1$ , is a *foreign key* referring to attribute  $B_1$  of table  $r_2$
- recall that this means:  
each value of column  $A_1$  is either null or is one of the values appearing in column  $B_1$  of  $r_2$

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### Specifying What to Do if RIC Violation Occurs

#### *RIC violation*

- can occur if a referenced tuple is deleted or modified
- action can be specified for each case using qualifiers  
ON DELETE or ON UPDATE

#### *Actions*

- three possibilities can be specified  
SET NULL, SET DEFAULT, CASCADE
- these are actions to be taken on the referencing tuple
- SET NULL – foreign key attribute value to be set null
- SET DEFAULT – foreign key attribute value to be set to its default value
- CASCADE – delete the referencing tuple if the referenced tuple is deleted or update the FK attribute if the referenced tuple is updated

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### Table Definition Example

```
create table students (
  rollNo char(8) not null,
  name varchar(15) not null,
  degree char(5),
  year smallint,
  sex char not null,
  deptNo smallint,
  advisor char(6),
  primary key(rollNo),
  foreign key(deptNo) references
                        department(deptId)
    on delete set null on update cascade,
  foreign key(advisor) references
                        professor(empId)
    on delete set null on update cascade
);
```

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### Modifying a Defined Schema

ALTER TABLE command can be used to modify a schema

#### *Adding a new attribute*

ALTER table student ADD address varchar(30);

#### *Deleting an attribute*

- need to specify what needs to be done about views or constraints that refer to the attribute being dropped
  - two possibilities
    - CASCADE – delete the views/constraints also
    - RESTRICT – do not delete the attributes if there are some views/constraints that refer to it.
  - ALTER TABLE student DROP degree RESTRICT
- Similarly, an entire table definition can be deleted

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## Data Manipulation in SQL

### Basic query syntax

select  $A_1, A_2, \dots, A_m$  ← a set of attributes  
from  $R_1, R_2, \dots, R_p$  ← from relations  $R_1, \dots, R_p$  that are  
where  $\theta$  ← the set of tables that  
← a boolean predicate that contain the relevant  
specifies when a combined tuples to answer the query.  
tuple of  $R_1, \dots, R_p$  contributes  
to the output.

Equivalent to:

$\pi_{A_1, A_2, \dots, A_m}(\sigma_{\theta}(R_1 \times R_2 \times \dots \times R_p))$  Assuming that each attribute  
name appears exactly once  
in the table.

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## Meaning of the Basic Query Block

- The *cross product*  $M$  of the tables in the from clause would be considered.  
Tuples in  $M$  that satisfy the condition  $\theta$  are *selected*.  
For each such tuple, values for the attributes  $A_1, A_2, \dots, A_m$  (mentioned in the select clause) are *projected*.
- This is a conceptual description  
- in practice more efficient methods are employed for evaluation.
- The word *select* in SQL should not be confused with select operation of relational algebra.

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## SQL Query Result

The result of any SQL query

- a table with *select* clause attributes as column names.
- duplicate rows may be present.  
- differs from the definition of a relation.
- duplicate rows can be eliminated by specifying DISTINCT keyword in the *select* clause, if necessary.  

```
SELECT DISTINCT name  
FROM student WHERE ...
```
- duplicate rows are essential while computing aggregate functions (average, sum etc).
- removing duplicate rows involves additional effort and is done only when necessary.

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### Example Relational Scheme with RIC's shown

student (rollNo, name, degree, year, sex, deptNo, advisor)  
 department (deptId, name, hod, phone)  
 professor (empId, name, sex, startYear, deptNo, phone)  
 course (courseId, cname, credits, deptNo)  
 enrollment (rollNo, courseId, sem, year, grade)  
 teaching (empId, courseId, sem, year, classRoom)  
 preRequisite (preReqCourse, courseId)

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### Example Queries Involving a Single Table

Get the rollNo, name of all women students in the dept no. 5.

```
select rollNo, name  
from student  
where sex = 'F' and deptNo = 5;
```

Get the employee Id, name and phone number of professors in the CS dept (deptNo = 3) who have joined after 1999.

```
select empId, name, phone  
from professor  
where deptNo = 3 and startYear > 1999;
```

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### Examples Involving Two or More Relations (1/2)

Get the rollNo, name of students in the CSE dept (deptNo = 3) along with their advisor's name and phone number.

```
select rollNo, s.name, f.name as advisorName,  
phone as advisorPhone  
from student as s, professor as f  
where s.advisor = f.empId and  
s.deptNo = 3;
```

table aliases are used to disambiguate the common attributes

table aliases are required if an attribute name appears in more than one table. Also when same relation appears twice in the from clause.

attribute renaming in the output

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### Examples Involving Two or More Relations (2/2)

Get the names, employee ID's, phone numbers of professors in CSE dept who joined before 1995.

```
select empId, f.name, f.phone
from professor as f, department as d
where f.deptNo = d.deptId and
      d.name = 'CSE' and
      f.startYear < 1995
```

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### Nested Queries or Subqueries

While dealing with certain complex queries

- beneficial to specify part of the computation as a separate query & make use of its result to formulate the main query.
- such queries – nested / subqueries.

Using subqueries

- makes the main query easy to understand / formulate
- sometimes makes it more efficient also
  - sub query result can be computed once and used many times.
  - not the case with all subqueries.

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### Nested Query Example

Get the rollNo, name of students who have a lady professor as their advisor.

```
select s.rollNo, s.name
from student s
where s.advisor IN
      (select empId
       from professor
        where sex = 'F');
```

IN Operator: One of the ways of making use of the subquery result

Subquery computes the empId's of lady professors

NOT IN can be used in the above query to get details of students who don't have a lady professor as their advisor.

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### Example of a Correlated Subquery

Get the roll number and name of students whose gender is same as their advisor's.

```
select s.rollNo, s.name
from student s
where s.sex = ALL ( select f.sex
                    from professor f
                    where f.empId = s.advisor );
```

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### The *EXISTS* Operator

Using *EXISTS*, we can check if a subquery result is non-empty

*EXISTS(S)* is *true* if *S* has at least one tuple / member  
is *false* if *S* contain no tuples

Get the employee Id and name of professors who advise at least one women student.

```
select f.empId, f.name
from professors f
where EXISTS ( select s.rollNo
               from student s
               where s.advisor = f.empId and
                     s.sex = 'F' );
```

a correlated  
subquery

SQL does not have an operator for universal quantification.

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### The *NOT EXISTS* Operator

Obtain the department Id and name of departments that do not offer any 4 credit courses.

```
select d.deptId, d.name
from department d
where NOT EXISTS ( select courseId
                  from course c
                  where c.deptNo = d.deptId and
                        c.credits = 4 );
```

a correlated  
subquery

Queries with *existentially* quantified predicates can be easily specified using *EXISTS* operator.

Queries with *universally* quantified predicates can only be specified after translating them to use *existential* quantifiers.

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### Example Involving Universal Quantifier

Determine the students who are enrolled for every course taught by Prof Ramanujam. Assume that Prof Ramanujam teaches at least one course.

As SQL does not have universal quantifier, we will rewrite the query this way:

Determine the student(s) who are st there **does not** exist a course taught by Prof Ramanujam which is **not** enrolled by the student.

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### Same query expressed in TRC

Determine the students who are enrolled for **every** course taught by Prof Ramanujam. Assume that Prof Ramanujam teaches at least one course.

```

1. {s.rollNo | student (s) ^
2.   (∀c)(course (c) ^
3.     ((∃t),(∃p)( teaching(t) ^ professor(p) ^
4.       t.courseId = c.courseId ^
5.       p.name = "Ramanujam" ^
6.       p.empId = t.empId )) →
7.     (∃e) (enrollment(e) ^
8.       e.courseId = c.courseId ^
9.       e.rollNo = s.rollNo)
10.  )
11. }
```

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### An Example Involving the Universal Quantifier

Determine the students who are enrolled for every course taught by Prof Ramanujam. Assume that Prof Ramanujam teaches at least one course.

```

select s.rollNo, s.name
from student s
where NOT EXISTS ( select t.*
                   from teaching t, professor p
                   where t.empId = p.empId and
                         p.name = "Ramanujam" and
                         NOT EXISTS
                           (select e.*
                            from enrollment e
                            where e.courseId = t.courseId
                              and e.rollNo = s.rollNo)
                   );
```

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### Another Example Involving the Universal Quantifier

Determine the students who have obtained either S or A grade in all the pre-requisite courses of the course CS7890. It is known that CS7890 has at least one pre-requisite.

```
select s.rollNo, s.name
from student s
where NOT EXISTS(select *
                  from preRequisite p
                  where p.courseId = "CS7890" and
                  NOT EXISTS
                    (select *
                     from enrollment e
                     where e.courseId = p.preReqcourse
                           and e.rollNo = s.rollNo and
                           e.grade = "S" or e.grade = "A")
                  );
```

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### Missing where Clause

If the *where* clause in an SQL query is not specified, it is treated as - the where condition is true for all tuple combinations.

- Essentially no filtering is done on the cross product of from clause tables.

Get the name and contact phone of all Departments.

```
select name, phone
from department
```

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### Union, Intersection and Difference Operations

- In SQL, using operators *UNION*, *INTERSECT* and *EXCEPT*, one can perform set *union*, *intersection* and *difference* respectively.
- Results of these operators are *sets* –  
i.e duplicates are automatically removed.
- Operands need to be union compatible and also have *same* attribute names in the *same* order.

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### Example using UNION

Obtain the roll numbers of students who are currently enrolled for either CS2300 or CS2320 courses.

```
(SELECT rollNo
FROM enrollment
WHERE courseId = 'CS2300' and
      sem = 'odd' and year = '2019' ) UNION
(SELECT rollNo
FROM enrollment
WHERE courseId = 'CS2320' and
      sem = 'odd' and year = '2019' );
```

Equivalent to:

```
(SELECT rollNo
FROM enrollment
WHERE (courseId = 'CS2300' or courseId = 'CS2320')
and sem = 'odd' and year = '2019' )
```

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### Example using INTERSECTION

Obtain the roll numbers of students who are currently enrolled for both CS2300 and CS2320 Courses.

```
(select rollNo
from enrollment
where courseId = 'CS2300' and
      sem = 'odd' and year = '2019' )

INTERSECT

(select rollNo
from enrollment
where courseId = 'CS2320' and
      sem = 'odd' and year = '2019');
```

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### Example using EXCEPT

Obtain the roll numbers of students who are currently not enrolled for CS2300 course.

```
(SELECT rollNo
FROM enrollment
WHERE sem = 'odd' and year = '2019')
EXCEPT
(SELECT rollNo
FROM enrollment
WHERE courseId = 'CS2300' and
      sem = 'odd' and year = '2019');
```

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### Aggregation of Data

#### Data analysis

- to get info on summary and trends in certain attributes
- need for computing aggregate values for data
- total value, average value etc

#### Aggregate functions in SQL

- five aggregate function are provided in SQL
- AVG, SUM, COUNT, MAX, MIN
- can be applied to any column of a table
- can be used in the *select* clause of SQL queries

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### Aggregate functions

- **AVG ([DISTINCT]A):**  
computes the average of (distinct) values in column A
- **SUM ([DISTINCT]A):**  
computes the sum of (distinct) values in column A
- **COUNT ([DISTINCT]A):**  
computes the number of (distinct) values in column A or no. of tuples in result
- **MAX (A):** computes the maximum of values in column A
- **MIN (A):** computes the minimum of values in column A

Optional  
keyword

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### Examples involving aggregate functions (1/2)

Suppose data about GATE exam in a particular year is available as a table with schema

*gateMarks*(*regNo*, *name*, *sex*, *branch*, *city*, *state*, *marks*)

Obtain the total number of students who have taken GATE in CS and their average marks

```
select count(regNo) as CsTotal, avg(marks) as CsAvg
from gateMarks
where branch = 'CS'
```

Output	
CsTotal	CsAvg

Get the maximum, minimum and average marks obtained by Students from the city of Hyderabad

```
select max(marks), min(marks), avg(marks)
from gateMarks
where city = 'Hyderabad';
```

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### Examples involving aggregate functions (2/2)

Get the names of students who obtained the maximum marks in the branch of EC

```
select name, max(marks)
from gateMarks
where branch = 'EC'
```

} Will not work

Only aggregate functions can be specified here. It does not make sense to include normal attributes ! (unless they are grouping attributes – to be seen later)

```
select regNo, name, marks
from gateMarks
where branch = 'EC' and marks = ANY
(select max(marks)
from gateMarks
where branch = 'EC');
```

Correct way of specifying the query

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### Date Aggregation and Grouping

#### Grouping

- Partition the set of tuples in a relation into groups based on certain criteria and compute aggregate functions for each group
- All tuples that agree on a set of attributes (i.e have the same value for each of these attributes ) are put into a group
- The specified aggregate functions are computed for each group
- Each group contributes one tuple to the output
- All the grouping attributes *must* also appear in the select clause
  - the result tuple of the group is listed along with the values of the grouping attributes of the group

Called the grouping attributes

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### Examples involving grouping(1/2)

Determine the maximum of the GATE CS marks obtained by students in each city, for all Cities. Assume 4 cities exist - Hyderabad, Chennai, Mysore and Bangalore.

```
select city, max(marks) as maxMarks
from gateMarks
where branch = 'CS'
group by city;
```

Result:

City	maxMarks
Hyderabad	87
Chennai	88
Mysore	90
Bangalore	86

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### Examples involving grouping(2/2)

In the University database, for each department, obtain the name, deptId and the total number of four credit courses offered by the department

```
Select deptId, name, count(*) as totalCourses
from department, course
where deptId = deptNo and credits = 4
group by deptId, name;
```

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### Having clause

After performing grouping, is it possible to report information about only a subset of the groups ?

- Yes, with the help of *having clause* which is always used in conjunction with Group By clause

Report the total enrollment in each course in the even semester of 2014; include only the courses with a minimum enrollment of 10.

```
Select courseId, count(rollNo) as Enrollment
from enrollment
where sem = even and year = 2014
group by courseId
having count(rollNo) ≥ 10;
```

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### Where clause versus Having clause

- Where clause
  - Performs tests on rows and eliminates rows not satisfying the specified condition
  - Performed *before* any grouping of rows is done
- Having clause
  - Always performed *after* grouping
  - Performs tests on groups and eliminates groups not satisfying the specified condition
  - Tests can only involve grouping attributes and aggregate functions

```
Select courseId, count(rollNo) as Enrollment
from enrollment
where sem = 2 and year = 2014
group by courseId
having count(rollNo) ≥ 10;
```

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### String Operators in SQL

- Specify strings by enclosing them in single quotes  
e.g., 'Chennai'

Common operations on strings –

- Pattern matching – using 'LIKE' comparison operator
  - specify patterns using special characters –
- Character '%' (percent) matches any Substring  
e.g., 'Ram%' matches any string starting with "Ram"
- Character '\_' (underscore) matches any single character  
e.g., (a) '\_\_\_\_nagar' matches with any string ending with "nagar", with any 3 characters before that.  
(b) '\_\_\_\_\_' matches any string with exactly four characters

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### Using the 'LIKE' operator

Obtain roll numbers and names of all students whose names end with 'Mohan'

```
select rollNo, name
from student
where name like 'Mohan';
```

- Patterns are case sensitive.
- Special characters (percent, underscore) can be included in patterns using an escape character '\' (backslash)

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### Join Operation

In SQL, usually joining of tuples from different relations is implicitly specified in the 'where' clause

Get the names of professors working in CSE dept.

```
select f.name
from professor as f, department as d
where f.deptNo = d.deptId and
d.name = 'CSE';
```

The above query specifies joining of professor and department relations on condition  $f.deptNo = d.deptId$  and selection on department relation using  $d.name = 'CSE'$

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### Explicit Specification of Joining in 'From' Clause

```
select f.name
from (professor as f join department as d on
      f.deptNo = d.deptId)
where d.name = 'CSE';
```

Join types:

1. inner join (default):  
from ( $r_1$  inner join  $r_2$  on <predicate>)  
use of just 'join' is equivalent to 'inner join'
2. left outer join:  
from ( $r_1$  left outer join  $r_2$  on <predicate>)
3. right outer join:  
from ( $r_1$  right outer join  $r_2$  on <predicate>)
4. full outer join:  
from ( $r_1$  full outer join  $r_2$  on <predicate>)

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### Natural join

The adjective 'natural' can be used with any of the join types to specify natural join.

FROM ( $r_1$  NATURAL <join type>  $r_2$  [USING <attr. list>])

- natural join by default considers all common attributes
- a subset of common attributes can be specified in an optional USING <attr. list> phrase

#### REMARKS

- Specifying join operation explicitly goes against the spirit of declarative style of query specification
- But the queries may be easier to understand
- The feature is to be used judiciously

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### Views ( or Virtual Tables)

- Views provide virtual relations which may contain data spread across different tables. Used by applications.
  - simplified query formulations
  - data hiding
  - a view of frequently used data – efficient query answering
- Once created, a view is always kept *up-to-date* by the RDBMS
- View is not part of conceptual schema
  - created to give a user group, concerned with a certain aspect of the information system, their *view* of the system
- View implementation
  - Views need not be stored as permanent tables
  - They can be created on-the-fly whenever needed or
  - They can also be *materialized* and kept up-to-date
- Tables involved in the view definition – base tables

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### Creating Views

CREATE VIEW v AS <query expr>

creates a view 'v', with structure and data defined by the outcome of the query expression

Create a view which contains name, employee Id and phone number of professors who joined CSE dept in or after the year 2000.

*create view profAft2K as*  
*(select f.name, empId, phone*  
*from professor as f, department as d*  
*where f.depNo = d.deptId and*  
*d.name = 'CSE' and*  
*f.startYear >= 2000);*

If the details of a new CSE professor are entered into *professor* table, the above view gets updated automatically

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### Queries on Views

Once created a view can be used in queries just like any other table.

e.g. Obtain names of professors in CSE dept, who joined after 2000 and whose name starts with 'Ram'

*select name*  
*from profAft2K*  
*where name like 'Ram%';*

The definition of the view is stored in DBMS, and executed to create the temporary table (view), when encountered in query

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### Operations on Views

- Querying is allowed
- Update operations are usually restricted
  - because – to update a view, we may require
    - to modify many base tables
    - there may not be a unique way of updating the base tables to reflect the update on view
    - views may contain some aggregate values
    - ambiguity where primary key of a base table is not included in view definition.

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### Restrictions on Updating Views

- Updates on views defined on joining of more than one table are not allowed
- For example, updates on the following view are not allowed
- Note that we are not keeping information about when a student has completed the course in the view

create a view StudentGrades with rollNo, name, courseId and grade

```
create view studentGrade(rollNo,name,courseId,grade) as
(select s.rollNo, s.name, e.courseId, e.grade
 from student s, enrollment e
 where s.rollNo = e.rollNo);
```

- Suppose we want to update grade in the view from "U" to "D" for one particular course for a student, there will be ambiguity in doing the update on base tables.

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### Restrictions on Updating Views

- Updates on views defined with 'group by' clause and aggregate functions is not permitted, as a tuple in view will not have a corresponding tuple in base relation.

- For example, updates on the following view are not allowed

Create a view deptAvgCredits which contains the average credits of courses offered by a dept.

```
create view deptAvgCredits(deptNo,avgCredits)
as select deptNo, avg(credits)
 from course
 group by deptNo;
```

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### Restrictions on Updating Views

- Updates on views which do not include Primary Key of base table, are also not permitted
- For example, updates on the following view are not allowed

Create a view StudentPhone with Student name and phone number.

```
create view StudentPhone (sname,sphone) as
(select name, phone
 from student);
```

View StudentPhone does not include Primary key of the base table.

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### Allowed Updates on Views

Updates to views are allowed only if

- defined on single base table
- not defined using 'group by' clause and aggregate functions
- view includes Primary Key of base table

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### Inserting data into a table

- Specify a tuple(or tuples) to be inserted  
*INSERT INTO student VALUES*  
(*'CS05D014', 'Mohan', 'PhD', 2005, 'M', 3, 'FCS008'*),  
(*'CS05S031', 'Madhav', 'MS', 2005, 'M', 4, 'FCE009'*);
- Specify the result of query to be inserted  
*INSERT INTO r<sub>1</sub> SELECT ... FROM ... WHERE ...*
- Specify that a sub-tuple be inserted  
*INSERT INTO student(rollNo, name, sex)*  
*VALUES (CS05M022, 'Rajasri', 'F'),*  
*(CS05B033, 'kalyan', 'M');*
  - the attributes that can be NULL or have declared default values can be left-out to be updated later

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### Deleting rows from a table

- Deletion of tuples is possible ; deleting only part of a tuple is not possible
- Deletion of tuples can be done *only from one* relation at a time
- Deleting a tuple might trigger further deletions due to *referentially triggered actions* specified as part of RIC's
- Generic form: *delete from r where <predicate>;*

Delete tuples from professor relation with start year as 1982.

*delete from professor*  
*where startyear = 1982;*

- If 'where' clause is not specified, then all the tuples of that relation are deleted ( Be careful !)

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### A Remark on Deletion

- The where predicate is evaluated for each of the tuples in the relation to mark them as qualified for deletion *before* any tuple is actually deleted from the relation
- Note that the result may be different if tuples are deleted as and when we find that they satisfy the where condition!

- An example:

Delete all tuples of students that scored the least marks in the CS branch:

```
DELETE
FROM gateMarks
WHERE branch = "CS" and
      marks = ANY ( SELECT MIN(marks)
                    FROM gateMarks
                    WHERE branch = "CS")
```

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### Updating tuples in a relation

```
update r
set <<attr = newValue> list>
where <predicates>;
```

Change phone number of all professors working in CSE dept to "94445 22605"

```
update professors
set phone = '9444422605'
where deptNo = (select deptId
               from department
               where name = 'CSE');
```

If 'where' clause is not specified, values for the specified attributes in all tuples is changed.

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### Miscellaneous features in SQL (1/3)

- Ordering of result tuples can be done using 'order by' clause  
e.g., List the names of professors who joined after 1980, in alphabetic order.

```
select name
from professor
where startYear > 1980
order by name;
```

- Use of 'null' to test for a null value, if the attribute can take null  
e.g., Obtain roll numbers of students who don't have phone numbers

```
select rollNo
from student
where phoneNumber is null;
```

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### Miscellaneous features in SQL (2/3)

- Use of 'between and' to test the range of a value  
e.g., Obtain names of professors who have joined between 1980 and 1990

```
select name
from professor
where startYear between 1980 and 1990;
```

- Change the column name in result relation  
e.g.,  
*select name as studentName, rollNo as studentNo
from student;*

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### Miscellaneous features in SQL (3/3)

- Use of 'distinct' key word in 'select' clause to determine duplicate tuples in result.

Obtain all distinct branches of study for students

```
select distinct d.name
from student as s, department as d
where s.deptNo = d.deptId;
```

- Use of asterisk (\*) to retrieve all the attribute values of selected tuples.

Obtain details of professors along with their department details.

```
select *
from professor as f, department as d
where f.deptNo = d.deptId;
```

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### Database System Architectures

Centralized Architecture – used long ago, before PCs were born  
Complete DB functionality – storage, running application programs, transaction processing etc – is on one system - Server  
Access systems are just display devices - terminals

Client/Server Architecture – two tier systems

- Client – powerful enough to do local processing
  - runs graphical user interface and application programs
  - sends Database queries/updates to Server
- Server – provides rest of the DB System functionality

Three Tier System Architectures – also possible – details left out here

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### Application Development Process: 2-tier Systems

Host language (HL) – the high-level programming language in which the application is developed (e.g., C, C++, Java etc.)

Managing Database Access – several approaches are available

- Embedded SQL approach – SQL commands are embedded in the HL programs
  - A static approach - SQL commands can't be given at runtime
  - Dynamic SQL
- Call Level Interface SQL/CLI – an API based approach
- JDBC – Java DB connectivity – an API based approach
- Use a Database programming language – Oracle's PL/SQL

Embedded SQL, Dynamic SQL – we will study in some detail  
Other approaches – to be studied by students

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### Impedance Mismatch

#### ■ Impedance Mismatch:

Problems due to difference in HL data model vs DB data model

- Data types of HL vs those in DB
- HL languages do not support set-of-records as supported by SQL

#### ■ Handling Data types

- For each SQL attribute data type – corresponding HL data type
- Specified as language *binding*
- To be done for each host language

#### ■ Handling SQL query results

- Results are either sets or multi-sets of tuples
- A data structure to hold results and an iterator are needed

#### ■ Does not arise in case of dedicated DB programming languages

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### Embedded SQL Approach

Host language (HL) – the high-level programming language in which the application is developed (e.g., C, C++, Java etc.)

Embedded SQL approach:

- SQL statements are interspersed in HL program for application development
- Pre-compiler replaces these with suitable library calls
  - Library is supplied by the RDBMS vendor
- SQL commands – identified by special reserved words – EXEC SQL

Data transfer –  
takes place through specially declared HL variables

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### Declaring Variables

Variables that need to be used in SQL statements are declared in a special section. These are called *shared* variables.

```
EXEC SQL BEGIN DECLARE SECTION
char rollNo[9];           //HL is C language
char studName[20], degree[6];
int year; char sex;
int deptNo; char advisor[9];
EXEC SQL END DECLARE SECTION
```

Note that schema for student relation is  
student(rollNo, name, degree, year, sex, deptNo, advisor)

Use in SQL statements: variable name is prefixed with a colon(:)  
e.g., :ROLLNO in an SQL statement refers to rollNo variable  
In HL program, shared variables can be used directly w/o colon.

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### Handling Error Conditions

The HL program needs to know if an SQL statement has executed successfully or otherwise

Special variable called SQLSTATE is used for this purpose  
It is a string of 6 characters.

- SQLSTATE is set to appropriate value by the RDBMS run-time system after executing each SQL statement
- Non-zero values indicate errors in execution
  - Different values indicate different types of error situations
- SQLSTATE variable must be declared in the HL program
- HL program needs to check for error situations and handle them appropriately.

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### Database Connections in Embedded SQL Approach

#### DB connection

- Needs to be established before accessing the DB in the app pgm
- Specify the particular server and authenticate the application
- Several connections - to access 2 or more DB servers
- Only one connection can be *active* at any time

#### SQL Commands

```
CONNECT TO <serverName> AS <connName>
AUTHORIZATION <uName, passWd>
```

```
To change to a different server
SET CONNECTION <connName>
```

```
DISCONNECT <connName>
```

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### Embedded SQL Statements – An example

Suppose we collect data through user interface into variables  
rollNo, studName, degree, year, sex, deptNo, advisor

A row into the student table can be inserted as follows:

```
EXEC SQL INSERT INTO STUDENT
VALUES (:rollNo, :studName, :degree,
       :year, :sex, :deptNo, :advisor);
```

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### Query result handling and Cursors

- HL languages do not support set-of-records as supported by SQL
- A *cursor* is a mechanism which allows us to retrieve one row at a time from the result of a query
- We can declare a cursor on any SQL query
- Once declared, we use open, fetch, move and close commands to work with cursors
- We usually need a cursor when embedded statement is a SELECT query
- INSERT, DELETE and UPDATE do not need a cursor.

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### Embedded SQL - Cursors (1/2)

We do not need a cursor if the query results in a single row.

```
e.g., EXEC SQL SELECT s.name, s.sex
      INTO :name, :sex
      FROM student s
      WHERE s.rollNo = :rollNo;
```

- Result row values name and phone are assigned to HL variables :name and :phone, using INTO clause
- Cursor is not required as the result always contains only one row ( rollNo is a key for student relation)

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### Embedded SQL - Cursors (2/2)

- If the result contains more than one row, cursor declaration is needed

e.g., `select s.name, s.degree  
from student s  
where s.sex = 'F';`

- Query results in a collection of rows
- HL program has to deal with set of records.
- The use of 'INTO' will not work here
- We can solve this problem by using a *cursor*.

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### Declaring a cursor on a query

`declare studInfo cursor for  
select name, degree  
from student  
where sex = 'F';`

Cursor name

- Command OPEN studInfo; opens the cursor and makes it point to first record
- To read current row of values into HL variables:  
FETCH studInfo INTO :name, :degree;
- After executing FETCH statement cursor is pointed to next row by default
- Cursor movement can be optionally controlled by the programmer
- After reading all records we close the cursor using the CLOSE studInfo command.

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### Dynamic SQL

- Useful for applications to generate and run SQL statements, based on user inputs
- Queries may not be known in advance

e.g., `char sqlString[ ] = {"select * from student"};  
EXEC SQL PREPARE runQ FROM sqlString;  
EXEC SQL EXECUTE runQ;`

- `sqlString` is a C variable that holds user submitted query
  - Typically built by previous statements in the HL program using end-user inputs.
- `runQ` is an SQL variable that holds the SQL statement.

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### Connecting to Database from HL – Other Approaches

ODBC (Open Database Connectivity), SQL/CLI and JDBC

- accessing database and data is through an API
- many DBMSs can be accessed
- no restriction on number of active connections
- appropriate drivers are required
- steps in accessing data from a HL program
  - select the data source
  - load the appropriate driver dynamically
  - establish the connection
  - authenticate the client
  - work with database
  - close the connection.

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### A comparison of the Approaches

#### Embedded SQL Approach

- + queries are part of source code, syntax-check at compile time
- + application programs are easy to understand, readable
- + development is easier
- Any changes to queries : recompilation required
- Complex applications requiring runtime query creation are difficult

#### API based Approach

- + More flexibility in programming
- + Complex applications can be developed
- Application development is complex, error-prone

#### DB Language Approach

- + No impedance mismatch
- Programmers need to learn a new language; apps not portable

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