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Database Management System

Lab Manual

Database is a collection of related data and data is a collection of facts and figures that can be processed to produce information. Mostly data represents recordable facts. Data aids in producing information, which is based on facts. For example, if we have data about marks obtained by all students, we can then conclude about toppers and average marks.

A **database management system** stores data in such a way that it becomes easier to retrieve, manipulate, and produce information.

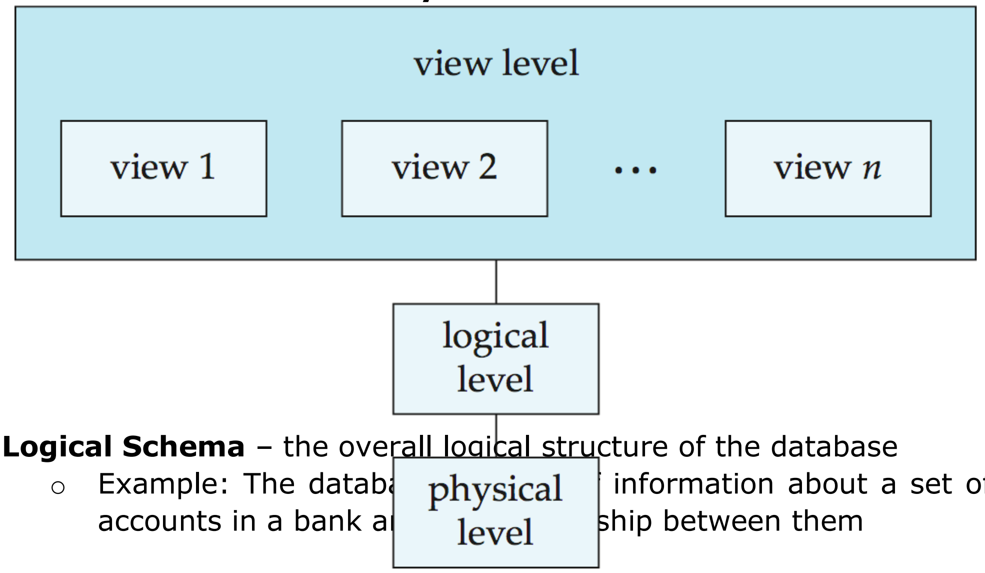
Database Applications:

- Banking: transactions
- Airlines: reservations, schedules
- Universities: registration, grades
- Sales: customers, products, purchases
- Online retailers: order tracking, customized recommendations
- Manufacturing: production, inventory, orders, supply chain
- Human resources: employee records, salaries, tax deductions

Drawbacks of using file systems

- Data redundancy and inconsistency
- Difficulty in accessing data
- Data isolation
- Integrity problem
- Atomicity of updates
- Concurrent access by multiple users

Architecture for a database system



- **Logical Schema** – the overall logical structure of the database
  - Example: The databa f information about a set of customers and accounts in a bank a ship between them

        - Analogous to type information of a variable in a program
- **Physical schema**– the overall physical structure of the database
- **Instance** – the actual content of the database at a particular point in time
    - Analogous to the value of a variable
- **Physical Data Independence** – the ability to modify the physical schema without changing the logical schema
    - Applications depend on the logical schema
    - In general, the interfaces between the various levels and components should be well defined so that changes in some parts do not seriously influence others.

Data Models:

Entity Relation Model

Entity-Relationship (ER) Model is based on the notion of real-world entities and relationships among them. While formulating real-world scenario into the database model, the ER Model creates entity set, relationship set, general attributes, and constraints.

ER Model is best used for the conceptual design of a database.

ER Model is based on:

- **Entities** and their attributes.
- **Relationships** among entities.

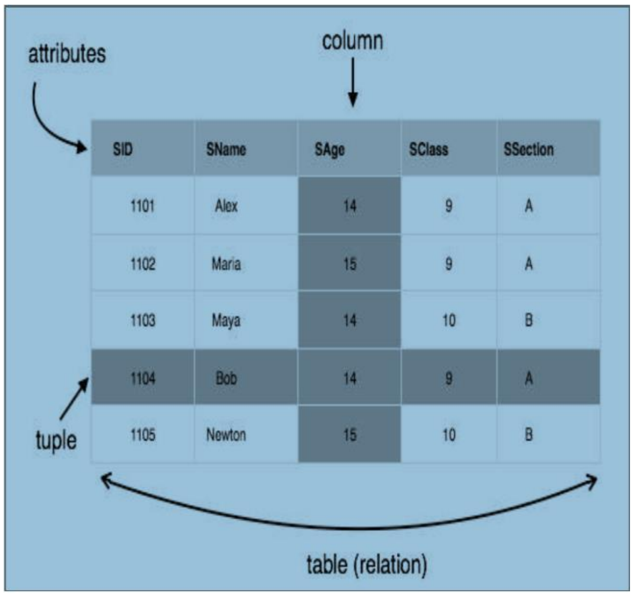
Entity
An entity in an ER Model is a real-world entity having properties called **attributes**.
Every attribute is defined by its set of values called **domain**.

For example, in a school database, a student is considered as an entity. Student has various attributes like name, age, class, etc.

Relationship
The logical association among entities is called **relationship**. Relationships are mapped with entities in various ways. Mapping cardinalities define the number of association between two entities.

Mapping cardinalities:
o one to one
o one to many
o many to one
o many to many
Relational Model

The most popular data model in DBMS is the Relational Model. It is more Scientific a model than others. This model is based on first-order predicate logic and defines a table as an **n-ary relation**

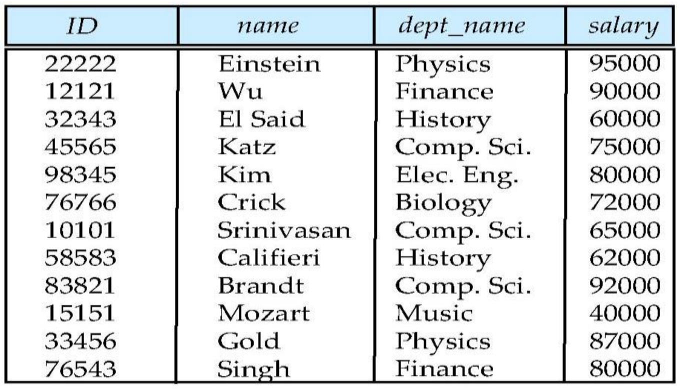


SID	SName	SAge	SClass	SSection
1101	Alex	14	9	A
1102	Maria	15	9	A
1103	Maya	14	10	B
1104	Bob	14	9	A
1105	Newton	15	10	B

The main highlights of this model are:

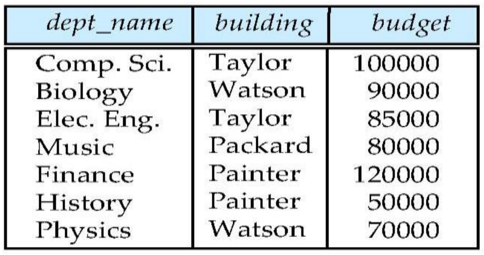
- Data is stored in tables called **relations**.
- Relations can be normalized.
- In normalized relations, values saved are atomic values.
- Each row in a relation contains a unique value

Example:



ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

(a) The *instructor* table



dept_name	*building*	*budget*
Comp. Sci.	Taylor	100000
Biology	Watson	90000
Elec. Eng.	Taylor	85000
Music	Packard	80000
Finance	Painter	120000
History	Painter	50000
Physics	Watson	70000

(b) The *department* table

Data Definition Language

- Specification notation for defining the database schema
- Example:

```
create table instructor (
        ID          char(5),
        name        varchar(20),
        dept_name   varchar(20),
        salary      numeric(8,2))
```

- DDL compiler generates a set of table templates stored in a *data dictionary*
- Data dictionary contains metadata (i.e., data about data)
    - Database schema
    - Integrity constraints
        - Primary key (ID uniquely identifies instructors)
    - Authorization
        - Who can access what

Data Manipulation Language

- Language for accessing and manipulating the data organized by the appropriate data model
    - DML also known as query language
- Two classes of languages
    - Pure – used for proving properties about computational power and for optimization
        - Relational Algebra
        - Tuple relational calculus
        - Domain relational calculus
    - Commercial – used in commercial systems
        - SQL is the most widely used commercial language

Structure Query Language

- The most widely used commercial language
- SQL is NOT a Turing machine equivalent language
- SQL is NOT a Turing machine equivalent language
- To be able to compute complex functions SQL is usually embedded in some higher-level language
- Application programs generally access databases through one of
    - Language extensions to allow embedded SQL
    - Application program interface (e.g., ODBC/JDBC) which allow SQL queries to be sent to a database

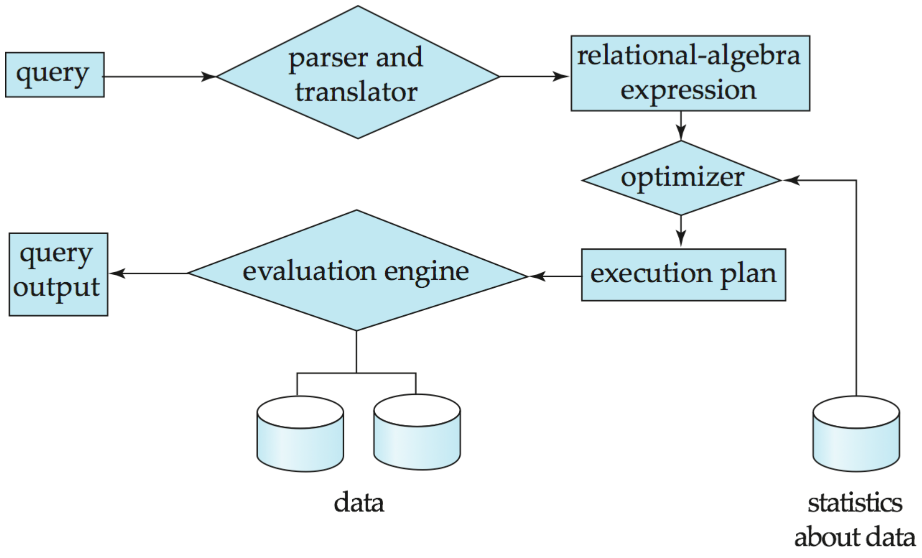
Storage Management

- Storage manager is a program module that provides the interface between the low-level data stored in the database and the application programs and queries submitted to the system.
- The storage manager is responsible to the following tasks:
    - Interaction with the OS file manager
    - Efficient storing, retrieving and updating of data

- Issues:
    - Storage access
    - File organization
    - Indexing and hashing

Query Processing

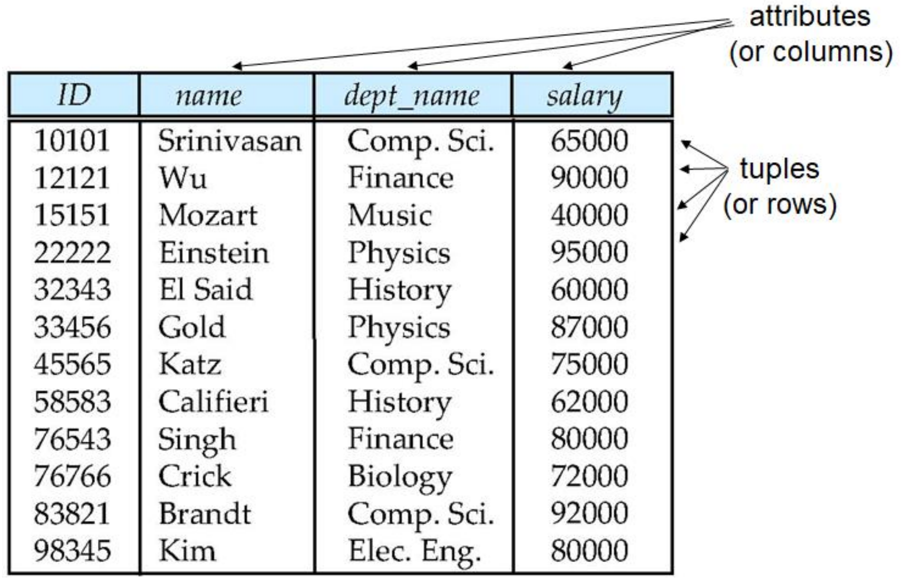
1. Parsing and translation
2. Optimization
3. Evaluation



Transaction Management

- A transaction is a collection of operations that performs a single logical function in a database application
- Transaction-management component ensures that the database remains in a consistent (correct) state despite system failures (e.g., power failures and operating system crashes) and transaction failures.
- Concurrency-control manager controls the interaction among the concurrent transactions, to ensure the consistency of the database.

Relational Model


attributes
(or columns)
tuples
(or rows)

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Relation schema and Instance

- $A_1, A_2, \ldots, A_n$ are *attributes*
- $R = (A_1, A_2, \ldots, A_n)$ is a *relation schema*
    - Example:
    - *instructor* = (*ID, name, dept_name, salary*)
- Formally, given sets $D_1, D_2, \ldots. D_n$ a relation r is a subset of
  $D_1 \times D_2 \times \ldots \times D_n$
  Thus, a relation is a set of n-tuples $(a_1, a_2, \ldots, a_n)$ where each $a_i \in D_i$

- The current values (relation instance) of a relation are specified by a table
- An element *t* of *r* is a *tuple*, represented by a *row* in a table

Keys

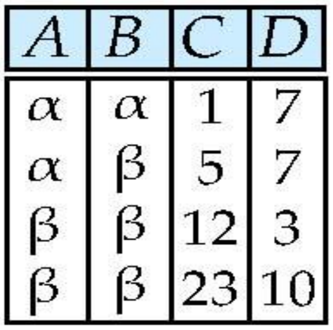
- Let $K \subseteq R$
- *K* is a superkey of *R* if values for *K* are sufficient to identify a unique tuple of each possible relation *r(R)*
- Example: {*ID*} and {ID,name} are both superkeys of *instructor.*
- Superkey *K* is a candidate key if *K* is minimal
  Example: {*ID*} is a candidate key for *Instructor*
- One of the candidate keys is selected to be the primary key.
- which one?
- Foreign key constraint: Value in one relation must appear in another
- Referencing relation
- Referenced relation
- Example – *dept_name* in i*nstructor* is a foreign key from *instructor* referencing *department*

Relational Query Language:

- Procedural vs .non-procedural, or declarative
- “Pure” languages:
  - Relational algebra
  - Tuple relational calculus
  - Domain relational calculus
- The above 3 pure languages are equivalent in computing power
- We will concentrate in this chapter on relational algebra
  - Not turning-machine equivalent
  - consists of 6 basic operations

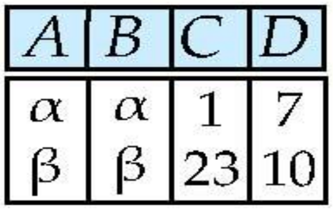
Select Operation – selection of rows (tuples)

- Relation r



A	B	C	D
α	α	1	7
α	β	5	7
β	β	12	3
β	β	23	10

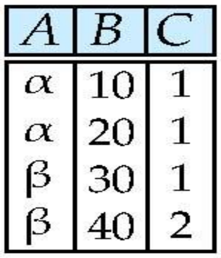
- $\sigma_{A=B \wedge D > 5}(r)$



A	B	C	D
α	α	1	7
β	β	23	10

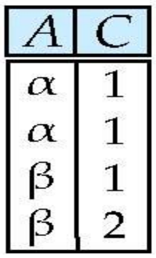
Project Operation – selection of columns (Attributes)

- Relation *r*:



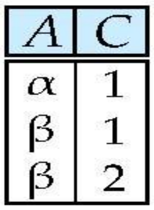
A	B	C
α	10	1
α	20	1
β	30	1
β	40	2

- $\Pi_{A,C}(r)$



A	C
α	1
α	1
β	1
β	2

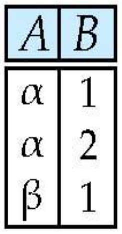
=



A	C
α	1
β	1
β	2

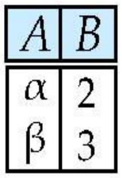
Union of two relations

- Relations *r, s:*



A	B
α	1
α	2
β	1

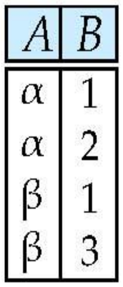
r



A	B
α	2
β	3

s

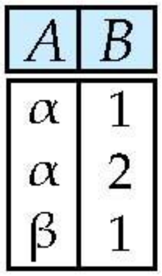
- r ∪ s:



A	B
α	1
α	2
β	1
β	3

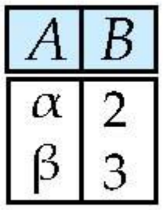
Set Difference of two relation

- Relations *r*, *s*:



A	B
α	1
α	2
β	1

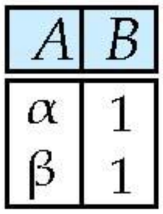
r



A	B
α	2
β	3

s

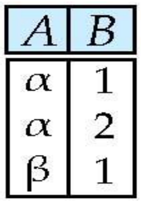
- *r – s:*



A	B
α	1
β	1

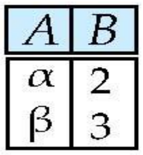
Set Intersection of two relations

- Relation *r, s*:



A	B
α	1
α	2
β	1

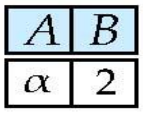
r



A	B
α	2
β	3

s

- *r ∩ s*



A	B
α	2

joining two relations -- Cartesian-product

- Relations *r, s*:

A	B
α	1
β	2

r

C	D	E
α	10	a
β	10	a
β	20	b
γ	10	b

s

- *r* x *s*:

A	B	C	D	E
α	1	α	10	a
α	1	β	10	a
α	1	β	20	b
α	1	γ	10	b
β	2	α	10	a
β	2	β	10	a
β	2	β	20	b
β	2	γ	10	b

Natural Join

Relations r, s:

A	B	C	D
α	1	α	a
β	2	γ	a
γ	4	β	b
α	1	γ	a
δ	2	β	b

r

B	D	E
1	a	α
3	a	β
1	a	γ
2	b	δ
3	b	ε

s

Natural Join

r $\bowtie$ s

A	B	C	D	E
α	1	α	a	α
α	1	α	a	γ
α	1	γ	a	α
α	1	γ	a	γ
δ	2	β	b	δ

$$\Pi_{A,\ r.B,\ C,\ r.D,\ E}\,(\sigma_{r.B\,=\,s.B\ \wedge\ r.D\,=\,s.D}\ (r \times s)))$$

Summary of Relational Algebra Operators

Symbol (Name)	Example of Use
σ (Selection)	$\sigma_{\text{salary} >= 85000}$ (*instructor*)
	Return rows of the input relation that satisfy the predicate.
Π (Projection)	$\Pi_{ID,\ salary}$ (*instructor*)
	Output specified attributes from all rows of the input relation. Remove duplicate tuples from the output.
x (Cartesian Product)	*instructor* x *department*
	Output pairs of rows from the two input relations that have the same value on all attributes that have the same name.
∪ (Union)	Π_{name} (*instructor*) ∪ Π_{name} (*student*)
	Output the union of tuples from the *two* input relations.
- (Set Difference)	Π_{name} (*instructor*) -- Π_{name} (*student*)
	Output the set difference of tuples from the two input relations.
⋈ (Natural Join)	*instructor* ⋈ *department*
	Output pairs of rows from the two input relations that have the same value on all attributes that have the same name.

Introduction to SQL (Structured Query Language)

Basic Data 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).
- **Small int.** 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. (ex., numeric(3,1), allows 44.5 to be stores exactly, but not 444.5 or 0.32)
- **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.

CREATE TABLE:

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 instructor (
        ID          char(5),
        name        varchar(20),
        dept_name   varchar(20),
        salary      numeric(8,2));
```

Integrity constraint in create table

- not null
- primary key (A_1, ..., A_n)
- foreign key (A_m, ..., A_n) references *r*

- *Example:*
- create table *instructor* (

```
        ID          char(5),
        name        varchar(20) not null,
        dept_name   varchar(20),
        salary      numeric(8,2),
        primary key (ID),
        foreign key (dept_name) references department);
```

Updates to table:

- Insert
  - insert into *instructor* values (‘10211’, ’Smith’, ’Biology’, 66000);
- Delete
  - Remove all tuples from the *student* relation
  - delete from *student*
- Drop Table
  - drop table *r*
- Alter
  - 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 exiting tuples in the relation are assigned *null* as the value for the new attribute.
  - alter table *r* drop *A*
    - where *A* is the name of an attribute of relation *r*
    - Dropping of attributes not supported by many databases.

Select Query

- The select clause lists the attributes desired in the result of a query
    - corresponds to the projection operation of the relational algebra
- Example: find the names of all instructors:

  select *name*
  from *instructor*
- **NOTE:** SQL names are case insensitive (i.e., you may use upper- or lower-case letters.)
    - E.g., *Name* ≡ *NAME* ≡ *name*
    - Some people use upper case wherever we use bold font.
- 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 department names of all instructors, and remove duplicates
        - select distinct *dept* from *instructor*
- The keyword all specifies that duplicates should not be removed.
        - select all *dept_name* from *instructor*
- An asterisk in the select clause denotes "all attributes"
        - select * from *instructor*
- An attribute can be a literal with no from clause
        - select '437'
    - Results is a table with one column and a single row with value "437"
    - Can give the column a name using:
        - select '437' as *FOO*
- An attribute can be a literal with from clause
        - select 'A' from *instructor*
    - Result is a table with one column and *N* rows (number of tuples in the *instructors* table), each row with value "A"

- The select clause can contain arithmetic expressions involving the operation, +, –, *, and /, and operating on constants or attributes of tuples.
    - The query:
    - select *ID, name, salary* from *instructor*
      would return a relation that is the same as the *instructor* relation, except that the value of the attribute *salary* is divided by 12.
- Can rename "*salary/12*" using the as clause:
    - select *ID, name, salary/12* as *monthly_salary*

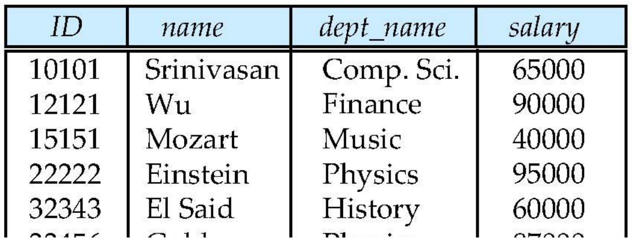
The where clause

- The where clause specifies conditions that the result must satisfy
    - Corresponds to the selection predicate of the relational algebra.
- To find all instructors in Comp. Sci. dept
        - select *name*
          from *instructor*
          where *dept_name* = 'Comp. Sci.'
- Comparison results can be combined using the logical connectives and, or, and not
    - To find all instructors in Comp. Sci. dept with salary > 80000
        - select *name*
          from *instructor*
          where *dept_name* = 'Comp. Sci.' and *salary* > 80000
- Comparisons can be applied to results of arithmetic expressions

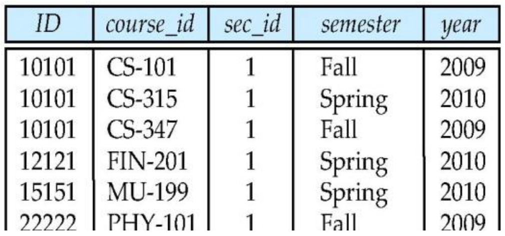
The From clause

- The from clause lists the relations involved in the query
    - Corresponds to the Cartesian product operation of the relational algebra.
- Find the Cartesian product *instructor X teaches*
        - select * from *instructor, teaches*
    - generates every possible instructor – teaches pair, with all attributes from both relations.
    - For common attributes (e.g., *ID*), the attributes in the resulting table are renamed using the relation name (e.g., *instructor.ID*)
- Cartesian product not very useful directly, but useful combined with where-clause condition (selection operation in relational algebra).

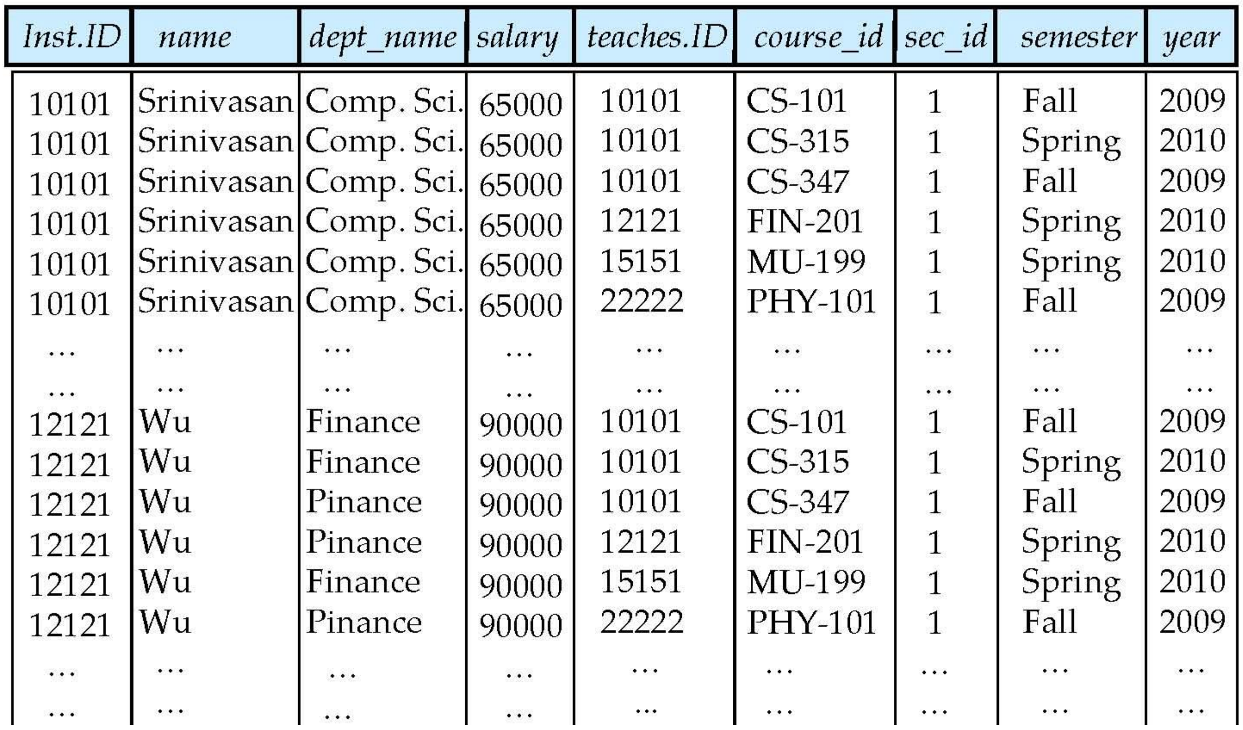
Cartesian Product Example:



ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000



ID	*course_id*	*sec_id*	*semester*	*year*
10101	CS-101	1	Fall	2009
10101	CS-315	1	Spring	2010
10101	CS-347	1	Fall	2009
12121	FIN-201	1	Spring	2010
15151	MU-199	1	Spring	2010
22222	PHY-101	1	Fall	2009



Inst.ID	*name*	*dept_name*	*salary*	*teaches.ID*	*course_id*	*sec_id*	*semester*	*year*
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	12121	FIN-201	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	15151	MU-199	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	22222	PHY-101	1	Fall	2009
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
12121	Wu	Finance	90000	10101	CS-101	1	Fall	2009
12121	Wu	Finance	90000	10101	CS-315	1	Spring	2010
12121	Wu	Pinance	90000	10101	CS-347	1	Fall	2009
12121	Wu	Pinance	90000	12121	FIN-201	1	Spring	2010
12121	Wu	Finance	90000	15151	MU-199	1	Spring	2010
12121	Wu	Pinance	90000	22222	PHY-101	1	Fall	2009
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…

Examples:

- Find the names of all instructors who have taught some course and the course_id
  - select *name, course_id*
    from *instructor , teaches*
    where *instructor.ID = teaches.ID*
- Find the names of all instructors in the Art department who have taught some course and the course_id
  - select *name, course_id*
    from *instructor , teaches*
    where *instructor.ID = teaches.ID and instructor. dept_name* = 'Art'

Rename operation:

- The SQL allows renaming relations and attributes using the as clause:
  - *old-name* as *new-name*
- Find the names of all instructors who have a higher salary than some instructor in 'Comp. Sci'.
  - select distinct *T.name*
    from *instructor* as *T, instructor* as *S*
    where *T.salary > S.salary* and *S.dept_name = 'Comp. Sci.'*
- Keyword as is optional and may be omitted
  instructor as *T* ≡ *instructor 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 instructors whose name includes the substring "dar".
  - select *name*
    from *instructor*
    where *name* like '%dar%'
- Match the string "100%"
  - like '100 \%' escape '\'
- in that above we use backslash (\) as the escape character.

- Patterns are case sensitive.
- Pattern matching examples:
  - 'Intro%' matches any string beginning with "Intro".
  - '%Comp%' matches any string containing "Comp" as a substring.
  - '_ _ _' matches any string of exactly three characters.
  - '_ _ _ %' matches any string of at least three characters.
- 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.

Between Clause

- SQL includes a between comparison operator
- Example: Find the names of all instructors with salary between \$90,000 and \$100,000 (that is, ³ \$90,000 and £ \$100,000)
    - select *name*
      from *instructor*
      where *salary* between 90000 and 100000
- Tuple comparison
    - select *name*, *course_id*
      from *instructor*, *teaches*
      where (*instructor*.*ID*, *dept_name*) = (*teaches*.*ID*, 'Biology');

Duplicates:

- In relations with duplicates, SQL can define how many copies of tuples appear in the result.
- Multi set versions of some of the relational algebra operators – given multi set 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. $\Pi_A(r)$: 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. t_2 in $r_1 \times r_2$

Set Operations

- Find courses that ran in Fall 2009 or in Spring 2010

(**select** *course_id* **from** *section* **where** *sem* = 'Fall' **and** *year* = 2009)
union
(**select** *course_id* **from** *section* **where** *sem* = 'Spring' **and** *year* = 2010)

- Find courses that ran in Fall 2009 and in Spring 2010

(**select** *course_id* **from** *section* **where** *sem* = 'Fall' **and** *year* = 2009)
intersect
(**select** *course_id* **from** *section* **where** *sem* = 'Spring' **and** *year* = 2010)

- Find courses that ran in Fall 2009 but not in Spring 2010

(**select** *course_id* **from** *section* **where** *sem* = 'Fall' **and** *year* = 2009)
except
(**select** *course_id* **from** *section* **where** *sem* = 'Spring' **and** *year* = 2010)

- Find the salaries of all instructors that are less than the largest salary.
    - select distinct *T.salary*
      from *instructor* as *T, instructor* as *S*
      where *T.salary < S.salary*
- Find all the salaries of all instructors
    - select distinct *salary*
      from *instructor*
- Find the largest salary of all instructors.
    - (select "second query")
      except
      (select "first query")

- Set operations union, intersect, and except
    - 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*

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 result of any arithmetic expression involving *null* is *null*
    - Example: 5 + *null* returns null
- The predicate is null can be used to check for null values.
    - Example: Find all instructors whose salary is null.
        - select *name* from *instructor* where *salary* is null
- Three values – *true*, *false*, *unknown*
- Any comparison with *null* returns *unknown*
    - Example*: 5 < null or null <> null or null = null*
- Three-valued logic using the value *unknown*:
    - OR: (*unknown* or *true*) = *true*,
      (*unknown* or *false*) = *unknown*
      (*unknown* or *unknown) = unknown*
    - AND: *(true* and *unknown) = unknown,*
      (false and *unknown) = false,*
      (unknown and *unknown) = unknown*
    - NOT*:* (not *unknown) = 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*

Aggregate functions

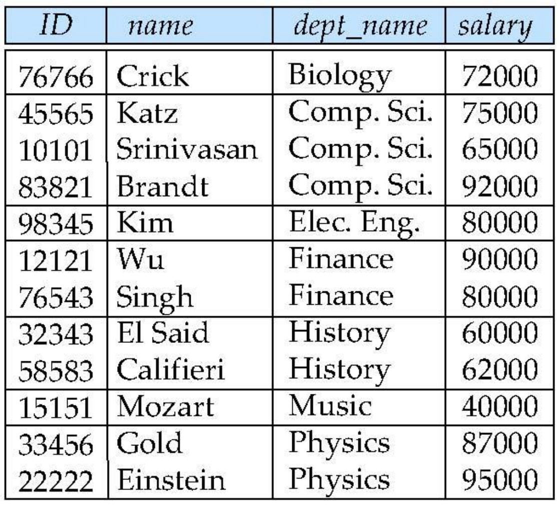
- These functions operate on the multiset of values of a column of a relation, and return a value
    - avg: average value
      min: minimum value
      max: maximum value
      sum: sum of values
      count: number of values

Examples:

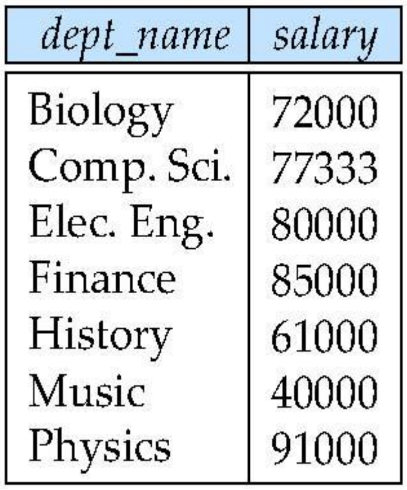
- Find the average salary of instructors in the Computer Science department
    - select avg (*salary*)
      from *instructor*
      where *dept_name*= 'Comp. Sci.';
- Find the total number of instructors who teach a course in the Spring 2010 semester
    - select count (distinct *ID*)
      from *teaches*
      where *semester* = 'Spring' and *year* = 2010;
- Find the number of tuples in the *course* relation
    - select count (*)
      from *course*;

Group by Function

- Find the average salary of instructors in each department
    - select *dept_name*, avg (*salary*) as *avg_salary*
      from *instructor*
      group by *dept_name*;



ID	*name*	*dept_name*	*salary*
76766	Crick	Biology	72000
45565	Katz	Comp. Sci.	75000
10101	Srinivasan	Comp. Sci.	65000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000
12121	Wu	Finance	90000
76543	Singh	Finance	80000
32343	El Said	History	60000
58583	Califieri	History	62000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
22222	Einstein	Physics	95000



dept_name	*salary*
Biology	72000
Comp. Sci.	77333
Elec. Eng.	80000
Finance	85000
History	61000
Music	40000
Physics	91000

Aggregate Function: Having clause

select *dept_name*, avg (*salary*) from *instructor* group by *dept_nam* having avg (*salary*) > 42000;

Nested Sub queries:

- SQL provides a mechanism for the nesting of subqueries. A subquery is a select-from-where expression that is nested within another query.
- The nesting can be done in the following SQL query

```
select A1, A2, ..., An
from r1, r2, ..., rm
where P
```

-

  as follows:
- A_i can be replaced be a subquery that generates a single value.
- r_i can be replaced by any valid subquery
- *P* can be replaced with an expression of the form:
- *B* <operation> (subquery)
- Where *B* is an attribute and <operation> to be defined later.

Sub queries in where clause:

- A common use of subqueries is to perform tests:
  - For set membership
  - For set comparisons
  - For set cardinality.
  -
- Find courses offered in Fall 2009 and in Spring 2010

```
select distinct course_id
from section
where semester = 'Fall' and year= 2009 and
        course_id in (select course_id
                      from section
                      where semester = 'Spring' and year= 2010);
```

- Find courses offered in Fall 2009 but not in Spring 2010

```
select distinct course_id
from section
where semester = 'Fall' and year= 2009 and
        course_id  not in (select course_id
                           from section
                           where semester = 'Spring' and year= 2010);
```

- Find the total number of (distinct) students who have taken course sections taught by the instructor with *ID* 10101

```
select count (distinct ID)
from takes
where (course_id, sec_id, semester, year) in
                         (select course_id, sec_id, semester, year
                          from teaches
                          where teaches.ID= 10101);
```

Set Comparison – "some" Clause

Find names of instructors with salary greater than that of some (at least one) instructor in the Biology department.

```
select distinct T.name
from instructor as T, instructor as S
where T.salary > S.salary and S.dept name = 'Biology';
```

Same query using > **some** clause

```
select name
from instructor
where salary > some (select salary
                     from instructor
                     where dept name = 'Biology');
```

Definition of Some clause:

F <comp> **some** $r \Leftrightarrow \exists\, t \in r$ such that (F <comp> t)
Where <comp> can be: $<, \leq, >, =, \neq$

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

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

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

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

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

Set comparison: all clause

- Find the names of all instructors whose salary is greater than the salary of all instructors in the Biology department.

- select *name* from *instructor* where *salary* > all (select *salary* from *instructor* where *dept name* = 'Biology');

Definition of 'all' clause

F <comp> **all** $r \Leftrightarrow \forall\, t \in r$ (F <comp> *t*)

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

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

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

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

($\neq$ **all**) $\equiv$ **not in**
However, (= **all**) $\not\equiv$ **in**

Test for Empty relation

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

Use of Exist clause

- Yet another way of specifying the query "Find all courses taught in both the Fall 2009 semester and in the Spring 2010 semester"

  -
    ```
    select course_id
      from section as S
      where semester = 'Fall' and year = 2009 and
              exists (select *
                        from section as T
                        where semester = 'Spring' and year= 2010
                              and S.course_id = T.course_id);
    ```
- Correlation name – variable S in the outer query
- Correlated subquery – the inner query

Use of ‘not exist’ clause

- Find all students who have taken all courses offered in the Biology department.

  select distinct *S*.*ID*, *S*.*name* from *student* as *S* where not exists ((select *course_id* from *course* where *dept_name* = ’Biology’) except (select *T*.*course_id* from *takes* as *T* where *S*.*ID* = *T*.*ID*));

  - First nested query lists all courses offered in Biology
  - Second nested query lists all courses a particular student took

Identify duplicate tuples

- The unique construct tests whether a subquery has any duplicate tuples in its result.
- The unique construct evaluates to “true” if a given subquery contains no duplicates .

- Find all courses that were offered at most once in 2009

```
select T.course_id
from course as T
where unique (select R.course_id
                    from section as R
                    where T.course_id= R.course_id
                              and R.year = 2009);
```

Sub queries in the form clause

- SQL allows a subquery expression to be used in the from clause

- Find the average instructors’ salaries of those departments where the average salary is greater than $42,000.”

```
select dept_name, avg_salary
from (select dept_name, avg (salary) as avg_salary
        from instructor
        group by dept_name)
where avg_salary > 42000;
```

- Note that we do not need to use the having clause

- Another way to write above query

```
select dept_name, avg_salary
from (select dept_name, avg (salary)
        from instructor
        group by dept_name) as dept_avg (dept_name, avg_salary)
where avg_salary > 42000;
```

With Clause

- The with clause provides a way of defining a temporary relation whose definition is available only to the query in which the with clause occurs.
- Find all departments with the maximum budget

```
with max_budget (value) as
        (select max(budget)
         from department)
select department.name
from department, max_budget
where department.budget = max_budget.value;
```

Scalar Subquery

- Scalar subquery is one which is used where a single value is expected
- List all departments along with the number of instructors in each department

    -
      ```
      select dept_name,
                  (select count(*)
                      from instructor
                     where department.dept_name = instructor.dept_name)
                  as num_instructors
      from department;
      ```
- Runtime error if subquery returns more than one result tuple

Deletion

- Delete all instructors
    - delete from *instructor*
- Delete all instructors from the Finance department

```
delete from instructor
where dept_name= 'Finance';
```

- Delete all tuples in the *instructor* relation for those instructors associated with a department located in the Watson building.

    -
      ```
      delete from instructor
                   where dept name in (select dept name
                                        from department
                                        where building = 'Watson');
      ```

Insertion

- Add a new tuple to *course*
    - insert into values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);

or equivalently

-
  ```
  insert into course (course_id, title, dept_name, credits)
          values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);
  ```

- Add a new tuple to *student* with *tot_creds* set to null

    -
      ```
      insert into student
              values ('3003', 'Green', 'Finance', null);
      ```

- Add all instructors to the *student* relation with tot_creds set to 0
  insert into *student*

  ```
          select ID, name, dept_name, 0
         from   instructor
  ```

- The select from where statement is evaluated fully before any of its results are inserted into the relation.

- Otherwise queries like

  insert into *table*1 select * from *table*1

  would cause problem

Updates

- Increase salaries of instructors whose salary is over $100,000 by 3%, and all others by a 5%
  - Write two update statements:

    -
      ```
      update instructor
                  set salary = salary * 1.03
                  where salary > 100000;
              update instructor
                   set salary = salary * 1.05
                   where salary <= 100000;
      ```
  - The order is important
  - Can be done better using the case statement (next slide)

Updates with scalar sub query

- Recompute and update tot_creds value for all students

```
update student S

 set tot_cred = (select sum(credits)
                 from takes, course
                 where takes.course_id = course.course_id and
                          S.ID= takes.ID.and
   takes.grade <> 'F' and
                          takes.grade is not null);
```

- Sets *tot_creds* to null for students who have not taken any course

  Instead of sum(*credits*), use:

  -
    ```
    case
                when sum(credits) is not null then sum(credits)
                else 0
            end
    ```

SQL Using Views:

A view is nothing more than a SQL statement that is stored in the database with an associated name. A view is actually a composition of a table in the form of a predefined SQL query.

A view can contain all rows of a table or select rows from a table. A view can be created from one or many tables which depends on the written SQL query to create a view.

Views, which are a type of virtual tables allow users to do the following −

- Structure data in a way that users or classes of users find natural or intuitive.
- Restrict access to the data in such a way that a user can see and (sometimes) modify exactly what they need and no more.
- Summarize data from various tables which can be used to generate reports.

Creating Views

Database views are created using the **CREATE VIEW** statement. Views can be created from a single table, multiple tables or another view.

To create a view, a user must have the appropriate system privilege according to the specific implementation.

The basic **CREATE VIEW** syntax is as follows −

```
CREATE VIEW view_name AS
SELECT column1, column2.....
FROM table_name
WHERE [condition];
```

You can include multiple tables in your SELECT statement in a similar way as you use them in a normal SQL SELECT query.

Example

Consider the CUSTOMERS table having the following records −

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
```

Following is an example to create a view from the CUSTOMERS table. This view would be used to have customer name and age from the CUSTOMERS table.

```
SQL > CREATE VIEW CUSTOMERS_VIEW AS
SELECT name, age
FROM  CUSTOMERS;
```

Now, you can query CUSTOMERS_VIEW in a similar way as you query an actual table. Following is an example for the same.

```
SQL > SELECT * FROM CUSTOMERS_VIEW;
```

This would produce the following result.

```
+----------+-----+
| name     | age |
+----------+-----+
| Ramesh   |  32 |
| Khilan   |  25 |
| kaushik  |  23 |
| Chaitali |  25 |
| Hardik   |  27 |
| Komal    |  22 |
| Muffy    |  24 |
```

The WITH CHECK OPTION

The WITH CHECK OPTION is a CREATE VIEW statement option. The purpose of the WITH CHECK OPTION is to ensure that all UPDATE and INSERTs satisfy the condition(s) in the view definition.

If they do not satisfy the condition(s), the UPDATE or INSERT returns an error.

The following code block has an example of creating same view CUSTOMERS_VIEW with the WITH CHECK OPTION.

```
CREATE VIEW CUSTOMERS_VIEW AS
SELECT name, age
FROM  CUSTOMERS
WHERE age IS NOT NULL
WITH CHECK OPTION;
```

The WITH CHECK OPTION in this case should deny the entry of any NULL values in the view's AGE column, because the view is defined by data that does not have a NULL value in the AGE column.

Updating a View

A view can be updated under certain conditions which are given below −

- The SELECT clause may not contain the keyword DISTINCT.
- The SELECT clause may not contain summary functions.
- The SELECT clause may not contain set functions.
- The SELECT clause may not contain set operators.
- The SELECT clause may not contain an ORDER BY clause.
- The FROM clause may not contain multiple tables.
- The WHERE clause may not contain subqueries.
- The query may not contain GROUP BY or HAVING.
- Calculated columns may not be updated.
- All NOT NULL columns from the base table must be included in the view in order for the INSERT query to function.

So, if a view satisfies all the above-mentioned rules then you can update that view. The following code block has an example to update the age of Ramesh.

```
SQL > UPDATE CUSTOMERS_VIEW
   SET AGE = 35
   WHERE name = 'Ramesh';
```

This would ultimately update the base table CUSTOMERS and the same would reflect in the view itself. Now, try to query the base table and the SELECT statement would produce the following result.

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  35 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
```

Inserting Rows into a View

Rows of data can be inserted into a view. The same rules that apply to the UPDATE command also apply to the INSERT command.

Here, we cannot insert rows in the CUSTOMERS_VIEW because we have not included all the NOT NULL columns in this view, otherwise you can insert rows in a view in a similar way as you insert them in a table.

Deleting Rows into a View

Rows of data can be deleted from a view. The same rules that apply to the UPDATE and INSERT commands apply to the DELETE command.

Following is an example to delete a record having AGE = 22.

```
SQL > DELETE FROM CUSTOMERS_VIEW
   WHERE age = 22;
```

This would ultimately delete a row from the base table CUSTOMERS and the same would reflect in the view itself. Now, try to query the base table and the SELECT statement would produce the following result.

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  35 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
+----+----------+-----+-----------+----------+
```

Dropping Views

Obviously, where you have a view, you need a way to drop the view if it is no longer needed. The syntax is very simple and is given below −

```
DROP VIEW view_name;
```

Following is an example to drop the CUSTOMERS_VIEW from the CUSTOMERS table.

```
DROP VIEW CUSTOMERS_VIEW;
```

SQL Transaction

A transaction is a unit of work that is performed against a database. Transactions are units or sequences of work accomplished in a logical order, whether in a manual fashion by a user or automatically by some sort of a database program.

A transaction is the propagation of one or more changes to the database. For example, if you are creating a record or updating a record or deleting a record from the table, then you are performing a transaction on that table. It is important to control these transactions to ensure the data integrity and to handle database errors.

Practically, you will club many SQL queries into a group and you will execute all of them together as a part of a transaction.

Properties of Transactions

Transactions have the following four standard properties, usually referred to by the acronym **ACID**.

- **Atomicity** − ensures that all operations within the work unit are completed successfully. Otherwise, the transaction is aborted at the point of failure and all the previous operations are rolled back to their former state.
- **Consistency** − ensures that the database properly changes states upon a successfully committed transaction.
- **Isolation** − enables transactions to operate independently of and transparent to each other.
- **Durability** − ensures that the result or effect of a committed transaction persists in case of a system failure.

Transaction Control

The following commands are used to control transactions.

- **COMMIT** − to save the changes.
- **ROLLBACK** − to roll back the changes.
- **SAVEPOINT** − creates points within the groups of transactions in which to ROLLBACK.
- **SET TRANSACTION** − Places a name on a transaction.

Transactional Control Commands

Transactional control commands are only used with the **DML Commands** such as - INSERT, UPDATE and DELETE only. They cannot be used while creating tables or dropping them because these operations are automatically committed in the database.

The COMMIT Command

The COMMIT command is the transactional command used to save changes invoked by a transaction to the database.

The COMMIT command is the transactional command used to save changes invoked by a transaction to the database. The COMMIT command saves all the transactions to the database since the last COMMIT or ROLLBACK command.

The syntax for the COMMIT command is as follows.

```
COMMIT;
```

Example

Consider the CUSTOMERS table having the following records −

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
+----+----------+-----+-----------+----------+
```

Following is an example which would delete those records from the table which have age = 25 and then COMMIT the changes in the database.

```
SQL> DELETE FROM CUSTOMERS
   WHERE AGE = 25;
SQL> COMMIT;
```

Thus, two rows from the table would be deleted and the SELECT statement would produce the following result.

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
+----+----------+-----+-----------+----------+
```

The ROLLBACK Command

The ROLLBACK command is the transactional command used to undo transactions that have not already been saved to the database. This command can only be used to undo transactions since the last COMMIT or ROLLBACK command was issued.

The syntax for a ROLLBACK command is as follows −

```
ROLLBACK;
```

Example

Consider the CUSTOMERS table having the following records −

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
+----+----------+-----+-----------+----------+
```

Following is an example, which would delete those records from the table which have the age = 25 and then ROLLBACK the changes in the database.

```
SQL> DELETE FROM CUSTOMERS
   WHERE AGE = 25;
SQL> ROLLBACK;
```

Thus, the delete operation would not impact the table and the SELECT statement would produce the following result.

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
+----+----------+-----+-----------+----------+
```

The SAVEPOINT Command

A SAVEPOINT is a point in a transaction when you can roll the transaction back to a certain point without rolling back the entire transaction.

The syntax for a SAVEPOINT command is as shown below.

```
SAVEPOINT SAVEPOINT_NAME;
```

This command serves only in the creation of a SAVEPOINT among all the transactional statements. The ROLLBACK command is used to undo a group of transactions.

The syntax for rolling back to a SAVEPOINT is as shown below.

```
ROLLBACK TO SAVEPOINT_NAME;
```

Following is an example where you plan to delete the three different records from the CUSTOMERS table. You want to create a SAVEPOINT before each delete, so that you can ROLLBACK to any SAVEPOINT at any time to return the appropriate data to its original state.

Example

Consider the CUSTOMERS table having the following records.

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
+----+----------+-----+-----------+----------+
```

The following code block contains the series of operations.

```
SQL> SAVEPOINT SP1;
Savepoint created.
SQL> DELETE FROM CUSTOMERS WHERE ID=1;
1 row deleted.
SQL> SAVEPOINT SP2;
Savepoint created.
SQL> DELETE FROM CUSTOMERS WHERE ID=2;
1 row deleted.
SQL> SAVEPOINT SP3;
Savepoint created.
SQL> DELETE FROM CUSTOMERS WHERE ID=3;
1 row deleted.
```

Now that the three deletions have taken place, let us assume that you have changed your mind and decided to ROLLBACK to the SAVEPOINT that you identified as SP2. Because SP2 was created after the first deletion, the last two deletions are undone −

```
SQL> ROLLBACK TO SP2;
Rollback complete.
```

Notice that only the first deletion took place since you rolled back to SP2.

```
SQL> SELECT * FROM CUSTOMERS;
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
|  7 | Muffy    |  24 | Indore    | 10000.00 |
+----+----------+-----+-----------+----------+
6 rows selected.
```

The RELEASE SAVEPOINT Command

The RELEASE SAVEPOINT command is used to remove a SAVEPOINT that you have created.

The syntax for a RELEASE SAVEPOINT command is as follows.

```
RELEASE SAVEPOINT SAVEPOINT_NAME;
```

Once a SAVEPOINT has been released, you can no longer use the ROLLBACK command to undo transactions performed since the last SAVEPOINT.

The SET TRANSACTION Command

The SET TRANSACTION command can be used to initiate a database transaction. This command is used to specify characteristics for the transaction that follows. For example, you can specify a transaction to be read only or read write.

The syntax for a SET TRANSACTION command is as follows.

```
SET TRANSACTION [ READ WRITE | READ ONLY ];
```

DATA BASE NORMALIZATION TECHNIQUES

Functional Dependency

Functional dependency (FD) is a set of constraints between two attributes in a relation. Functional dependency says that if two tuples have same values for attributes A1, A2,..., An, then those two tuples must have to have same values for attributes B1, B2, ..., Bn.

Functional dependency is represented by an arrow sign (→) that is, X→Y, where X functionally determines Y. The left-hand side attributes determine the values of attributes on the right-hand side.

Armstrong's Axioms

If F is a set of functional dependencies then the closure of F, denoted as F^+, is the set of all functional dependencies logically implied by F. Armstrong's Axioms are a set of rules, that when applied repeatedly, generates a closure of functional dependencies.

- **Reflexive rule** − If alpha is a set of attributes and beta is_subset_of alpha, then alpha holds beta.
- **Augmentation rule** − If a → b holds and y is attribute set, then ay → by also holds. That is adding attributes in dependencies, does not change the basic dependencies.
- **Transitivity rule** − Same as transitive rule in algebra, if a → b holds and b → c holds, then a → c also holds. a → b is called as a functionally that determines b.

Trivial Functional Dependency

- **Trivial** − If a functional dependency (FD) X → Y holds, where Y is a subset of X, then it is called a trivial FD. Trivial FDs always hold.
- **Non-trivial** − If an FD X → Y holds, where Y is not a subset of X, then it is called a non-trivial FD.
- **Completely non-trivial** − If an FD X → Y holds, where x intersect Y = Φ, it is said to be a completely non-trivial FD.

Normalization

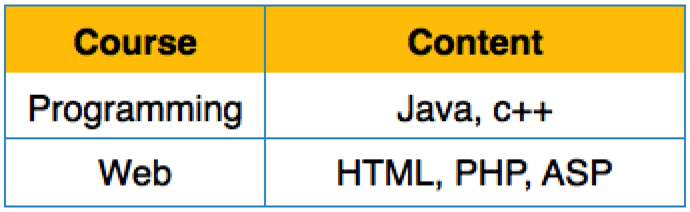
If a database design is not perfect, it may contain anomalies, which are like a bad dream for any database administrator. Managing a database with anomalies is next to impossible.

- **Update anomalies** − If data items are scattered and are not linked to each other properly, then it could lead to strange situations. For example, when we try to update one data item having its copies scattered over several places, a few instances get updated properly while a few others are left with old values. Such instances leave the database in an inconsistent state.
- **Deletion anomalies** − We tried to delete a record, but parts of it was left undeleted because of unawareness, the data is also saved somewhere else.
- **Insert anomalies** − We tried to insert data in a record that does not exist at all.

Normalization is a method to remove all these anomalies and bring the database to a consistent state.

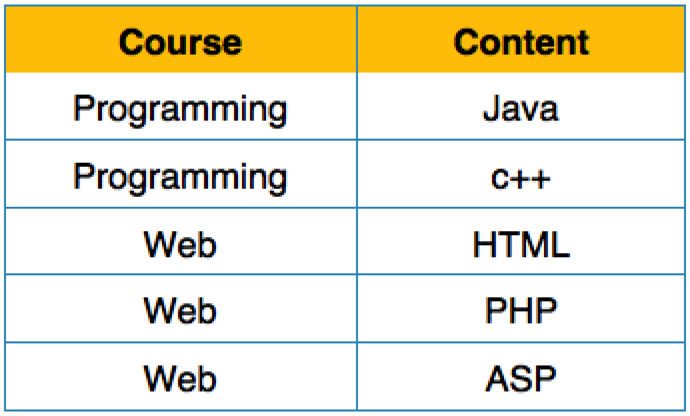
First Normal Form

First Normal Form is defined in the definition of relations (tables) itself. This rule defines that all the attributes in a relation must have atomic domains. The values in an atomic domain are indivisible units.



Course	Content
Programming	Java, c++
Web	HTML, PHP, ASP

We re-arrange the relation (table) as below, to convert it to First Normal Form.



Course	Content
Programming	Java
Programming	c++
Web	HTML
Web	PHP
Web	ASP

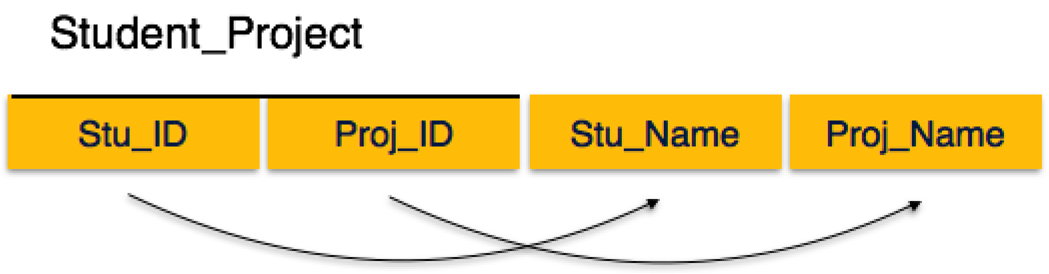
Each attribute must contain only a single value from its pre-defined domain.

Second Normal Form

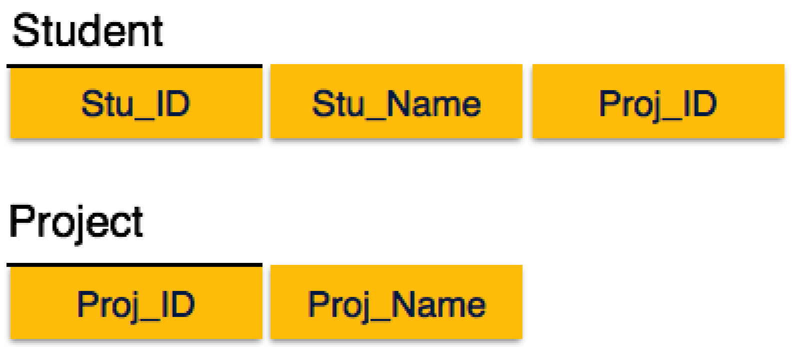
Before we learn about the second normal form, we need to understand the following −

- **Prime attribute** − An attribute, which is a part of the prime-key, is known as a prime attribute.
- **Non-prime attribute** − An attribute, which is not a part of the prime-key, is said to be a non-prime attribute.

If we follow second normal form, then every non-prime attribute should be fully functionally dependent on prime key attribute. That is, if X → A holds, then there should not be any proper subset Y of X, for which Y → A also holds true.



We see here in Student_Project relation that the prime key attributes are Stu_ID and Proj_ID. According to the rule, non-key attributes, i.e. Stu_Name and Proj_Name must be dependent upon both and not on any of the prime key attribute individually. But we find that Stu_Name can be identified by Stu_ID and Proj_Name can be identified by Proj_ID independently. This is called **partial dependency**, which is not allowed in Second Normal Form.

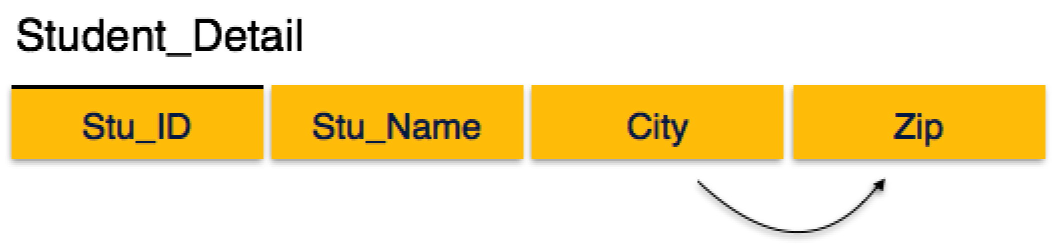


We broke the relation in two as depicted in the above picture. So there exists no partial dependency.

Third Normal Form

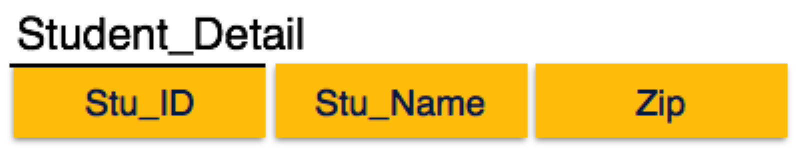
For a relation to be in Third Normal Form, it must be in Second Normal form and the following must satisfy −

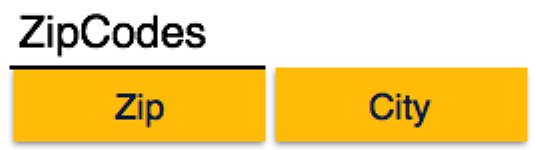
- No non-prime attribute is transitively dependent on prime key attribute.
- For any non-trivial functional dependency, X → A, then either −
    - X is a superkey or,
    - A is prime attribute.



We find that in the above Student_detail relation, Stu_ID is the key and only prime key attribute. We find that City can be identified by Stu_ID as well as Zip itself. Neither Zip is a superkey nor is City a prime attribute. Additionally, Stu_ID → Zip → City, so there exists **transitive dependency**.

To bring this relation into third normal form, we break the relation into two relations as follows −





Boyce-Codd Normal Form

Boyce-Codd Normal Form (BCNF) is an extension of Third Normal Form on strict terms. BCNF states that −

- For any non-trivial functional dependency, X → A, X must be a super-key.

In the above image, Stu_ID is the super-key in the relation Student_Detail and Zip is the super-key in the relation ZipCodes. So,

Stu_ID → Stu_Name, Zip

and

Zip → City

Which confirms that both the relations are in BCNF.

EMBEDDED SQL

Embedded and dynamic SQL define how SQL statements can be embedded within general-purpose programming languages, such as C, C++, and Java.

Embedded SQL provides a means by which a program can interact with a database server. However, under embedded SQL, the SQL statements are identified at compile time using a pre-processor. The pre-processor submits the SQL statements to the database system for precompilation and optimization; then it replaces the SQL statements in the application program with appropriate code and function calls before invoking the programming-language compiler.

The SQL standard defines embedding of SQL in a variety of programming languages, such as C, C++, Cobol, Pascal, Java, PL/I, and Fortran. A language in which SQL queries are embedded is referred to as a *host* language, and the SQL structures permitted in the host language constitute *embedded* SQL. Programs written in the host language can use the embedded SQL syntax to access and update data stored in a database. An embedded SQL program must be processed by a special pre-processor prior to compilation. The pre-processor replaces embedded SQL requests with host-language declarations and procedure calls that allow runtime execution of the database accesses. Then, the resulting program is compiled by the host-language compiler. This is the main distinction between embedded SQL and JDBC or ODBC.

In JDBC, SQL statements are interpreted at runtime (even if they are prepared first using the prepared statement feature). When embedded SQL is used, some SQL-related errors (including data-type errors) may be caught at compile time.

To identify embedded SQL requests to the pre-processor, we use the EXEC SQL statement; it has the form:

EXEC SQL <embedded SQL statement >;

The exact syntax for embedded SQL requests depends on the language in which SQL is embedded. In some languages, such as Cobol, the semicolon is replaced with END-EXEC.

We place the statement SQL INCLUDE SQLCA in the program to identify the place where the pre-processor should insert the special variables used for communication between the program and the database system.
Before executing any SQL statements, the program must first connect to the database. This is done using:

EXEC SQL **connect to** *server* **user** *user-name* **using** *password*;

Here, *server* identifies the server to which a connection is to be established. Variables of the host language can be used within embedded SQL statements, but they must be preceded by a colon (:) to distinguish them from SQL variables. Variables used as above must be declared within a DECLARE section, as illustrated below. The syntax for declaring the variables, however, follows the usual host anguage syntax.

EXEC SQL BEGIN DECLARE SECTION;
int *credit amount*;
EXEC SQL END DECLARE SECTION;

Embedded SQL statements are similar in form to regular SQL statements. There are, however, several important differences, as we note here. To write a relational query, we use the **declare cursor** statement. The result of the query is not yet computed. Rather, the program must use the **open** and **fetch** commands (discussed later in this section) to obtain the result tuples. As we shall see, use of a cursor is analogous to iterating through a result set in JDBC.

Consider the university schema. Assume that we have a host-language variable *credit amount* in our program, declared as we saw earlier, and that we wish to find the names of all students who have taken more than *credit amount* credit hours. We can write this query as follows:

EXEC SQL
declare *c* **cursor for**
select *ID*, *name*
from *student*
where *tot cred* > :*credit amount*;

The variable *c* in the preceding expression is called a *cursor* for the query. We use this variable to identify the query. We then use the **open** statement, which causes the query to be evaluated.

The **open** statement for our sample query is as follows:
EXEC SQL **open** *c*;

This statement causes the database system to execute the query and to save the results within a temporary relation. The query uses the value of the host-language variable (*credit amount*) at the time the **open** statement is executed. If the SQL query results in an error, the database system stores an error diagnostic in the SQL communication-area (SQLCA) variables. We then use a series of **fetch** statements, each of which causes the values of one tuple to be placed in host-language variables. The **fetch** statement requires one host-language variable for each attribute of the result relation. For our example query, we need one variable to hold the *ID* value and another to hold the *name* value. Suppose that those variables are *si* and *sn*, respectively, and have been declared within a DECLARE section.

Then the statement:
EXEC SQL **fetch** *c* **into** :*si*, :*sn*;

Produces a tuple of the result relation. The program can then manipulate the variables *si* and *sn* by using the features of the host programming language. A single **fetch** request returns only one tuple. To obtain all tuples of the result, the program must contain a loop to iterate over all tuples. Embedded SQL assists the programmer in managing this iteration. Although a relation is conceptually a set, the tuples of the result of a query are in some fixed physical order. When the program executes an **open** statement on a cursor, the cursor is set to point to the first tuple of the result. Each time it executes a **fetch** statement, the cursor is updated to point to the next tuple of the result. When no further tuples remain to be processed, the character array variable SQLSTATE in the SQLCA is set to ’02000’ (meaning “no more data”); the exact syntax for accessing this variable depends on the specific database system you use. Thus, we can use a **while** loop (or equivalent loop) to process each tuple of the result.

We must use the **close** statement to tell the database system to delete the temporary relation that held the result of the query. For our example, this statement takes the form

EXEC SQL **close** *c*;

Embedded SQL expressions for database modification (**update**, **insert**, and **delete**) do not return a result. Thus, they are somewhat simpler to express. A database-modification request takes the form EXEC SQL < any valid **update, insert,** or **delete**>; Host-language variables, preceded by a colon, may appear in the SQL database modification expression. If an error condition arises in the execution of the statement, a diagnostic is set in the SQLCA. Database relations can also be updated through cursors. For example, if we want to add 100 to the *salary* attribute of every instructor in the Music department,

we could declare a cursor as follows.

EXEC SQL
declare *c* **cursor for**
select *
from *instructor*
where *dept name*= ‘Music’
for update;
We then iterate through the tuples by performing **fetch** operations on the cursor
(as illustrated earlier), and after fetching each tuple we execute the following code:

EXEC SQL
update *instructor*
set *salary* = *salary* + 100
where current of *c*;

Transactions can be committed using EXEC SQL COMMIT, or rolled back using

EXEC SQL ROLLBACK.

Queries in embedded SQL are normally defined when the program is written. There are rare situations where a query needs to be defined at runtime. For example, an application interface may allow a user to specify selection conditions on one or more attributes of a relation, and may construct the **where** clause of an SQL query at runtime, with conditions on only those attributes for which the user specifies selections. In such cases, a query string can be constructed and prepared at runtime, using a statement of the form EXEC SQL PREPARE <query-name>

FROM :<variable>, and a cursor can be opened on the query name.

For more help:

“https://docs.oracle.com/cd/B19306_01/appdev.102/b14407/pc_06sql.htm”

Example Embedded Program:

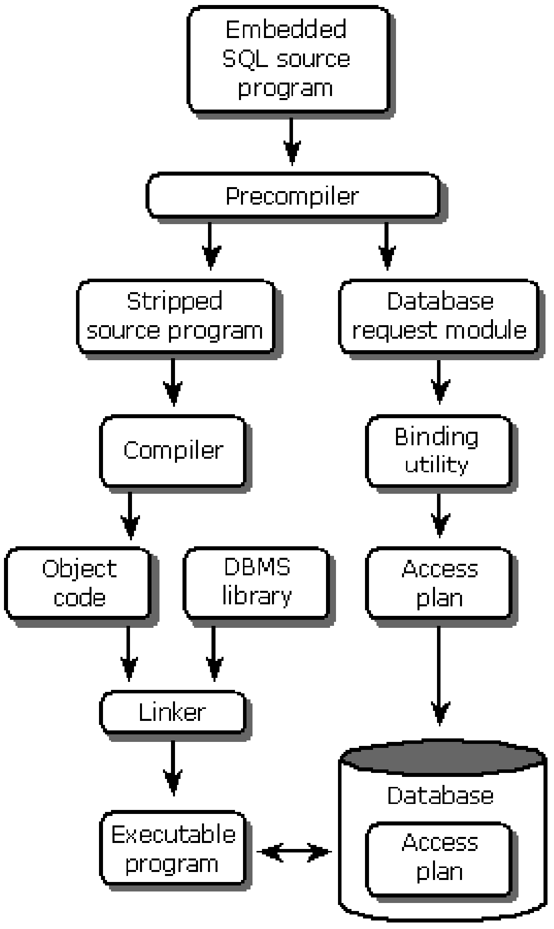
The following code is a simple embedded SQL program, written in C. The program illustrates many, but not all, of the embedded SQL techniques. The program prompts the user for an order number, retrieves the customer number, salesperson, and status of the order, and displays the retrieved information on the screen.

```
int main() {
   EXEC SQL INCLUDE SQLCA;
   EXEC SQL BEGIN DECLARE SECTION;
      int OrderID;         /* Employee ID (from user)         */
      int CustID;           /* Retrieved customer ID         */
      char SalesPerson[10]   /* Retrieved salesperson name       */
      char Status[6]         /* Retrieved order status         */
   EXEC SQL END DECLARE SECTION;

   /* Set up error processing */
   EXEC SQL WHENEVER SQLERROR GOTO query_error;
   EXEC SQL WHENEVER NOT FOUND GOTO bad_number;

   /* Prompt the user for order number */
   printf ("Enter order number: ");
   scanf_s("%d", &OrderID);

   /* Execute the SQL query */
   EXEC SQL SELECT CustID, SalesPerson, Status
      FROM Orders
      WHERE OrderID = :OrderID
      INTO :CustID, :SalesPerson, :Status;

   /* Display the results */
   printf ("Customer number:  %d\n", CustID);
   printf ("Salesperson: %s\n", SalesPerson);
   printf ("Status: %s\n", Status);
   exit();

query_error:
   printf ("SQL error: %ld\n", sqlca->sqlcode);
   exit();

bad_number:
   printf ("Invalid order number.\n");
   exit();
}
```

Compiling an Embedded SQL Program

Because an embedded SQL program contains a mix of SQL and host language statements, it cannot be submitted directly to a compiler for the host language. Instead, it is compiled through a multistep process. Although this process differs from product to product, the steps are roughly the same for all products.

This illustration shows the steps necessary to compile an embedded SQL program.



Five steps are involved in compiling an embedded SQL program:

1. The embedded SQL program is submitted to the SQL precompiler, a programming tool. The precompiler scans the program, finds the embedded SQL statements, and processes them. A different precompiler is required for each programming language supported by the DBMS. DBMS products typically offer precompilers for one or more languages, including C, Pascal, COBOL, Fortran, Ada, PL/I, and various assembly languages.

2. The precompiler produces two output files. The first file is the source file, stripped of its embedded SQL statements. In their place, the precompiler substitutes calls to proprietary DBMS routines that provide the run-time link between the program and the DBMS. Typically, the names and the calling sequences of these routines are known only to the precompile and the DBMS; they are not a public interface to the DBMS. The second file is a copy of all the embedded SQL statements used in the program. This file is sometimes called a database request module, or DBRM.
3. The source file output from the precompile is submitted to the standard compiler for the host programming language (such as a C or COBOL compiler). The compiler processes the source code and produces object code as its output. Note that this step has nothing to do with the DBMS or with SQL.
4. The linker accepts the object modules generated by the compiler, links them with various library routines, and produces an executable program. The library routines linked into the executable program include the proprietary DBMS routines described in step 2.
5. The database request module generated by the precompile is submitted to a special binding utility. This utility examines the SQL statements, parses, validates, and optimizes them, and then produces an access plan for each statement. The result is a combined access plan for the entire program, representing an executable version of the embedded SQL statements. The binding utility stores the plan in the database, usually assigning it the name of the application program that will use it. Whether this step takes place at compile time or run time depends on the DBMS.

Triggers in PL/SQL

Triggers are stored programs, which are automatically executed or fired when some events occur. Triggers are, in fact, written to be executed in response to any of the following events −

- A **database manipulation (DML)** statement (DELETE, INSERT, or UPDATE)
- A **database definition (DDL)** statement (CREATE, ALTER, or DROP).
- A **database operation** (SERVERERROR, LOGON, LOGOFF, STARTUP, or SHUTDOWN).

Triggers can be defined on the table, view, schema, or database with which the event is associated.

Benefits of Triggers

Triggers can be written for the following purposes −

- Generating some derived column values automatically
- Enforcing referential integrity
- Event logging and storing information on table access
- Auditing
- Synchronous replication of tables
- Imposing security authorizations
- Preventing invalid transactions

Creating Triggers

The syntax for creating a trigger is −

```
CREATE [OR REPLACE ] TRIGGER trigger_name
{BEFORE | AFTER | INSTEAD OF }
{INSERT [OR] | UPDATE [OR] | DELETE}
[OF col_name]
ON table_name
[REFERENCING OLD AS o NEW AS n]
[FOR EACH ROW]
WHEN (condition)
DECLARE
   Declaration-statements
BEGIN
   Executable-statements
EXCEPTION
   Exception-handling-statements
END;
```

Where,

- CREATE [OR REPLACE] TRIGGER trigger_name − Creates or replaces an existing trigger with the *trigger_name*.
- {BEFORE | AFTER | INSTEAD OF} − This specifies when the trigger will be executed. The INSTEAD OF clause is used for creating trigger on a view.
- {INSERT [OR] | UPDATE [OR] | DELETE} − This specifies the DML operation.
- [OF col_name] − This specifies the column name that will be updated.
- [ON table_name] − This specifies the name of the table associated with the trigger.
- [REFERENCING OLD AS o NEW AS n] − This allows you to refer new and old values for various DML statements, such as INSERT, UPDATE, and DELETE.
- [FOR EACH ROW] − This specifies a row-level trigger, i.e., the trigger will be executed for each row being affected. Otherwise the trigger will execute just once when the SQL statement is executed, which is called a table level trigger.
- WHEN (condition) − This provides a condition for rows for which the trigger would fire. This clause is valid only for row-level triggers.

Example

Select * from customers;

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
+----+----------+-----+-----------+----------+
```

The following program creates a **row-level** trigger for the customers table that would fire for INSERT or UPDATE or DELETE operations performed on the CUSTOMERS table. This trigger will display the salary difference between the old values and new values −

```
CREATE OR REPLACE TRIGGER display_salary_changes
BEFORE DELETE OR INSERT OR UPDATE ON customers
FOR EACH ROW
WHEN (NEW.ID > 0)
DECLARE
   sal_diff number;
BEGIN
   sal_diff := :NEW.salary  - :OLD.salary;
   dbms_output.put_line('Old salary: ' || :OLD.salary);
   dbms_output.put_line('New salary: ' || :NEW.salary);
   dbms_output.put_line('Salary difference: ' || sal_diff);
END;
```

Triggering a Trigger

Let us perform some DML operations on the CUSTOMERS table. Here is one INSERT statement, which will create a new record in the table −

```
INSERT INTO CUSTOMERS (ID,NAME,AGE,ADDRESS,SALARY)
VALUES (7, 'Kriti', 22, 'HP', 7500.00 );
```

When a record is created in the CUSTOMERS table, the above create trigger, **display_salary_changes** will be fired and it will display the following result −

```
Old salary:
New salary: 7500
Salary difference:
```

Because this is a new record, old salary is not available and the above result comes as null. Let us now perform one more DML operation on the CUSTOMERS table. The UPDATE statement will update an existing record in the table −

```
UPDATE customers
SET salary = salary + 500
WHERE id = 2;
```

When a record is updated in the CUSTOMERS table, the above create trigger, **display_salary_changes** will be fired and it will display the following result −

```
Old salary: 1500
New salary: 2000
Salary difference: 500
```

Cursors in PL/SQL

Oracle creates a memory area, known as the context area, for processing an SQL statement, which contains all the information needed for processing the statement; for example, the number of rows processed, etc.

A **cursor** is a pointer to this context area. PL/SQL controls the context area through a cursor. A cursor holds the rows (one or more) returned by a SQL statement. The set of rows the cursor holds is referred to as the **active set**.

You can name a cursor so that it could be referred to in a program to fetch and process the rows returned by the SQL statement, one at a time. There are two types of cursors −

- Implicit cursors
- Explicit cursors

Implicit Cursors

Implicit cursors are automatically created by Oracle whenever an SQL statement is executed, when there is no explicit cursor for the statement. Programmers cannot control the implicit cursors and the information in it.

Whenever a DML statement (INSERT, UPDATE and DELETE) is issued, an implicit cursor is associated with this statement. For INSERT operations, the cursor holds the data that needs to be inserted. For UPDATE and DELETE operations, the cursor identifies the rows that would be affected.

In PL/SQL, you can refer to the most recent implicit cursor as the **SQL cursor**, which always has attributes such as **%FOUND, %ISOPEN, %NOTFOUND**, and **%ROWCOUNT**. The SQL cursor has additional attributes, **%BULK_ROWCOUNT** and **%BULK_EXCEPTIONS**, designed for use with the **FORALL** statement. The following table provides the description of the most used attributes −

S.No	Attribute & Description
1	**%FOUND** Returns TRUE if an INSERT, UPDATE, or DELETE statement affected one or more rows or a SELECT INTO statement returned one or more rows. Otherwise, it returns FALSE.
2	**%NOTFOUND** The logical opposite of %FOUND. It returns TRUE if an INSERT, UPDATE, or DELETE statement affected no rows, or a SELECT INTO statement returned no rows. Otherwise, it returns FALSE.
3	**%ISOPEN** Always returns FALSE for implicit cursors, because Oracle closes the SQL cursor automatically after executing its associated SQL statement.

4	**%ROWCOUNT** Returns the number of rows affected by an INSERT, UPDATE, or DELETE statement, or returned by a SELECT INTO statement.

Any SQL cursor attribute will be accessed as **sql%attribute_name** as shown below in the example.

Example

We will be using the CUSTOMERS table we had created

Select * from customers;

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
+----+----------+-----+-----------+----------+
```

The following program will update the table and increase the salary of each customer by 500 and use the **SQL%ROWCOUNT** attribute to determine the number of rows affected −

```
DECLARE
   total_rows number(2);
BEGIN
   UPDATE customers
   SET salary = salary + 500;
   IF sql%notfound THEN
      dbms_output.put_line('no customers selected');
   ELSIF sql%found THEN
      total_rows := sql%rowcount;
      dbms_output.put_line( total_rows || ' customers selected ');
   END IF;
END;
/
```

If you check the records in customers table, you will find that the rows have been updated

Select * from customers;

```
+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2500.00 |
|  2 | Khilan   |  25 | Delhi     |  2000.00 |
|  3 | kaushik  |  23 | Kota      |  2500.00 |
|  4 | Chaitali |  25 | Mumbai    |  7000.00 |
|  5 | Hardik   |  27 | Bhopal    |  9000.00 |
|  6 | Komal    |  22 | MP        |  5000.00 |
+----+----------+-----+-----------+----------+
```

Explicit Cursors

Explicit cursors are programmer-defined cursors for gaining more control over the **context area**. An explicit cursor should be defined in the declaration section of the PL/SQL Block. It is created on a SELECT Statement which returns more than one row.

The syntax for creating an explicit cursor is −

```
CURSOR cursor_name IS select_statement;
```

Working with an explicit cursor includes the following steps −

- Declaring the cursor for initializing the memory
- Opening the cursor for allocating the memory
- Fetching the cursor for retrieving the data
- Closing the cursor to release the allocated memory

Declaring the Cursor

Declaring the cursor defines the cursor with a name and the associated SELECT statement. For example −

```
CURSOR c_customers IS
   SELECT id, name, address FROM customers;
```

Opening the Cursor

Opening the cursor allocates the memory for the cursor and makes it ready for fetching the rows returned by the SQL statement into it. For example, we will open the above defined cursor as follows −

```
OPEN c_customers;
```

Fetching the Cursor

Fetching the cursor involves accessing one row at a time. For example, we will fetch rows from the above-opened cursor as follows −

```
FETCH c_customers INTO c_id, c_name, c_addr;
```

Closing the Cursor

Closing the cursor means releasing the allocated memory. For example, we will close the above-opened cursor as follows −

```
CLOSE c_customers;
```

Example

Following is a complete example to illustrate the concepts of explicit cursors &minua;

```
DECLARE
   c_id customers.id%type;
   c_name customerS.No.ame%type;
   c_addr customers.address%type;
   CURSOR c_customers is
      SELECT id, name, address FROM customers;
BEGIN
   OPEN c_customers;
   LOOP
   FETCH c_customers into c_id, c_name, c_addr;
      EXIT WHEN c_customers%notfound;
      dbms_output.put_line(c_id || ' ' || c_name || ' ' || c_addr);
   END LOOP;
   CLOSE c_customers;
END;
/
```

When the above code is executed at the SQL prompt, it produces the following result −

```
1 Ramesh Ahmedabad
2 Khilan Delhi
3 kaushik Kota
4 Chaitali Mumbai
5 Hardik Bhopal
6 Komal MP
```

Procedures in PL/SQL

A **subprogram** is a program unit/module that performs a particular task. These subprograms are combined to form larger programs. This is basically called the 'Modular design'. A subprogram can be invoked by another subprogram or program which is called the **calling program**.

A subprogram can be created −

- At the schema level
- Inside a package
- Inside a PL/SQL block

At the schema level, subprogram is a **standalone subprogram**. It is created with the CREATE PROCEDURE or the CREATE FUNCTION statement. It is stored in the database and can be deleted with the DROP PROCEDURE or DROP FUNCTION statement.

A subprogram created inside a package is a **packaged subprogram**. It is stored in the database and can be deleted only when the package is deleted with the DROP PACKAGE statement. We will discuss packages in the chapter **'PL/SQL - Packages'**.

PL/SQL subprograms are named PL/SQL blocks that can be invoked with a set of parameters. PL/SQL provides two kinds of subprograms −

- **Functions** − These subprograms return a single value; mainly used to compute and return a value.
- **Procedures** − These subprograms do not return a value directly; mainly used to perform an action.

This chapter is going to cover important aspects of a **PL/SQL procedure**. We will discuss **PL/SQL function** in the next chapter.

Parts of a PL/SQL Subprogram

Each PL/SQL subprogram has a name, and may also have a parameter list. Like anonymous PL/SQL blocks, the named blocks will also have the following three parts −

S.No	Parts & Description
1	**Declarative Part** It is an optional part. However, the declarative part for a subprogram does not start with the DECLARE keyword. It contains declarations of types, cursors, constants, variables, exceptions, and nested subprograms. These items are local to the subprogram and cease to exist when the subprogram completes execution.
2	**Executable Part** This is a mandatory part and contains statements that perform the designated action.

3	**Exception-handling** This is again an optional part. It contains the code that handles run-time errors.

Creating a Procedure

A procedure is created with the **CREATE OR REPLACE PROCEDURE** statement. The simplified syntax for the CREATE OR REPLACE PROCEDURE statement is as follows −

```
CREATE [OR REPLACE] PROCEDURE procedure_name
[(parameter_name [IN | OUT | IN OUT] type [, ...])]
{IS | AS}
BEGIN
  < procedure_body >
END procedure_name;
```

Where,

- *procedure-name* specifies the name of the procedure.
- [OR REPLACE] option allows the modification of an existing procedure.
- The optional parameter list contains name, mode and types of the parameters. **IN** represents the value that will be passed from outside and OUT represents the parameter that will be used to return a value outside of the procedure.
- *procedure-body* contains the executable part.
- The AS keyword is used instead of the IS keyword for creating a standalone procedure.

Example

The following example creates a simple procedure that displays the string 'Hello World!' on the screen when executed.

```
CREATE OR REPLACE PROCEDURE greetings
AS
BEGIN
   dbms_output.put_line('Hello World!');
END;
/
.
```

Executing a Standalone Procedure

A standalone procedure can be called in two ways −

- Using the **EXECUTE** keyword
- Calling the name of the procedure from a PL/SQL block

The above procedure named **'greetings'** can be called with the EXECUTE keyword as −

```
EXECUTE greetings;
```

The procedure can also be called from another PL/SQL block −

```
BEGIN
   greetings;
END;
/
```

The above call will display −

```
Hello World

PL/SQL procedure successfully completed.
```

Deleting a Standalone Procedure

A standalone procedure is deleted with the **DROP PROCEDURE** statement. Syntax for deleting a procedure is −

```
DROP PROCEDURE procedure-name;
```

You can drop the greetings procedure by using the following statement −

```
DROP PROCEDURE greetings;
```

Parameter Modes in PL/SQL Subprograms

The following table lists out the parameter modes in PL/SQL subprograms −

S.No	Parameter Mode & Description
1	**IN** An IN parameter lets you pass a value to the subprogram. **It is a read-only parameter**. Inside the subprogram, an IN parameter acts like a constant. It cannot be assigned a value. You can pass a constant, literal, initialized variable, or expression as an IN parameter. You can also initialize it to a default value; however, in that case, it is omitted from the subprogram call. **It is the default mode of parameter passing. Parameters are passed by reference**.
2	**OUT** An OUT parameter returns a value to the calling program. Inside the subprogram, an OUT parameter acts like a variable. You can change its value and reference the value after assigning it. **The actual parameter must be variable and it is passed by value**.

3	**IN OUT** An **IN OUT** parameter passes an initial value to a subprogram and returns an updated value to the caller. It can be assigned a value and the value can be read. The actual parameter corresponding to an IN OUT formal parameter must be a variable, not a constant or an expression. Formal parameter must be assigned a value. **Actual parameter is passed by value.**

IN & OUT Mode Example 1

This program finds the minimum of two values. Here, the procedure takes two numbers using the IN mode and returns their minimum using the OUT parameters.

```
DECLARE
   a number;
   b number;
   c number;
PROCEDURE findMin(x IN number, y IN number, z OUT number) IS
BEGIN
   IF x < y THEN
      z:= x;
   ELSE
      z:= y;
   END IF;
END;
BEGIN
   a:= 23;
   b:= 45;
   findMin(a, b, c);
   dbms_output.put_line(' Minimum of (23, 45) : ' || c);
END;
/
```

When the above code is executed at the SQL prompt, it produces the following result −

```
Minimum of (23, 45) : 23

PL/SQL procedure successfully completed.
```

IN & OUT Mode Example 2

This procedure computes the square of value of a passed value. This example shows how we can use the same parameter to accept a value and then return another result.

```
DECLARE
   a number;
PROCEDURE squareNum(x IN OUT number) IS
BEGIN
  x := x * x;
END;
BEGIN
   a:= 23;
   squareNum(a);
   dbms_output.put_line(' Square of (23): ' || a);
END;
/
```

When the above code is executed at the SQL prompt, it produces the following result −

```
Square of (23): 529

PL/SQL procedure successfully completed.
```

Methods for Passing Parameters

Actual parameters can be passed in three ways −

- Positional notation
- Named notation
- Mixed notation

Positional Notation

In positional notation, you can call the procedure as −

```
findMin(a, b, c, d);
```

In positional notation, the first actual parameter is substituted for the first formal parameter; the second actual parameter is substituted for the second formal parameter, and so on. So, **a** is substituted for **x, b** is substituted for **y, c** is substituted for **z** and **d** is substituted for **m**.

Named Notation

In named notation, the actual parameter is associated with the formal parameter using the **arrow symbol (=>)**. The procedure call will be like the following −

```
findMin(x => a, y => b, z => c, m => d);
```

Mixed Notation

In mixed notation, you can mix both notations in procedure call; however, the positional notation should precede the named notation.

The following call is legal −

```
findMin(a, b, c, m => d);
```

However, this is not legal:

```
findMin(x => a, b, c, d);
```

Functions in PL/SQL

A function is same as a procedure except that it returns a value. Therefore, all the discussions of the previous chapter are true for functions too.

Creating a Function

A standalone function is created using the **CREATE FUNCTION** statement. The simplified syntax for the **CREATE OR REPLACE PROCEDURE** statement is as follows −

```
CREATE [OR REPLACE] FUNCTION function_name
[(parameter_name [IN | OUT | IN OUT] type [, ...])]
RETURN return_datatype
{IS | AS}
BEGIN
   < function_body >
END [function_name];
```

Where,

- *function-name* specifies the name of the function.
- [OR REPLACE] option allows the modification of an existing function.
- The optional parameter list contains name, mode and types of the parameters. IN represents the value that will be passed from outside and OUT represents the parameter that will be used to return a value outside of the procedure.
- The function must contain a **return** statement.
- The *RETURN* clause specifies the data type you are going to return from the function.
- *function-body* contains the executable part.
- The AS keyword is used instead of the IS keyword for creating a standalone function.

Example

The following example illustrates how to create and call a standalone function. This function returns the total number of CUSTOMERS in the customers table.

We will use the CUSTOMERS table.

```
Select * from customers;

+----+----------+-----+-----------+----------+
| ID | NAME     | AGE | ADDRESS   | SALARY   |
+----+----------+-----+-----------+----------+
|  1 | Ramesh   |  32 | Ahmedabad |  2000.00 |
|  2 | Khilan   |  25 | Delhi     |  1500.00 |
|  3 | kaushik  |  23 | Kota      |  2000.00 |
|  4 | Chaitali |  25 | Mumbai    |  6500.00 |
|  5 | Hardik   |  27 | Bhopal    |  8500.00 |
|  6 | Komal    |  22 | MP        |  4500.00 |
+----+----------+-----+-----------+----------+
CREATE OR REPLACE FUNCTION totalCustomers
RETURN number IS
   total number(2) := 0;
BEGIN
   SELECT count(*) into total
   FROM customers;

   RETURN total;
END;
/
```

Calling a Function

While creating a function, you give a definition of what the function has to do. To use a function, you will have to call that function to perform the defined task. When a program calls a function, the program control is transferred to the called function.

A called function performs the defined task and when its return statement is executed or when the **last end statement** is reached, it returns the program control back to the main program.

To call a function, you simply need to pass the required parameters along with the function name and if the function returns a value, then you can store the returned value. Following program calls the function **totalCustomers** from an anonymous block −

```
DECLARE
   c number(2);
BEGIN
   c := totalCustomers();
   dbms_output.put_line('Total no. of Customers: ' || c);
END;
/
```

When the above code is executed at the SQL prompt, it produces the following result −

```
Total no. of Customers: 6

PL/SQL procedure successfully completed.
```

Example

The following example demonstrates Declaring, Defining, and Invoking a Simple PL/SQL Function that computes and returns the maximum of two values.

```
DECLARE
   a number;
   b number;
   c number;
FUNCTION findMax(x IN number, y IN number)
RETURN number
IS
```

```
  z number;
BEGIN
  IF x > y THEN
    z:= x;
  ELSE
    Z:= y;
  END IF;
  RETURN z;
END;
BEGIN
  a:= 23;
  b:= 45;
  c := findMax(a, b);
  dbms_output.put_line(' Maximum of (23,45): ' || c);
END;
/
```

When the above code is executed at the SQL prompt, it produces the following result −

```
Maximum of (23,45): 45

PL/SQL procedure successfully completed.
```

PL/SQL Recursive Functions

We have seen that a program or subprogram may call another subprogram. When a subprogram calls itself, it is referred to as a recursive call and the process is known as **recursion**.

To illustrate the concept, let us calculate the factorial of a number. Factorial of a number n is defined as −

```
n! = n*(n-1)!
  = n*(n-1)*(n-2)!
    ...
  = n*(n-1)*(n-2)*(n-3)... 1
```

The following program calculates the factorial of a given number by calling itself recursively −

```
DECLARE
  num number;
  factorial number;

FUNCTION fact(x number)
RETURN number
IS
  f number;
BEGIN
  IF x=0 THEN
    f := 1;
```

```
   ELSE
      f := x * fact(x-1);
   END IF;
RETURN f;
END;

BEGIN
   num:= 6;
   factorial := fact(num);
   dbms_output.put_line(' Factorial '|| num || ' is ' || factorial);
END;
/
```

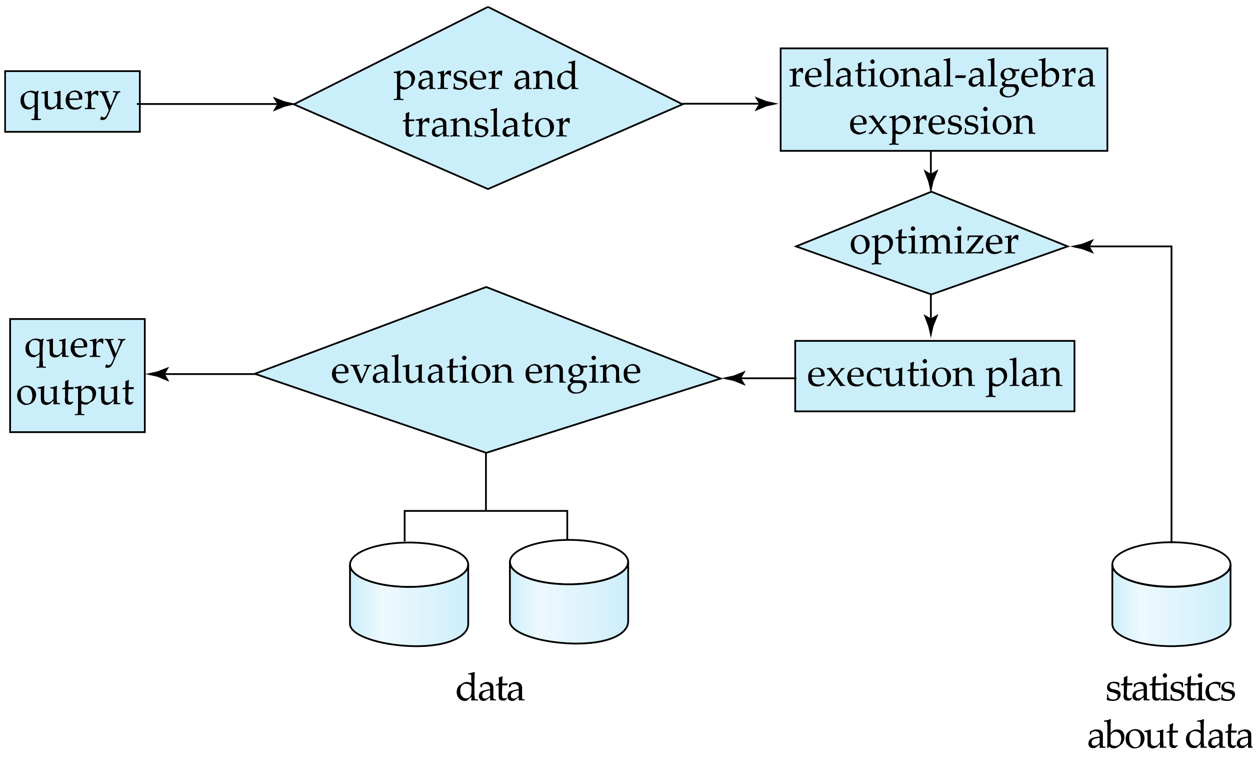
When the above code is executed at the SQL prompt, it produces the following result −

```
Factorial 6 is 720

PL/SQL procedure successfully completed.
```

Query Processing

Steps in query processing

1. Parsing and translation
2. Optimization
3. Evaluation



- Parsing and translation
    - translate the query into its internal form. This is then translated into relational algebra.
    - Parser checks syntax, verifies relations
- Evaluation
    - The query-execution engine takes a query-evaluation plan, executes that plan, and returns the answers to the query.

Steps in query processing

- A relational algebra expression may have many equivalent expressions
    - E.g., $\sigma_{salary<75000}(\prod_{salary}(instructor))$ is equivalent to $\prod_{salary}(\sigma_{salary<75000}(instructor))$
- Each relational algebra operation can be evaluated using one of several different algorithms
    - Correspondingly, a relational-algebra expression can be evaluated in many ways.

- Annotated expression specifying detailed evaluation strategy is called an evaluation-plan.
    - E.g., can use an index on *salary* to find instructors with salary < 75000,
    - or can perform complete relation scan and discard instructors with salary ≥ 75000
- **Query Optimization**: Amongst all equivalent evaluation plans choose the one with lowest cost.
    - Cost is estimated using statistical information from the database catalog

  e.g. number of tuples in each relation, size of tuples, etc

Measures of Query cost

- Cost is generally measured as total elapsed time for answering query
    - Many factors contribute to time cost
        - *disk accesses, CPU*, or even network *communication*
- Typically disk access is the predominant cost, and is also relatively easy to estimate. Measured by taking into account
    - Number of seeks * average-seek-cost
    - Number of blocks read * average-block-read-cost
    - Number of blocks written * average-block-write-cost
        - Cost to write a block is greater than cost to read a block
            - data is read back after being written to ensure that the write was successful

- For simplicity we just use the number of block transfers *from disk and the* number of seeks as the cost measures
  t_T – time to transfer one block
  t_S – time for one seek
- Cost for b block transfers plus S seeks
  $b * t_T + S * t_S$
- We ignore CPU costs for simplicity
- Real systems do take CPU cost into account
- We do not include cost to writing output to disk in our cost formulae
- Several algorithms can reduce disk IO by using extra buffer space
- Amount of real memory available to buffer depends on other concurrent queries and OS processes, known only during execution
- We often use worst case estimates, assuming only the minimum amount of memory needed for the operation is available
- Required data may be buffer resident already, avoiding disk I/O
  But hard to take into account for cost estimation

SELECT OPERATION

- File scan
    - Algorithm A1 (linear search). Scan each file block and test all records to see whether they satisfy the selection condition.
    - Cost estimate = b_r block transfers + 1 seek
    - b_r denotes number of blocks containing records from relation *r*
- If selection is on a key attribute, can stop on finding record
    - cost = (b_r /2) block transfers + 1 seek

- Linear search can be applied regardless of selection condition or ordering of records in the file, or availability of indices

  Note: binary search generally does not make sense since data is not stored consecutively except when there is an index available, and binary search requires more seeks than index search

SELECTION USING INDICES

- Index scan – search algorithms that use an index
  - selection condition must be on search-key of index.
- A2 (primary index, equality on key). Retrieve a single record that satisfies the corresponding equality condition
  - *Cost* = $(h_i + 1) * (t_T + t_S)$
- A3 (primary index, equality on nonkey) Retrieve multiple records.
  - Records will be on consecutive blocks
    - Let b = number of blocks containing matching records
  - *Cost* = $h_i * (t_T + t_S) + t_S + t_T * b$
- A4 (secondary index, equality on nonkey).
  - Retrieve a single record if the search-key is a candidate key
    - *Cost* = $(h_i + 1) * (t_T + t_S)$
  - Retrieve multiple records if search-key is not a candidate key
    - each of *n* matching records may be on a different block
    - Cost = $(h_i + n) * (t_T + t_S)$
      - Can be very expensive!
- Can implement selections of the form $\sigma_{A \leq V}(r)$ or $\sigma_{A \geq V}(r)$ by using
  - a linear file scan,
  - or by using indices in the following ways:
- A5 (primary index, comparison). (Relation is sorted on A)
    - For $\sigma_{A \geq V}(r)$ use index to find first tuple $\geq v$ and scan relation sequentially from there
    - For $\sigma_{A \leq V}(r)$ just scan relation sequentially till first tuple $> v$; do not use index
- A6 (secondary index, comparison).
    - For $\sigma_{A \geq V}(r)$ use index to find first index entry $\geq v$ and scan index sequentially from there, to find pointers to records.
    - For $\sigma_{A \leq V}(r)$ just scan leaf pages of index finding pointers to records, till first entry $> v$
    - In either case, retrieve records that are pointed to
      - requires an I/O for each record
      - Linear file scan may be cheaper

List of Experiments:

As this subject is following the project based teaching learning methodology, consider the project ABC using SQL based software XYZ and contains N team members. Each team required to prepare the report for the following experiments.

Experiment 1

Advantages of DBMS over file processing system in ABC on the following points. Write meaning and example for each.

- Data redundancy and inconsistency
- Difficulty in accessing the data
- Data isolation
- Integrity problems
- Atomicity problems
- Concurrent-access anomalies
- Security problems

Experiment 2

Development of relational model for the ABC

- Identify the various relations that exists in the ABC
- Identify the super-key, candidate-key, primary key and foreign key for the identified relations.
- Develop the relational model for ABC

Experiment 3

Relational Algebra queries for the ABC. Clearly write the definition as well as relational algebra queries for each.

- Develop at least N queries using each of following operators
    1. Selection
    2. Projection
    3. Cartesian product
    4. Union
    5. Set difference
    6. Natural join
    7. Composition of any two from (1-6) operators
    8. Composition of any three of above (1-6) operators

Experiment 4

Development of E-R model for the ABC

- Identify the various entities and entity sets that exists in the ABC
- Identify the super-key, candidate-key and primary key for the identified entity sets.
- Identify the all possible relations that exists between entity sets
- Develop the E-R model for ABC

5. Installation of XYZ relational database management system

Objective: To learn basics of softwares that can be used for SQL Query evaluations.

6. Introduction to SQL, DDL, DML, DCL, database and table creation, alteration, defining Constraints, primary key, foreign key, unique, not null, check, IN operator.

Objective: To learn basic concept of SQL Schemas and key dependences.

7. Study and use of inbuilt SQL functions - aggregate functions, Built-in functions Numeric, date, string functions

Objective: To learn basics of built in functions of SQL.

8. Study, write and use the set operations, sub-queries, correlated sub-queries in SQL

Objective: To learn some advanced built in functions of SQL.

9. Study and use of group by, having, order by features of SQL

Objective: To learn basics build in features of SQL Query.

10. Study different types of join operations, Exist, Any, All and relevant features of SQL.

Objective: To learn basics build in features of SQL Query.

11. Study and implement different types of Views

Objective: To learn some advanced features of SQL Query.

12. Study and use of Transaction control commands, Commit, Rollback, Save point features of SQL.

Objective: To learn and implement transactions using SQL Query.

13. Study and apply Database Normalization techniques.

Objective: To learn and implement database normalization using SQL Query.

14. Introduction to Embedded SQL, PL SQL Concepts

Objective: To learn and implement embedded SQL using host language as a C or JAVA.

15. Study and Implementation of Cursors, Stored Procedures, Stored Function, Triggers.

Objective: To learn and implement cursors, subprograms and functions using SQL Query. To understand how the concept of trigger can help in solving data base queries.

16. Analysis of query cost, creating indices and evaluating their effect on query Evaluation Plans and cost.

Objective: To learn cost estimation of SQL Query in terms of time and space.