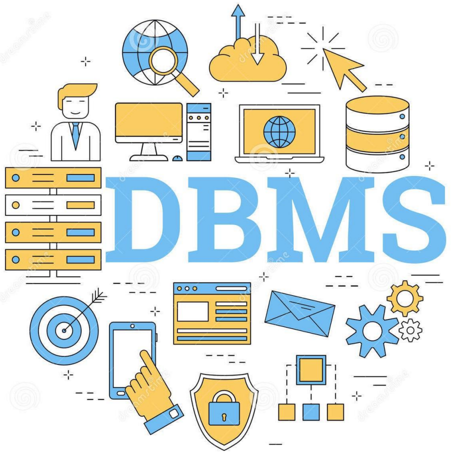
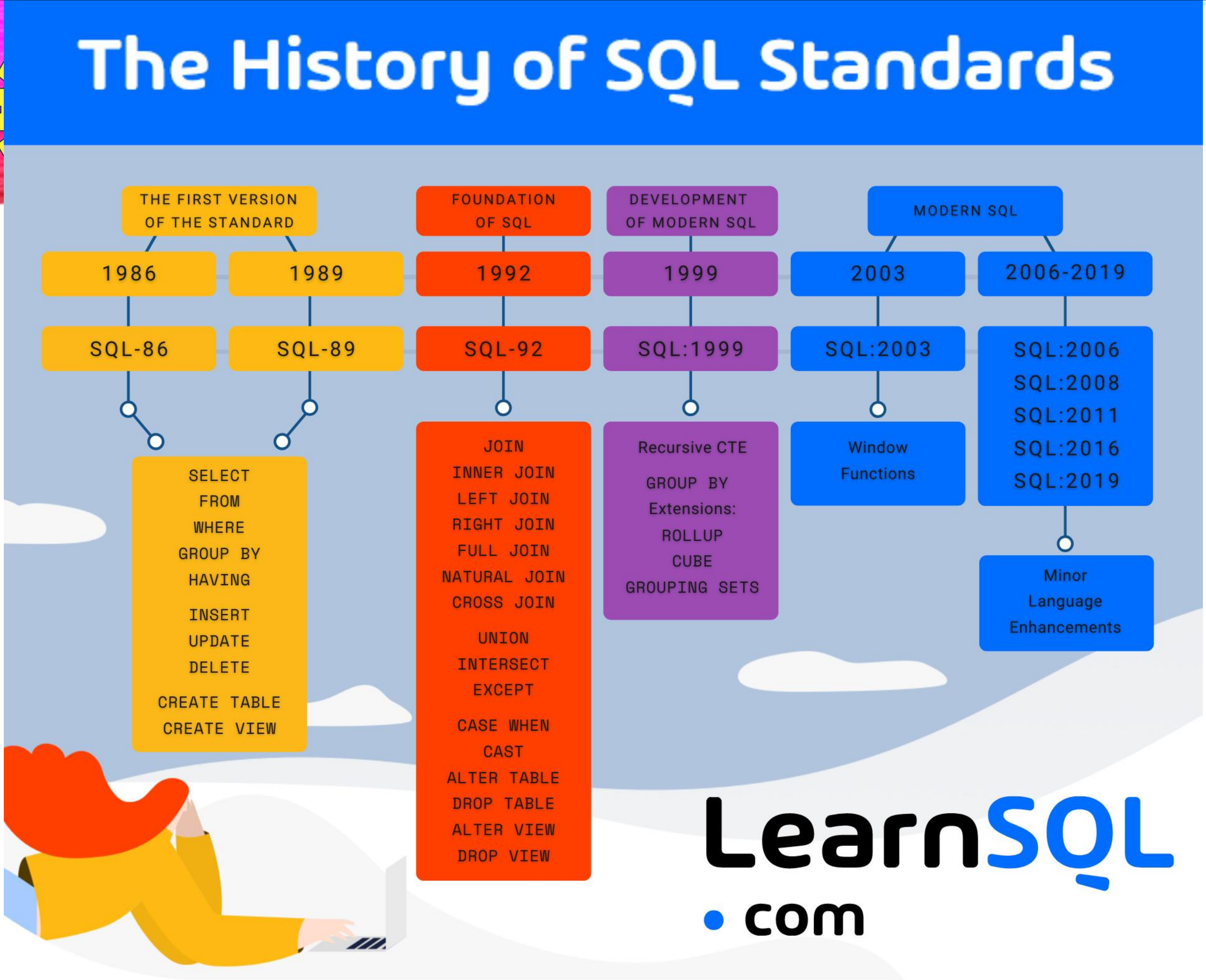
# Unit I – Relational Model

Relational Data Model - keys, referential integrity and foreign keys, Relational Algebra - **SQL fundamentals- Introduction, data definition in SQL, table, key and foreign key definitions, update behaviors** -Intermediate SQL-Advanced SQL features -Embedded SQL- Dynamic SQL, CASE Studies- Oracle: Database Design and Querying Tools; SQL Variations and Extensions



# History


The History of SQL Standards
THE FIRST VERSION OF THE STANDARD
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MODERN SQL
1986
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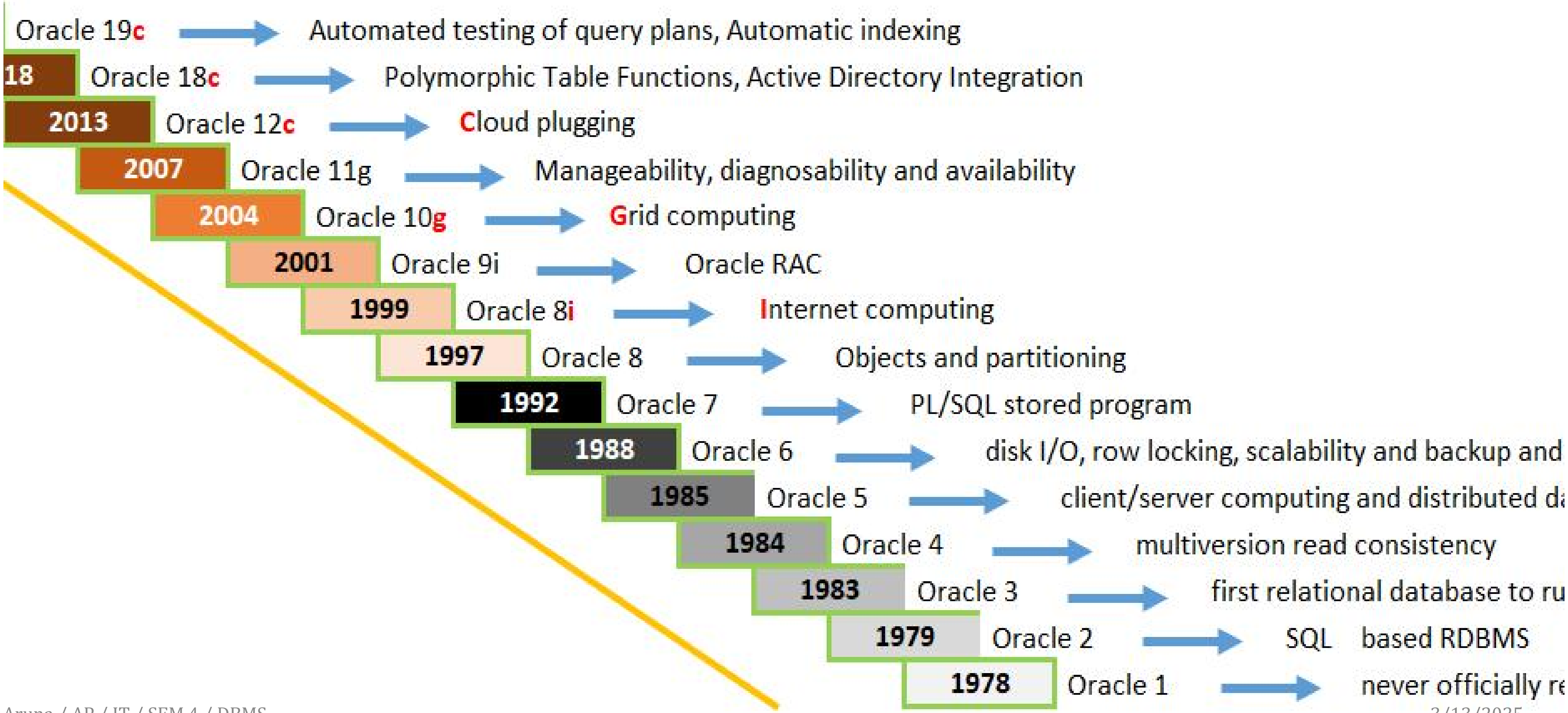
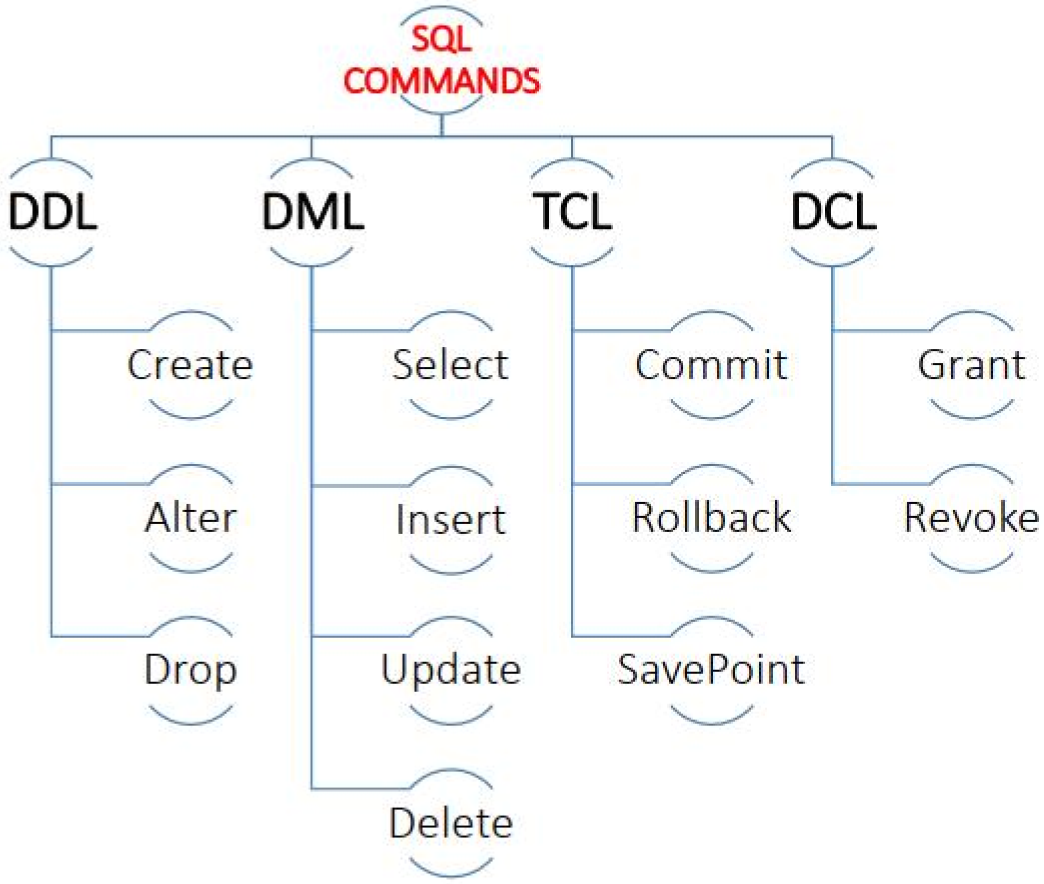
# History of Oracle Database Versions



# SQL Parts




- DML - Data Manipulation Language
- DDL - Data Definition Language
- DCL - Data Control Language
- TCL - Transaction Control Language
- DQL - Data Query Language

# Data Definition Language

- The SQL data-definition language (DDL) allows the specification of information about relations, including:
  - The schema for each relation.
  - The type of values associated with each attribute.
  - The Integrity constraints
  - The set of indices to be maintained for each relation.
  - Security and authorization information for each relation.
  - The physical storage structure of each relation on disk.

# Domain Types in SQL

- **char(n).** Fixed length character string, with user-specified length *n.*
- **varchar(n).** Variable length character strings, with user-specified maximum length *n.*
- **int.** Integer (a finite subset of the integers that is machine-dependent).
- **smallint.** Small integer (a machine-dependent subset of the integer domain type).
- **numeric(p,d).** Fixed point number, with user-specified precision of *p* digits, with *d* digits to the right of decimal point. (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 Construct



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

**create table** *r*

$(A_1\ D_1, A_2\ D_2, ..., A_n\ D_n,$

(integrity-constraint$_1$),

...,

(integrity-constraint$_k$))

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

- *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 $A_i$

# Integrity Constraints in Create Table

- Types of integrity constraints
  - **primary key** ($A_1$, ..., $A_n$ )
  - **foreign key** ($A_m$, ..., $A_n$ ) **references** *r*
  - **not null**
- SQL prevents any update to the database that violates an integrity constraint.

# Integrity Constraints in Create Table

```
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);
```

# Few More Relation Definitions

```
create table student (
    ID          varchar(5),
    name        varchar(20) not null,
    dept_name   varchar(20),
    tot_cred    numeric(3,0),
    primary key (ID),
      foreign key (dept_name) references department);
```

# Few More Relation Definitions

- **create table** *takes* (

```
ID          varchar(5),
course_id   varchar(8),
sec_id      varchar(8),
semester    varchar(6),
year        numeric(4,0),
grade       varchar(2),
  primary key (ID, course_id, sec_id, semester, year) ,
  foreign key (ID) references student,
foreign key (course_id, sec_id, semester, year) references section);
```

# Few More Relation Definitions

- **create table** *course* (

  *course_id* **varchar**(8),

  *title* **varchar(**50),

  *dept_name* **varchar**(20),

  *credits* **numeric**(2,0),

  **primary key** *(course_id),*

  **foreign key** (*dept_name*) **references** *department*);

# Updates to tables



- **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.

# Basic Query Structure

- A typical SQL query has the form:

**select** $A_1, A_2, ..., A_n$

**from** $r_1, r_2, ..., r_m$

**where** $P$

$A_i$ represents an attribute
  - $R_i$ represents a relation
  - $P$ is a predicate.
- The result of an SQL query is a relation.

# The select Clause

- 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.

# The select Clause (Cont.)

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

**select distinct** *dept_name*
**from** *instructor*

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

**select all** *dept_name*
**from** *instructor*

# The select Clause (Cont.)



- 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 (Cont.)



- 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/12*
    **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.'

- SQL allows the use of the logical connectives **and, or,** and **not**
- The operands of the logical connectives can be expressions involving the comparison operators <, <=, >, >=, =, and <>.
- Comparisons can be applied to results of arithmetic expressions
- To find all instructors in Comp. Sci. dept with salary > 70000

  **select** *name*
  **from** *instructor*
  **where** *dept_name* = 'Comp. Sci.' **and** *salary* > 70000

# 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).

# Assessment

- 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'

# The 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.

# String Operations (Cont.)

https://www.geeksforgeeks.org/sql-string-functions/

- 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.

# Ordering the Display of Tuples

- List in alphabetic order the names of all instructors

    **select distinct** *name*

    **from** *instructor*

    **order by** *name*

- We may specify **desc** for descending order or **asc** for ascending order, for each attribute; ascending order is the default.
    - Example: **order by** *name* **desc**
- Can sort on multiple attributes
    - Example: **order by** *dept_name, name*

# Where Clause Predicates



- SQL includes a **between** comparison operator
- Example: Find the names of all instructors with salary between $90,000 and $100,000 (that is, ≥ $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');

# Set Operations



- Find courses that ran in Fall 2017 or in Spring 2018

(**select** *course_id* **from** *section* **where** *sem* = 'Fall' **and** *year* = 2017)

**union**

(**select** *course_id* **from** *section* **where** *sem* = 'Spring' **and** *year* = 2018)

- Find courses that ran in Fall 2017 and in Spring 2018

(**select** *course_id* **from** *section* **where** *sem* = 'Fall' **and** *year* = 2017)

**intersect**

(**select** *course_id* **from** *section* **where** *sem* = 'Spring' **and** *year* = 2018)

Find courses that ran in Fall 2017 but not in Spring 2018

(**select** *course_id* **from** *section* **where** *sem* = 'Fall' **and** *year* = 2017)

**except**

(**select** *course_id* **from** *section* **where** *sem* = 'Spring' **and** *year* = 2018)

# Set Operations (Cont.)

- Set operations **union**, **intersect**, and **except**
  - Each of the above operations automatically eliminates duplicates
- To retain all duplicates use the
  - **union all**,
  - **intersect all**
  - **except all**.

# 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**
- The predicate **is not null** succeeds if the value on which it is applied is not null.

# 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

# Aggregate Functions 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 2018 semester
  - **select count** (**distinct** *ID*)
    **from** *teaches*
    **where** *semester* = 'Spring' **and** *year* = 2018;
- Find the number of tuples in the *course* relation
  - **select count** (*)
    **from** *course*;

# Aggregate Functions – Group By

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

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| | |

# Aggregate Functions – Having Clause

- Find the names and average salaries of all departments whose average salary is greater than 42000

**select** *dept_name*, **avg** (*salary*) **as** *avg_salary*

**from** *instructor*

**group by** *dept_name*

**having avg** (*salary*) > 42000;

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

# Nested Subqueries

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

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

as follows:

- **From clause:** $r_i$ can be replaced by any valid subquery
- **Where clause:** $P$ can be replaced with an expression of the form:

  $B$ <operation> (subquery)

  $B$ is an attribute and <operation> to be defined later.
- **Select clause:**

  $A_i$ can be replaced be a subquery that generates a single value.

# Set Membership

- Find courses offered in Fall 2017 and in Spring 2018

```
select distinct course_id
from section
where semester = 'Fall' and year= 2017 and
        course_id in (select course_id
                      from section
                      where semester = 'Spring' and year= 2018);
```

## Set Membership

- Find courses offered in Fall 2017 and in Spring 2018

```
select distinct course_id
from section
where semester = 'Fall' and year= 2017 and
        course_id in (select course_id
                      from section
                      where semester = 'Spring' and year= 2018);
```

- Find courses offered in Fall 2017 but not in Spring 2018

```
select distinct course_id
from section
where semester = 'Fall' and year= 2017 and
        course_id  not in (select course_id
                           from section
                           where semester = 'Spring' and year= 2018);
```

# Set Membership (Cont.)

- Name all instructors whose name is neither “Mozart” nor Einstein”

```
select distinct name
from instructor
where  name not in ('Mozart', 'Einstein')
```

- 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);
```

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

# 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 < **some**

| |
|---|
| 0 |
| 5 |
| 6 |

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

(5 < **some**

| |
|---|
| 0 |
| 5 |

) = false

(5 = **some**

| |
|---|
| 0 |
| 5 |

) = true

(5 $\neq$ **some**

| |
|---|
| 0 |
| 5 |

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

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

- $F \text{ <comp> } \textbf{all } r \Leftrightarrow \forall\, t \in r \; (F \text{ <comp> } t)$

(5 < **all**
| |
|---|
| 0 |
| 5 |
| 6 |

) = false

(5 < **all**
| |
|---|
| 6 |
| 10 |

) = true

(5 = **all**
| |
|---|
| 4 |
| 5 |

) = false

($5 \neq$ **all**
| |
|---|
| 4 |
| 6 |

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

($\neq$ **all**) $\equiv$ **not in**

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

# Test for Empty Relations

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

# Use of "exists" Clause

- Yet another way of specifying the query "Find all courses taught in both the Fall 2017 semester and in the Spring 2018 semester"

```
select course_id
from section as S
where semester = 'Fall' and year = 2017 and
        exists  (select *
                 from section as T
                 where semester = 'Spring' and year= 2018
                         and S.course_id = T.course_id);
```

- **Correlation name** – variable S  in the outer query
- **Correlated subquery** – the inner query

# Use of "not exists" 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

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

# Test for Absence of 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 2017

```
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 = 2017);
```

# Subqueries 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*;

# Complex Queries using With Clause

- Find all departments where the total salary is greater than the average of the total salary at all departments

```
with dept _total (dept_name, value) as
        (select dept_name, sum(salary)
         from instructor
         group by dept_name),
dept_total_avg(value) as
       (select avg(value)
       from dept_total)
select dept_name
from dept_total, dept_total_avg
where dept_total.value > dept_total_avg.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

# Modification of the Database

- Deletion of tuples from a given relation.
- Insertion of new tuples into a given relation
- Updating of values in some tuples in a given relation

# 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');

# Deletion (Cont.)

- Delete all instructors whose salary is less than the average salary of instructors

```
delete from instructor
where salary < (select avg (salary)
                from instructor);
```

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

# Insertion

- Add a new tuple to *course*

  **insert into** *course*
  **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*);

# Insertion (Cont.)

- Make each student in the Music department who has earned more than 144 credit hours an instructor in the Music department with a salary of  $18,000.

**insert into** *instructor*
  **select** *ID, name, dept_name, 18000*
  **from** *student*
  **where** *dept_name* = 'Music' **and** *total_cred* > 144;

- 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



- Give a 5% salary raise to all instructors

```
update instructor
  set salary = salary * 1.05
```

- Give a 5% salary raise to those instructors who earn less than 70000

```
update instructor
  set salary = salary * 1.05
  where salary < 70000;
```

- Give a 5% salary raise to instructors whose salary is less than average

```
update instructor
set salary = salary * 1.05
where salary < (select avg (salary)
                from instructor);
```

# Updates (Cont.)



- 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)

# Case Statement for Conditional Updates

- Same query as before but with case statement

**update** *instructor*
    **set** *salary* = **case**
        **when** *salary* <= 100000 **then** *salary* * 1.05
        **else** *salary* * 1.03
        **end**

# Updates with Scalar Subqueries

- 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
```


Thank You!