Chapter 4 : Intermediate SQL

Database System Concepts, 7th Ed.

Chapter 4: Intermediate SQL

- Join Expressions
- Views
- Transactions
- Integrity Constraints
- SQL Data Types and Schemas
- Index Definition in SQL
- Authorization

Problem?

Employee	
LastName	**DepartmentName**
Rafferty	Sales
Jones	Engineering
Heisenberg	Engineering
Robinson	Clerical
Smith	Clerical
Williams	NULL

Redundant Data!!!

Solution

Employee	
LastName	**DepartmentName**
Rafferty	Sales
Jones	Engineering
Heisenberg	Engineering
Robinson	Clerical
Smith	Clerical
Williams	NULL

Employee Table

Department Table

LastName
Rafferty
Jones
Heisenberg
Robinson
Smith
Williams

DepartmentName
Sales
Engineering
Engineering
Clerical
Clerical
NULL

Solution

Employee	
LastName	**DepartmentName**
Rafferty	Sales
Jones	Engineering
Heisenberg	Engineering
Robinson	Clerical
Smith	Clerical
Williams	NULL

Employee Table

Department Table

LastName
Rafferty
Jones
Heisenberg
Robinson
Smith
Williams

DepartmentName
Sales
Engineering
Clerical
Marketing

Delete Redundant Data!

Solution
Add primary key (ID)

Employee	
LastName	**DepartmentName**
Rafferty	Sales
Jones	Engineering
Heisenberg	Engineering
Robinson	Clerical
Smith	Clerical
Williams	NULL

Employee Table

Department Table

LastName
Rafferty
Jones
Heisenberg
Robinson
Smith
Williams

Department	
DepartmentID	**DepartmentName**
31	Sales
33	Engineering
34	Clerical
35	Marketing

Solution

Employee	
LastName	**DepartmentName**
Rafferty	Sales
Jones	Engineering
Heisenberg	Engineering
Robinson	Clerical
Smith	Clerical
Williams	NULL

Employee Table

Department Table

How to make a relationship between two tables?

Foreign Key

LastName
Rafferty
Jones
Heisenberg
Robinson
Smith
Williams

Department	
DepartmentID	**DepartmentName**
31	Sales
33	Engineering
34	Clerical
35	Marketing

Solution

Employee

LastName	DepartmentName
Rafferty	Sales
Jones	Engineering
Heisenberg	Engineering
Robinson	Clerical
Smith	Clerical
Williams	NULL

Employee Table

Department Table

Employee

LastName	DepartmentID
Rafferty	
Jones	
Heisenberg	
Robinson	
Smith	
Williams	

Department

DepartmentID	DepartmentName
31	Sales
33	Engineering
34	Clerical
35	Marketing

Solution

Employee	
LastName	**DepartmentName**
Rafferty	Sales
Jones	Engineering
Heisenberg	Engineering
Robinson	Clerical
Smith	Clerical
Williams	NULL

Employee Table

Department Table

Employee	
LastName	**DepartmentID**
Rafferty	31
Jones	33
Heisenberg	33
Robinson	34
Smith	34
Williams	NULL

Department	
DepartmentID	**DepartmentName**
31	Sales
33	Engineering
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35	Marketing

Structured Query Language (SQL)

SELECT *<attribute list>*
FROM *<table list >*
WHERE *<condition>*

- Language for constructing a new table from argument table(s).
  - FROM indicates source tables
  - WHERE indicates which *rows* to retain
    - It acts as a filter
  - SELECT indicates which *columns* to extract from retained rows
    - Projection
- The result is a table.

Example

SELECT *Name*
FROM *Student*
WHERE *Id* > 4999;

Id	*Name*	*Address*	*Status*
1234	John	123 Main	fresh
5522	Mary	77 Pine	senior
9876	Bill	83 Oak	junior

Student

Name
Mary
Bill

Result

Examples

SELECT *Id*, *Name* FROM Student;

SELECT *Id*, *Name* FROM Student
WHERE *Status* = 'senior';

SELECT * FROM Student
WHERE *Status* = 'senior‘;

result is a table with one column and one row

SELECT COUNT(*) FROM Student
WHERE *Status* = 'senior';

More Complex Example

- **Goal:** table in which each row names a senior and gives a course taken and grade
- Combines information in two tables:
  - Student: *Id*, *Name*, *Address*, *Status*
  - Transcript: *StudId*, *CrsCode*, *Semester*, *Grade*

SELECT *Name*, *CrsCode*, *Grade*
FROM Student, Transcript
WHERE *StudId* = *Id* AND *Status* = '*senior*';

Join

SELECT *a1*, *b1*
FROM T1, T2
WHERE *a2* = *b2*

T1

a1	*a2*	*a3*
A	1	xxy
B	17	rst

T2

b1	*b2*
3.2	17
4.8	17

FROM T1, T2
yields:

a1	*a2*	*a3*	*b1*	*b2*
A	1	xxy	3.2	17
A	1	xxy	4.8	17
B	17	rst	3.2	17
B	17	rst	4.8	17

WHERE *a2* = *b2*
yields:

B	17	rst	3.2	17
B	17	rst	4.8	17

SELECT *a1*, *b1*
yields result:

B	3.2
B	4.8

14

Modifying Tables

UPDATE *Student*
SET *Status* = 'soph'
WHERE *Id* = 111111111;

INSERT INTO Student (*Id*, *Name*, *Address*, *Status*)
VALUES (999999999, 'Bill', '432 Pine', 'senior')

DELETE FROM Student
WHERE *Id* = 111111111

Practice

Find the titles of courses in the Comp. Sci. department that have 3 credits.

select *title*
from *course*
where *dept name* = 'Comp. Sci.'
and *credits* = 3

Find the highest salary of any instructor.

select max(*salary***)**
from *instructor*

Find all instructors earning the highest salary (there may be more than one with the same salary).

select *ID, name*
from *instructor*
where salary = (**select max(**salary**) from** *instructor*)

Practice

write a query that finds departments whose names contain the string "Sci" as a substring.

```
select dept_name
from department
where dept_name like '%Sci%'
```

Find all instructors who do not work for Computer Science department. (Assume that all people work for exactly one department).

```
select name
from instructor
where dept_name <> 'Comp. Sci.'
```


Practice

Modify the database so that Kim now teaches in Biology.
(Assume that each person has only one tuple in the *instructor* relation)

update *instructor*
set *dept_name* = 'Biology'
where *name* = 'Kim'

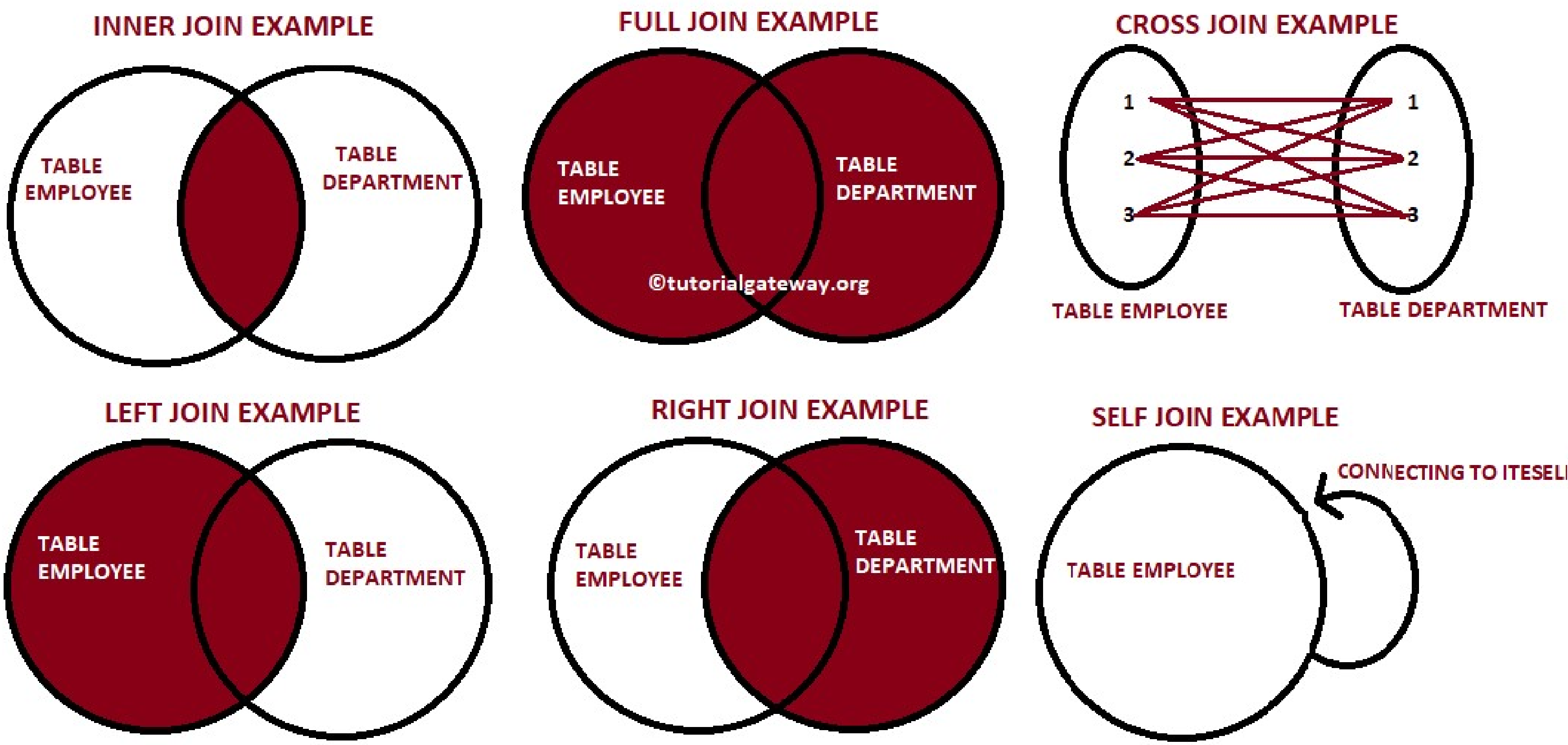
Increase the salary of each instructor in the Comp. Sci. department by 10%.

update *instructor*
set *salary* = *salary* * 1.10
where *dept name* = 'Comp. Sci.'

Joined Relations

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

Join


INNER JOIN EXAMPLE
TABLE EMPLOYEE
TABLE DEPARTMENT
FULL JOIN EXAMPLE
TABLE EMPLOYEE
TABLE DEPARTMENT
©tutorialgateway.org
CROSS JOIN EXAMPLE
1
2
3
1
2
3
TABLE EMPLOYEE
TABLE DEPARTMENT
LEFT JOIN EXAMPLE
TABLE EMPLOYEE
TABLE DEPARTMENT
RIGHT JOIN EXAMPLE
TABLE EMPLOYEE
TABLE DEPARTMENT
SELF JOIN EXAMPLE
CONNECTING TO ITESELF
TABLE EMPLOYEE

Semantics of JOINs

SELECT $x_1.a_1, x_1.a_2, \ldots, x_n.a_k$
FROM R_1 AS x_1, R_2 AS x_2, …, R_n AS x_n
WHERE Conditions($x_1, \ldots, x_n$)

Answer = {}
for x_1 **in** R_1 **do**
  for x_2 **in** R_2 **do**
    …..
      for x_n **in** R_n **do**
        if Conditions($x_1, \ldots, x_n$)
          then Answer = Answer $\cup$ $\{(x_1.a_1, x_1.a_2, \ldots, x_n.a_k)\}$
return Answer

An example of SQL semantics

R

A
1
3

S

B	C
2	3
3	4
3	5

```
SELECT R.A
FROM   R, S
WHERE  R.A = S.B
```

Cross Product

A	B	C
1	2	3
1	3	4
1	3	5
3	2	3
3	3	4
3	3	5

Apply Selections / Conditions

A	B	C
3	3	4
3	3	5

Apply Projection

Output

A
3
3

Practice

MySQL supports the following types of joins:

- Cross join
- Inner join
- Left join
- Right join

MySQl Tutorial:
http://www.mysqltutorial.org/

https://en.wikipedia.org/wiki/Join_(SQL)

Example

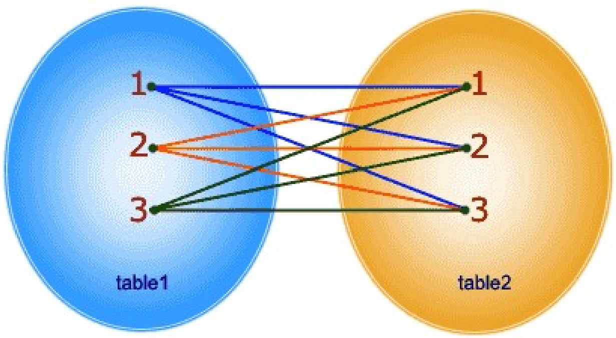
T1

col1	*col2*
1	11
2	22

T2

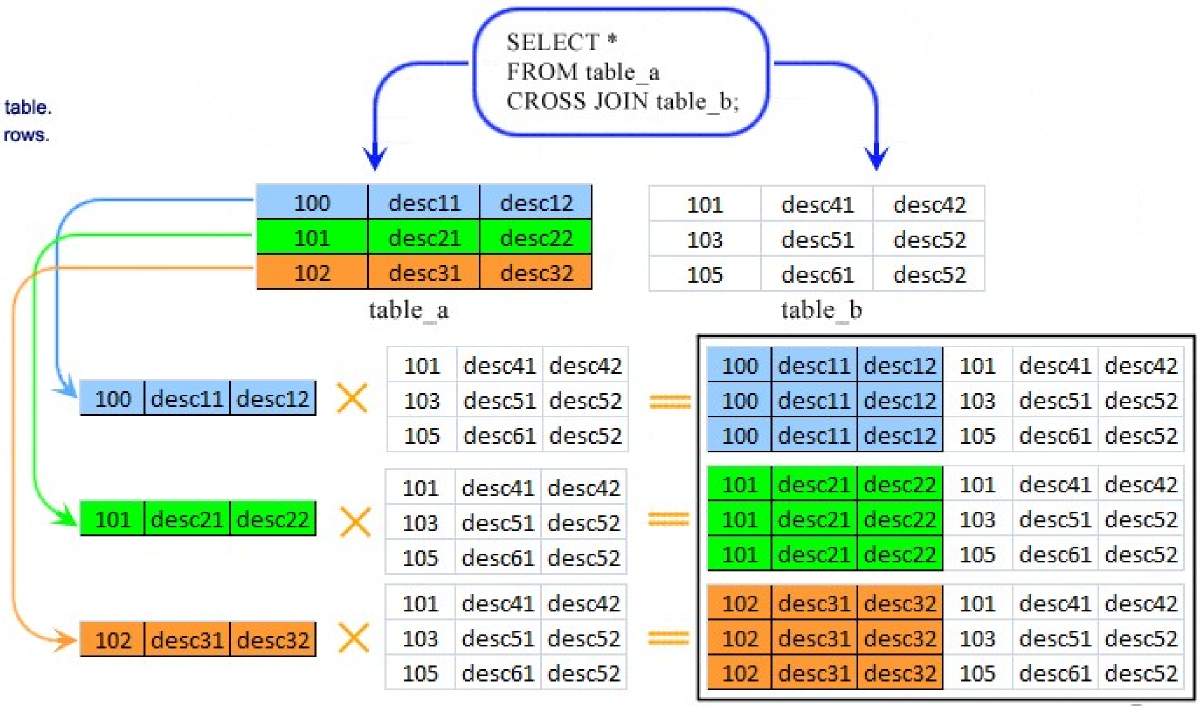
col1	*col3*
10	101
2	202

SELECT * FROM table1 CROSS JOIN table2;



In CROSS JOIN, each row from 1st table joins with all the rows of another table.
If 1st table contain x rows and y rows in 2nd one the result set will be x * y rows.

Cross Join
Cartesian Product



id	des1	des2	id	des3	des4
100	desc11	desc12	101	desc41	desc42
100	desc11	desc12	103	desc51	desc52
100	desc11	desc12	105	desc61	desc62
101	desc21	desc22	101	desc41	desc42
101	desc21	desc22	103	desc51	desc52
101	desc21	desc22	105	desc61	desc62
102	desc31	desc32	101	desc41	desc42
102	desc31	desc32	103	desc51	desc52
102	desc31	desc32	105	desc61	desc62

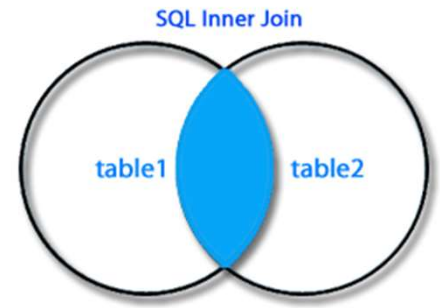
Cross Join

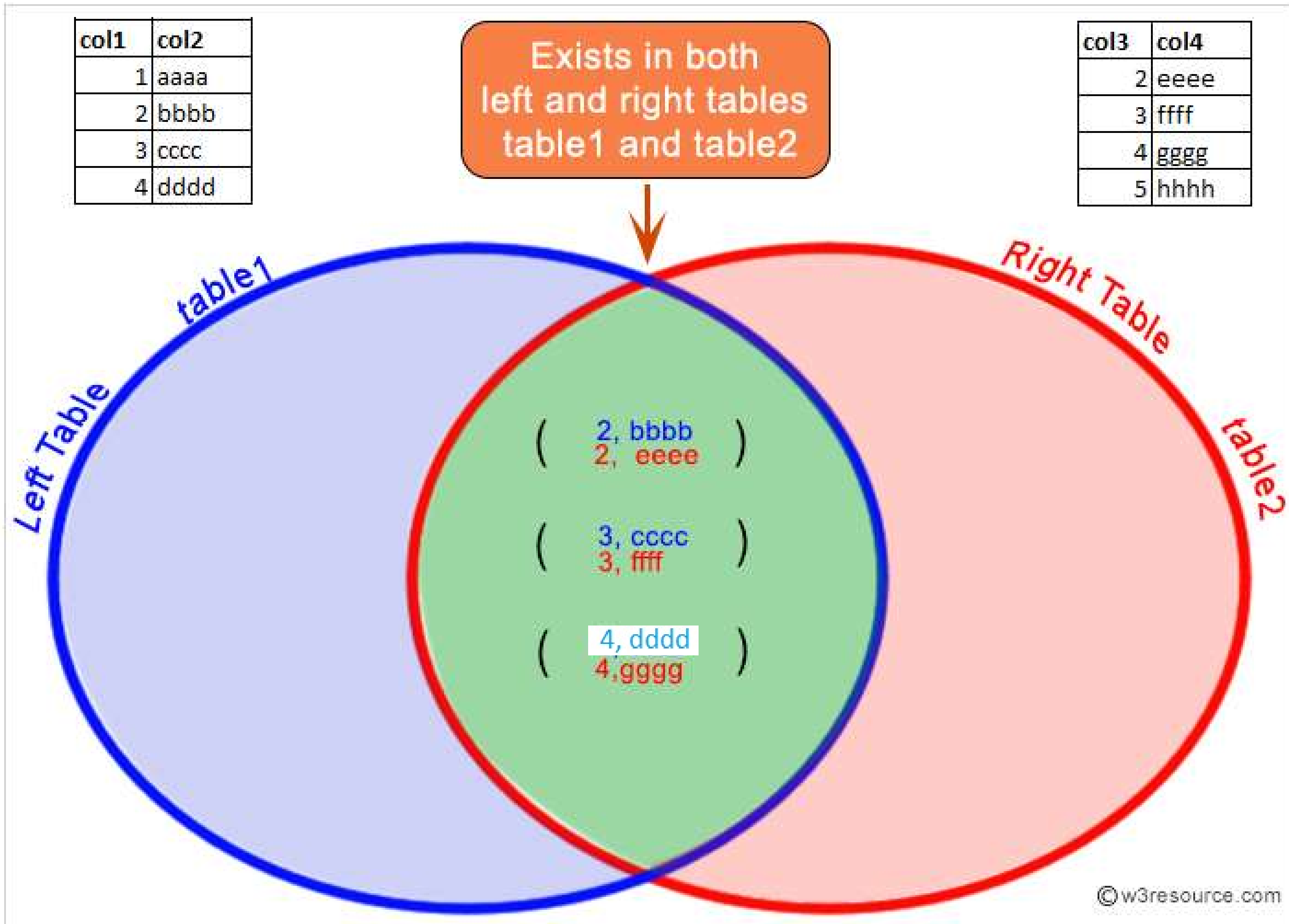
Employee	
LastName	**DepartmentID**
Rafferty	31
Jones	33
Heisenberg	33
Robinson	34
Smith	34
Williams	NULL

Department	
DepartmentID	**DepartmentName**
31	Sales
33	Engineering
34	Clerical
35	Marketing

Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Rafferty	31	Sales	31
Jones	33	Sales	31
Heisenberg	33	Sales	31
Smith	34	Sales	31
Robinson	34	Sales	31
Williams	NULL	Sales	31
Rafferty	31	Engineering	33
Jones	33	Engineering	33
Heisenberg	33	Engineering	33
Smith	34	Engineering	33
Robinson	34	Engineering	33
Williams	NULL	Engineering	33
Rafferty	31	Clerical	34
Jones	33	Clerical	34
Heisenberg	33	Clerical	34
Smith	34	Clerical	34
Robinson	34	Clerical	34
Williams	NULL	Clerical	34
Rafferty	31	Marketing	35
Jones	33	Marketing	35
Heisenberg	33	Marketing	35
Smith	34	Marketing	35
Robinson	34	Marketing	35
Williams	NULL	Marketing	35

Inner Join


SQL Inner Join
table1
table2


col1 col2
1 aaaa
2 bbbb
3 cccc
4 dddd
Exists in both
left and right tables
table1 and table2
col3 col4
2 eeee
3 ffff
4 gggg
5 hhhh
Left Table
table1
Right Table
table2
(2, bbbb 2, eeee)
(3, cccc 3, ffff)
(4, dddd 4,gggg)
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Join Condition

- The **on** condition allows a general predicate over the relations being joined.
- This predicate is written like a **where** clause predicate except for the use of the keyword **on**.
- Query example

  select *
  from *student* **join** *takes* **on** *student_ID = takes_ID*

  - The **on** condition above specifies that a tuple from *student* matches a tuple from *takes* if their *ID* values are equal.
- Equivalent to:

  select *
  from *student , takes*
  where *student_ID = takes_ID*

Inner join

Employee	
LastName	**DepartmentID**
Rafferty	31
Jones	33
Heisenberg	33
Robinson	34
Smith	34
Williams	NULL

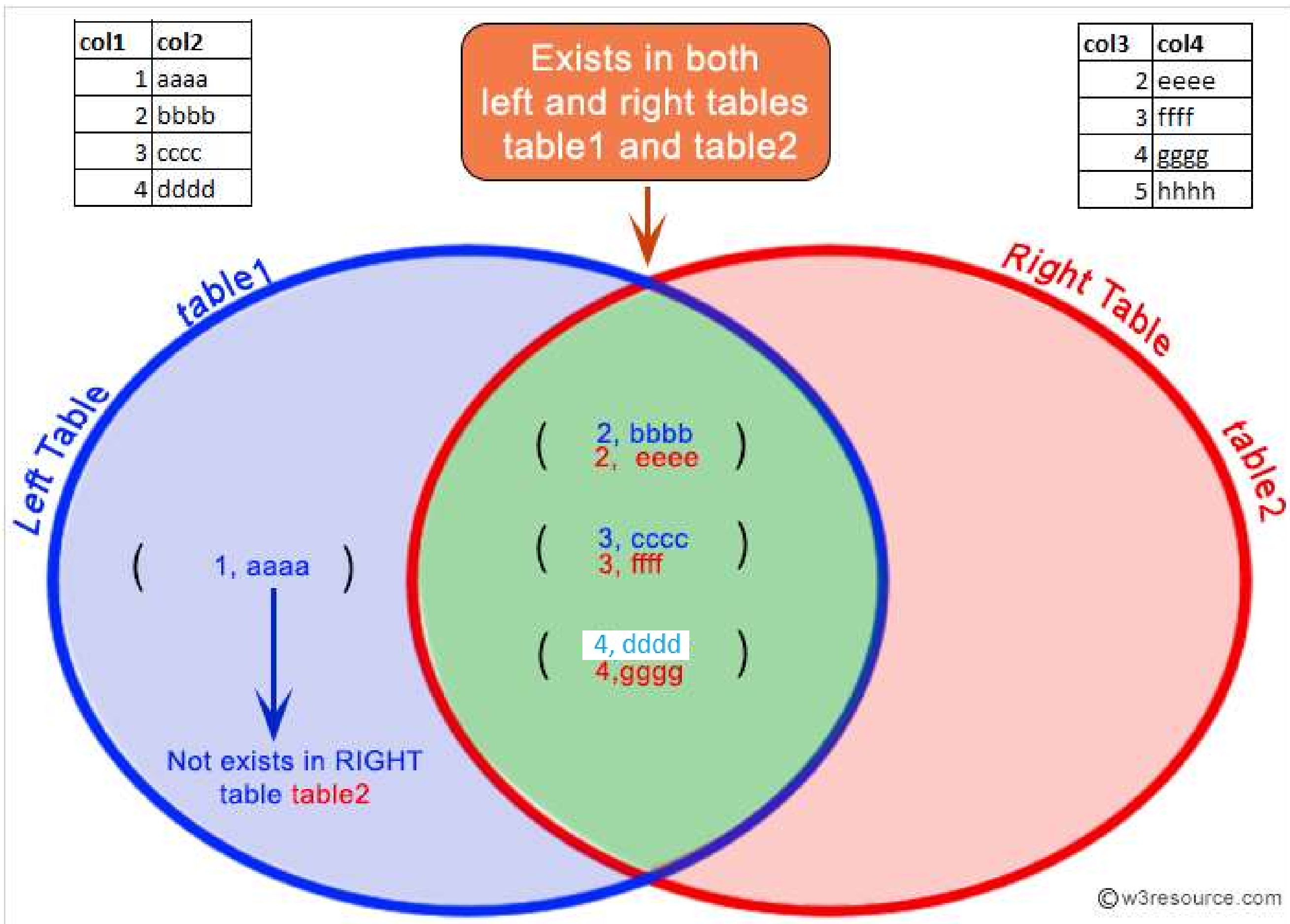
Department	
DepartmentID	**DepartmentName**
31	Sales
33	Engineering
34	Clerical
35	Marketing

Employee.LastName	Employee.DepartmentID	Department.DepartmentName
Robinson	34	Clerical
Jones	33	Engineering
Smith	34	Clerical
Heisenberg	33	Engineering
Rafferty	31	Sales

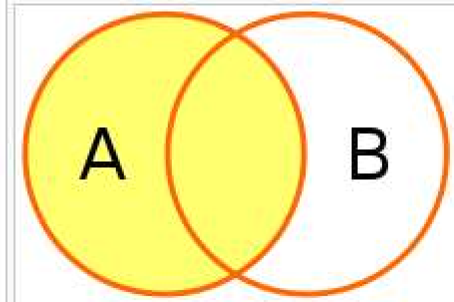
Outer Join

- An extension of the join operation that avoids loss of information.
- Computes the join and then adds tuples form one relation that does not match tuples in the other relation to the result of the join.
- Uses *null* values.
- Three forms of outer join:
  - left outer join
  - right outer join
  - full outer join

Left (outer) Join



Left Outer Join



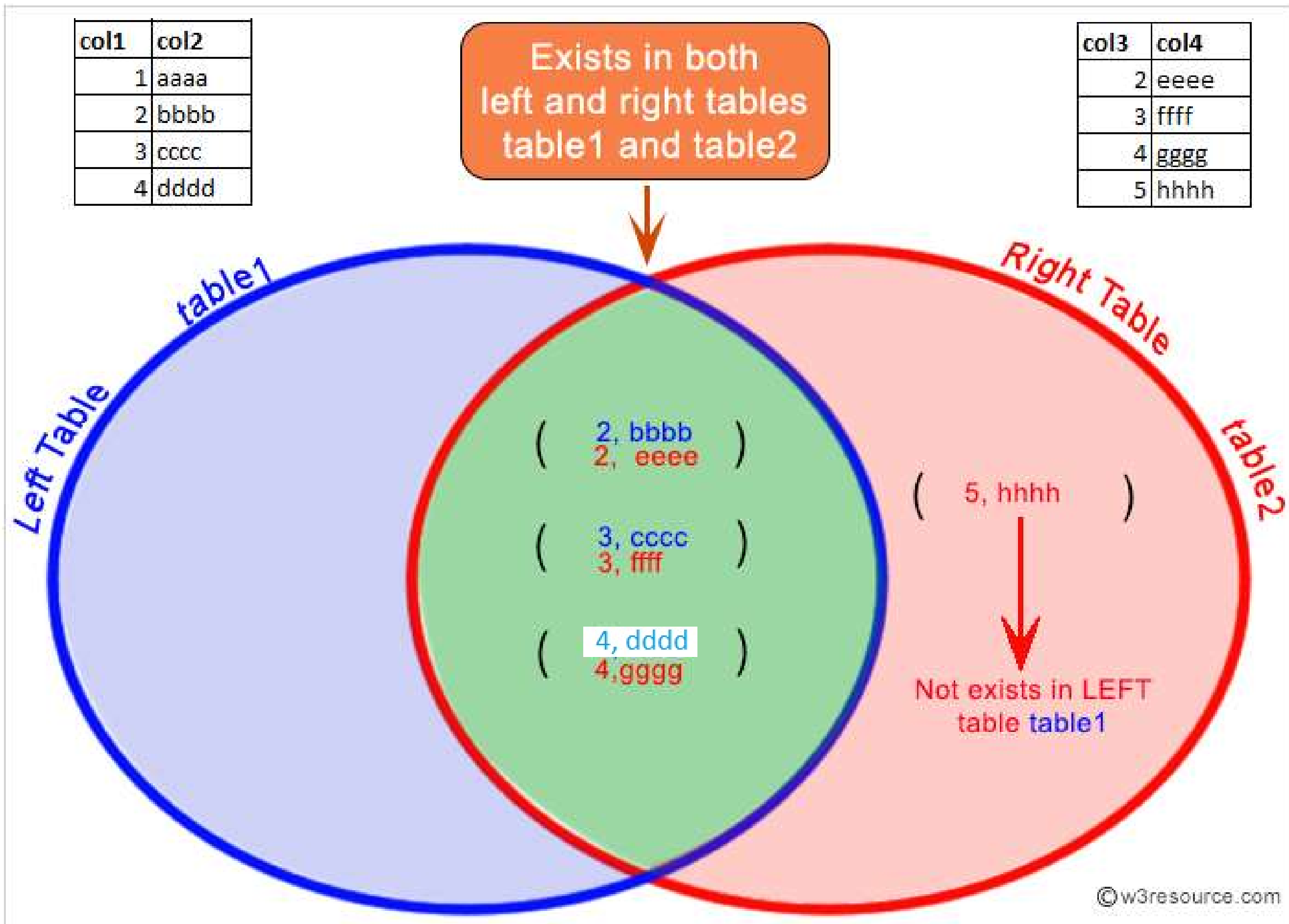
A Venn Diagram representing the Left Join SQL statement between tables A and B.

Employee	
LastName	**DepartmentID**
Rafferty	31
Jones	33
Heisenberg	33
Robinson	34
Smith	34
Williams	NULL

Department	
DepartmentID	**DepartmentName**
31	Sales
33	Engineering
34	Clerical
35	Marketing

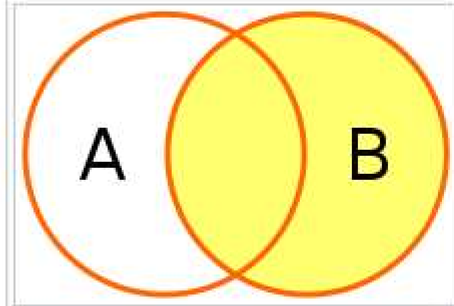
Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Jones	33	Engineering	33
Rafferty	31	Sales	31
Robinson	34	Clerical	34
Smith	34	Clerical	34
Williams	NULL	NULL	NULL
Heisenberg	33	Engineering	33

Right(Outer) Join



33

Right Outer Join



A Venn Diagram representing the Right Join SQL statement between tables A and B.

Employee

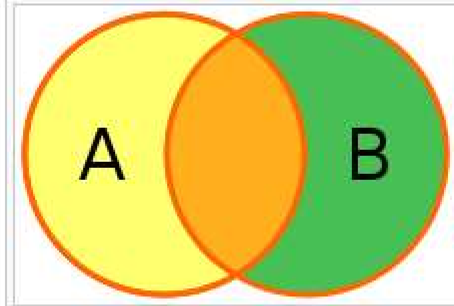
LastName	DepartmentID
Rafferty	31
Jones	33
Heisenberg	33
Robinson	34
Smith	34
Williams	NULL

Department

DepartmentID	DepartmentName
31	Sales
33	Engineering
34	Clerical
35	Marketing

Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Smith	34	Clerical	34
Jones	33	Engineering	33
Robinson	34	Clerical	34
Heisenberg	33	Engineering	33
Rafferty	31	Sales	31
NULL	NULL	*Marketing*	*35*

Full Outer Join



A Venn Diagram representing the Full Join SQL statement between tables A and B.

Employee	
LastName	DepartmentID
Rafferty	31
Jones	33
Heisenberg	33
Robinson	34
Smith	34
Williams	NULL

Department	
DepartmentID	DepartmentName
31	Sales
33	Engineering
34	Clerical
35	Marketing

Employee.LastName	Employee.DepartmentID	Department.DepartmentName	Department.DepartmentID
Smith	34	Clerical	34
Jones	33	Engineering	33
Robinson	34	Clerical	34
Williams	NULL	NULL	NULL
Heisenberg	33	Engineering	33
Rafferty	31	Sales	31
NULL	NULL	*Marketing*	*35*

Other Join

Equi-join:

An equi-join is a specific type of comparator-based join, that uses only **equality (=)** comparisons in the join-predicate. Using other comparison operators (such as <) disqualifies a join as an equi-join. The query shown above has already provided an example of an equi-join:

```
SELECT *
FROM employee JOIN department
 ON employee.DepartmentID = department.DepartmentID;
```

We can write equi-join as below:

```
SELECT *
FROM employee, department
WHERE employee.DepartmentID = department.DepartmentID;
```

Other Join

Natural join:

The natural join is a special case of equi-join. Natural join (⋈) is a binary operator that is written as (R ⋈ S) where R and S are relations.

The result of the natural join is the set of all combinations of tuples in R and S that are **equal on their common attribute names**. For an example consider the tables Employee and Dept and their natural join:

Employee

Name	EmpId	DeptName
Harry	3415	Finance
Sally	2241	Sales
George	3401	Finance
Harriet	2202	Sales

Dept

DeptName	Manager
Finance	George
Sales	Harriet
Production	Charles

Employee ⋈ Dept

Name	EmpId	DeptName	Manager
Harry	3415	Finance	George
Sally	2241	Sales	Harriet
George	3401	Finance	George
Harriet	2202	Sales	Harriet

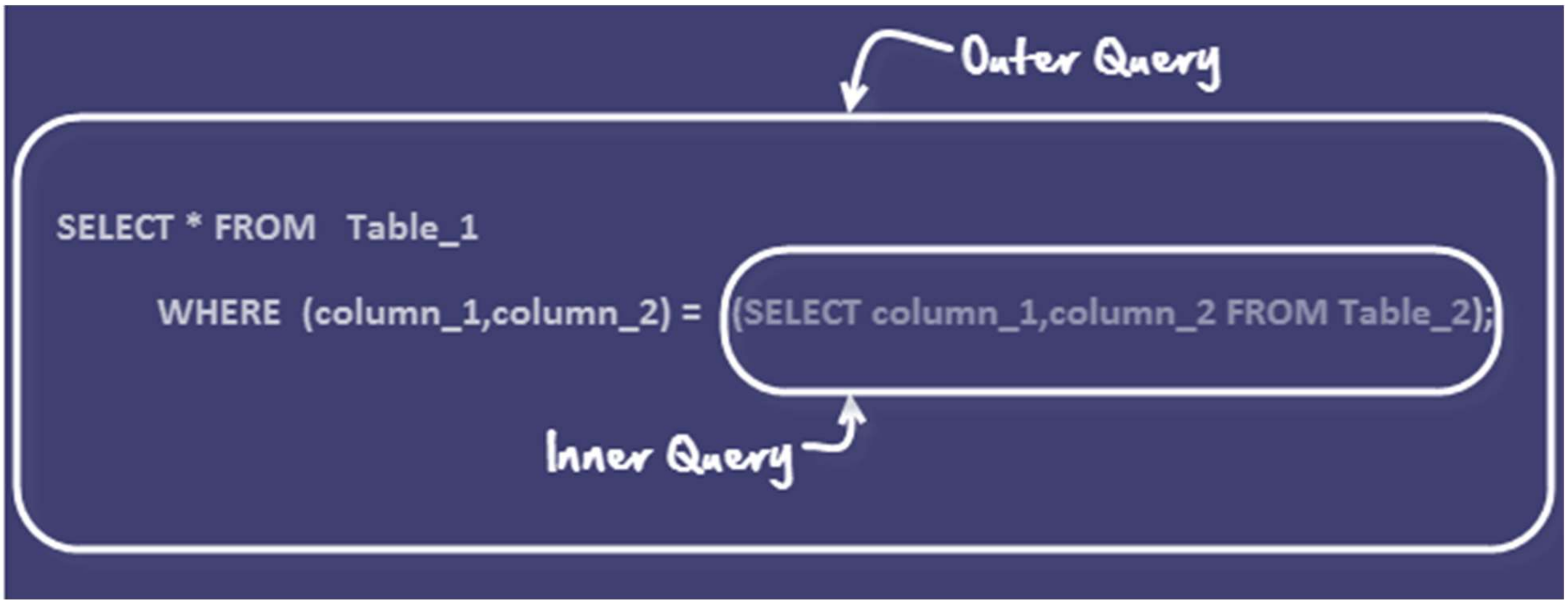
```sql
SELECT *
FROM employee NATURAL JOIN department;
```

Implementation of Division

- Using Subquery

Subquery

- A sub query is a select query that is contained inside another query. The inner select query is usually used to determine the results of the outer select query.



Subqueries are embedded queries inside another query. The embedded query is known as the **inner query** and the container query is known as the **outer query**.

Example

movies = (movie_id, title, director, year_released, category_id)

```
SELECT category_name
FROM categories
WHERE category_id = ( SELECT MIN(category_id)
                      FROM movies );
```

First the INNER Query is executed

```
SELECT MIN(category_id) from movies
```

INNER Query gives following result

MIN(category_id)
1

Output of INNER Query is substituted in OUTER Query

```
SELECT category_name FROM categories WHERE category_id =1
```

On Execution OUTER Query gives following Result

category_name
Comedy

The above is a form of **Row Sub-Query**. In such sub-queries the, inner query can give only **ONE result**. The permissible operators when work with row subqueries are [=, >, =, <=, ,!=,]

Example

```
SELECT full_names,contact_number
FROM members
WHERE membership_number IN ( SELECT membership_number
                                                    FROM movierentals
                                                    WHERE return_date IS NULL );
```

First the INNER Query is executed

```
SELECT membership_number FROM movierentals WHERE return_date IS NULL
```

INNER Query gives following result

membership_number
1
3

Output of INNER Query is substituted in OUTER Query

```
SELECT full_names,contact_number FROM   members  WHERE  membership_number IN (1,3)
```

On Execution OUTER Query gives following Result

full_names	contact_number
Janet Jones	0759 253 542
Robert Phil	12345

In this case, the inner query returns **more than one results**. The above is type of **Table sub-query.**

Subqueries

- A subquery may occur in:
  - A SELECT clause
  - A FROM clause
  - A WHERE clause
- **Rule of thumb**: avoid writing nested queries when possible; keep in mind that sometimes it's impossible

Correlated Nested Queries

Output a row <*prof, dept*> if *prof* has taught a course in *dept*.

```
SELECT  P.Name, D.Name                        --outer query
FROM Professor P, Department D
WHERE  P.Id  IN      -- set of  all ProfId’s who have taught a course in D.DeptId
             (SELECT T.ProfId                               --subquery
              FROM Teaching T, Course C
              WHERE T.CrsCode = C.CrsCode  AND
                    C.DeptId = D.DeptId                     --correlation
             )
```

Correlated Nested Queries (con't)

- Tuple variables T and C are local to subquery
- Tuple variables P and D are global to subquery
- Correlation: subquery uses a global variable, D
- Correlated queries can be expensive to evaluate

1. Subqueries in SELECT

Company(cid, cname, city)
Product (pname, price, cid)

For each product return the city where it is manufactured

1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

For each product return the city where it is manufactured

```
SELECT X.pname, ( SELECT Y.city
                  FROM Company Y
                  WHERE Y.cid=X.cid) as City
FROM  Product X
```

1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

For each product return the city where it is manufactured

```
SELECT X.pname, (SELECT Y.city
                 FROM Company Y
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```

What happens if the subquery returns more than one city?

We get a runtime error
(Some DBMS simply ignore the extra values)

1. Subqueries in SELECT

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Company(<u>cid</u>, cname, city)

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"correlated subquery"

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SELECT X.pname, (SELECT Y.city
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```

"correlated subquery"

What happens if the subquery returns more than one city?

We get a runtime error
(Some DBMS simply ignore the extra values)

1. Subqueries in SELECT

Product (<u>pname</u>, price, cid)
Company(<u>cid</u>, cname, city)

Whenever possible, don't use a nested queries:

```
SELECT X.pname, (SELECT Y.city
                 FROM Company Y
                 WHERE Y.cid=X.cid) as City
FROM  Product X
```

=

```
SELECT X.pname, Y.city
FROM   Product X, Company Y
WHERE X.cid=Y.cid
```

1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

Whenever possible, don't use a nested queries:

```
SELECT X.pname, (SELECT Y.city
                 FROM Company Y
                 WHERE Y.cid=X.cid) as City
FROM  Product X
```

=

```
SELECT X.pname, Y.city
FROM   Product X, Company Y
WHERE X.cid=Y.cid
```

We have "unnested" the query

1. Subqueries in SELECT

Product (<u>pname</u>, price, cid)
Company(<u>cid</u>, cname, city)

Compute the number of products made by each company

```
SELECT DISTINCT C.cname, (SELECT count(*)
                          FROM Product P
                          WHERE P.cid=C.cid)
FROM  Company C
```


1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

Compute the number of products made by each company

```
SELECT DISTINCT C.cname, (SELECT count(*)
                          FROM Product P
                          WHERE P.cid=C.cid)
FROM  Company C
```

Better: we can unnest by using a GROUP BY

```
SELECT C.cname, count(*)
FROM Company C, Product P
WHERE C.cid=P.cid
GROUP BY C.cname
```

1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

But are these really equivalent?

```
SELECT DISTINCT C.cname, (SELECT count(*)
                          FROM Product P
                          WHERE P.cid=C.cid)
FROM  Company C
```

```
SELECT C.cname, count(*)
FROM Company C, Product P
WHERE C.cid=P.cid
GROUP BY C.cname
```

1. Subqueries in SELECT

Product (pname, price, cid)
Company(cid, cname, city)

But are these really equivalent?

```
SELECT DISTINCT C.cname, (SELECT count(*)
                          FROM Product P
                          WHERE P.cid=C.cid)
FROM  Company C
```

```
SELECT C.cname, count(*)
FROM Company C, Product P
WHERE C.cid=P.cid
GROUP BY C.cname
```

No! Different results if a company has no products

```
SELECT C.cname, count(pname)
FROM Company C LEFT OUTER JOIN Product P
ON C.cid=P.cid
GROUP BY C.cname
```

2. Subqueries in FROM

Product (<u>pname</u>, price, cid)
Company(<u>cid</u>, cname, city)

Find all products whose prices is > 20 and < 500

```
SELECT X.pname
FROM (SELECT * FROM Product AS Y WHERE price > 20) as X
WHERE X.price < 500
```

Unnest this query !

```
SELECT pname FROM Product
WHERE price > 20 and price < 500
```

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

Find all companies that make some products with price < 200

3. Subqueries in WHERE

Find all companies that make some products with price < 200

Product (pname, price, cid)
Company(cid, cname, city)

Existential quantifiers

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

- Find all companies that make some products with price < 200

- Existential quantifiers

- Using IN

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE C.cid IN (SELECT P.cid
                 FROM Product P
                 WHERE P.price < 200)
```

SQL EXISTS Operator

- The EXISTS operator is used to test for the existence of any record in a subquery.
- The EXISTS operator returns true if the subquery returns one or more records.
- **Exists** Syntax:

```
SELECT column_name(s)
FROM table_name
WHERE EXISTS (SELECT column_name
              FROM table_name
              WHERE condition);
```

Example 1

ProductID	ProductName	SupplierID	Price
1	Chais	1	18
2	Chang	1	21
3	Syrup	1	10
4	Seasoning	2	22
5	Gumbo	2	19

SupplierID	SupplierName	ContactName	City
1	Exotic Liquid	Charlotte Cooper	LA
2	Cajun Delights	Shelley Burke	NY
3	Homestead	Regina Murphy	SF

```
SELECT DISTINCT SupplierName
FROM Suppliers AS S
WHERE EXISTS (SELECT ProductName
              FROM Products AS P
              WHERE P.SupplierID = S.SupplierID
               AND Price < 20);
```

This SQL statement returns TRUE and lists the suppliers with a product price less than 20

Example 2

ProductID	ProductName	SupplierID	Price
1	Chais	1	18
2	Chang	1	21
3	Syrup	1	10
4	Seasoning	2	22
5	Gumbo	2	19

SupplierID	SupplierName	ContactName	City
1	Exotic Liquid	Charlotte Cooper	LA
2	Cajun Delights	Shelley Burke	NY
3	Homestead	Regina Murphy	SF

```
SELECT DISTINCT SupplierName
FROM Suppliers AS S
WHERE EXISTS (SELECT ProductName
              FROM Products AS P
              WHERE P.SupplierID = S.SupplierID
               AND Price = 22);
```

This SQL statement returns TRUE and lists the suppliers with a product price equal to 22

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

- Find all companies that make some products with price < 200

- Existential quantifiers

- Using EXISTS:

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE  EXISTS (SELECT *
                              FROM Product P
                              WHERE C.cid = P.cid and P.price < 200)
```

3. Subqueries in WHERE

Product (<u>pname</u>, price, cid)
Company(<u>cid</u>, cname, city)

- Find all companies that make <u>some</u> products with price < 200

- Existential quantifiers

- Using ANY:

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE 200 > ANY (SELECT price
                 FROM Product P
                 WHERE P.cid = C.cid)
```


3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

- Find all companies that make some products with price < 200

- Existential quantifiers

- Using ANY:

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE 200 > ANY (SELECT price
                 FROM Product P
                 WHERE P.cid = C.cid)
```

Not supported in MySQL

3. Subqueries in WHERE

Product (<u>pname</u>, price, cid)
Company(<u>cid</u>, cname, city)

- Find all companies that make <u>some</u> products with price < 200

- Existential quantifiers

- Now let's unnest it:

```
SELECT DISTINCT  C.cname
FROM     Company C, Product P
WHERE  C.cid= P.cid and P.price < 200
```

3. Subqueries in WHERE

Product (pname, price, cid)
Company(cid, cname, city)

- Find all companies that make some products with price < 200

- Existential quantifiers

- Now let's unnest it:

```
SELECT DISTINCT  C.cname
FROM    Company C, Product P
WHERE   C.cid= P.cid and P.price < 200
```

Existential quantifiers are easy! ☺

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

same as:

Find all companies that make only products with price < 200

Product (pname, price, cid)
Company(cid, cname, city)

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

same as:

Find all companies that make only products with price < 200

Product (pname, price, cid)
Company(cid, cname, city)

Universal quantifiers

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

same as:

Find all companies that make only products with price < 200

Product (pname, price, cid)
Company(cid, cname, city)

Universal quantifiers

Universal quantifiers are hard! ☹

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

1. Find *the other* companies: i.e. s.t. some product ≥ 200

```
SELECT DISTINCT  C.cname
FROM      Company C
WHERE  C.cid IN (SELECT P.cid
                 FROM Product P
                 WHERE P.price >= 200)
```

Product (pname, price, cid)
Company(cid, cname, city)

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

1. Find *the other* companies: i.e. s.t. some product ≥ 200

```
SELECT DISTINCT  C.cname
FROM      Company C
WHERE   C.cid IN (SELECT P.cid
                  FROM Product P
                  WHERE P.price >= 200)
```

Product (pname, price, cid)
Company(cid, cname, city)

2. Find all companies s.t. all their products have price < 200

```
SELECT DISTINCT  C.cname
FROM      Company C
WHERE   C.cid NOT IN (SELECT P.cid
                      FROM Product P
                      WHERE P.price >= 200)
```

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

Product (pname, price, cid)
Company(cid, cname, city)

Universal quantifiers

Using EXISTS:

```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE NOT EXISTS (SELECT *
                  FROM Product P
                  WHERE P.cid = C.cid and P.price >= 200)
```

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

Product (pname, price, cid)
Company(cid, cname, city)

Universal quantifiers

Using ALL:

```
SELECT DISTINCT  C.cname
FROM      Company C
WHERE 200 >= ALL (SELECT price
                  FROM Product P
                  WHERE P.cid = C.cid)
```

3. Subqueries in WHERE

Find all companies s.t. all their products have price < 200

Product (pname, price, cid)
Company(cid, cname, city)

Universal quantifiers

Using ALL:

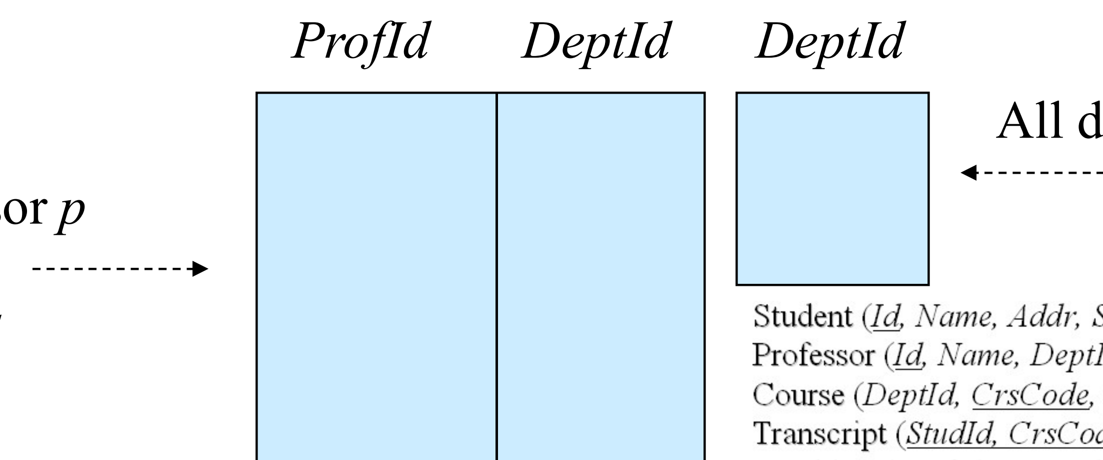
```
SELECT DISTINCT  C.cname
FROM     Company C
WHERE 200 > ALL  (SELECT price
                  FROM Product P
                  WHERE P.cid = C.cid)
```

Not supported in MySQL

Division in SQL

- *Query type*: Find the subset of items in one set that are related to *all* items in another set
- *Example*: Find professors who taught courses in *all* departments
  - Why does this involve division?

Contains row <*p*,*d*> if professor *p* taught a course In department *d*



All department Ids

Student (<u>Id</u>, *Name, Addr, Status*)
Professor (<u>Id</u>, *Name, DeptId*)
Course (*DeptId*, <u>*CrsCode*</u>, *CrsName, Descr*)
Transcript (<u>*StudId, CrsCode, Semester*</u>, *Grade*)
Teaching (*ProfId*, <u>*CrsCode, Semester*</u>)
Department (*DeptId, Name*)

$$\pi_{\text{ProfId, DeptId}}(\text{Teaching} \bowtie \text{Course}) \ / \ \pi_{\text{DeptId}}(\text{Department})$$

Division Solution Sketch (1)

SELECT P.*Id*
FROM Professor P
WHERE P taught courses in **all** departments

⇓

SELECT P.*Id*
FROM Professor P
WHERE there does not **exist** any department that P has never taught a course

⇓

SELECT P.*Id*
FROM Professor P
WHERE NOT EXISTS (the departments that P has never taught a course)

Division Solution Sketch (1)

SELECT P.*Id*
FROM Professor P
WHERE NOT EXISTS(the departments that P has never taught a course)

⇩

SELECT P.*Id*
FROM Professor P
WHERE NOT EXISTS (
  B: All departments
  EXCEPT
  A: the departments that P has ever taught a course)

- But how do we formulate A and B?

Division – SQL Solution in details

```
SELECT  P.Id
FROM  Professor P
WHERE NOT EXISTS
   ( SELECT  D.DeptId          -- set B of all dept Ids
    FROM  Department D
    EXCEPT
    SELECT  C.DeptId          -- set A of dept Ids of depts in which P taught a course
    FROM  Teaching T, Course C
    WHERE  T.ProfId = P.Id       -- global variable
    AND  T.CrsCode = C.CrsCode)
```

Constraints on a Single Relation

- **not null**
- **Default value**
- **unique**
- **check** (P), where P is a predicate

Not Null Constraints

- **not null**
  - Declare *name* and *budget* to be **not null**

    name **varchar**(20) **not null**
    budget **numeric**(12,2) **not null**

Default Value

-Value to be assigned if attribute value in a row is not specified

```
CREATE TABLE Student (
   Id  INTEGER,
   Name  CHAR(20) NOT NULL,
   Address  CHAR(50),
   Status  CHAR(10) DEFAULT 'freshman',
   PRIMARY KEY (Id) )
```

Unique Constraints

- **unique** (A_1, A_2, …, A_m)
  - The unique specification states that the attributes A_1, A_2, …, A_m form a candidate key.
  - Candidate keys are permitted to be null (in contrast to primary keys).

The check clause

- The **check** (P) clause specifies a predicate P that must be satisfied by every tuple in a relation.
- Example: ensure that semester is one of fall, winter, spring or summer

```
create table section
    (course_id varchar (8),
     sec_id varchar (8),
     semester varchar (6),
     year numeric (4,0),
     building varchar (15),
     room_number varchar (7),
     time slot id varchar (4),
     primary key (course_id, sec_id, semester, year),
     check (semester in ('Fall', 'Winter', 'Spring', 'Summer')))
```

Referential Integrity

- Ensures that a value that appears in one relation for a given set of attributes also appears for a certain set of attributes in another relation.
  - Example: If "Biology" is a department name appearing in one of the tuples in the *instructor* relation, then there exists a tuple in the *department* relation for "Biology".
- Let A be a set of attributes. Let R and S be two relations that contain attributes A and where A is the primary key of S. A is said to be a **foreign key** of R if for any values of A appearing in R these values also appear in S.

Referential Integrity (Cont.)

- Foreign *keys can be* specified as part of the SQL **create table** statement

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

- By default, a foreign key references the primary-key attributes of the referenced table.
- SQL allows a list of attributes of the referenced relation to be specified explicitly.

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

Cascading Actions in Referential Integrity

- When a referential-integrity constraint is violated, the normal procedure is to reject the action that caused the violation.
- An alternative, in case of delete or update is to cascade

create table *course* (
    (…
    dept_name **varchar**(20),
    foreign key (*dept_name*) **references** *department*
        on delete cascade
        on update cascade,
    . . .)

- Instead of cascade we can use :
  - **set null**,
  - **set default**

Integrity Constraint Violation During Transactions

- Consider:

```
create table person (
    ID  char(10),
    name char(40),
    mother char(10),
    father  char(10),
    primary key ID,
    foreign key father references person,
    foreign key mother references  person)
```

- How to insert a tuple without causing constraint violation?
  - Insert father and mother of a person before inserting person
  - OR, set father and mother to null initially, update after inserting all persons (not possible if father and mother attributes declared to be **not null**)
  - OR defer constraint checking

Assertions

- An **assertion** is a predicate expressing a condition that we wish the database always to satisfy.
- Element of schema (like table)
- Applies to entire database (not just the individual rows of a single table)
  - hence it works even if Employee is empty
- The following constraints, can be expressed using assertions:
- For each tuple in the *student* relation, the value of the attribute *tot_cred* must equal the sum of credits of courses that the student has completed successfully.
- An instructor cannot teach in two different classrooms in a semester in the same time slot
- An assertion in SQL takes the form:

  create assertion <assertion-name> **check** (<predicate>);

Assertion Example

```
CREATE ASSERTION DontFireEveryone
  CHECK (0 < SELECT  COUNT (*)  FROM Employee)
```

Sample

Employee

Id	MgrId	EmpName	Salary	StartDate
1111	3333	Kathy	50K	2012
2222	3333	John	60K	2011
3333	0000	Cook	100K	2000
4444	0000	Mathew	75K	2012
5555	1111	Jun	40K	2015

Primary Key（ID),
FOREIGN KEY（MgrId) References Employee(Id)

Query: Find the employee(s) who their salaries are higher than their managers

```sql
SELECT E1.Id, E1.MgrId, E1.EmpName, E1.salary, E2.salary as Manager_Salary
FROM employee as E1
inner join employee as E2
On E1.MgrId = E2.Id
where E1.salary > E2.salary
```

Assertion

```
CREATE ASSERTION KeepEmployeeSalariesDown
   CHECK (NOT EXISTS(
               SELECT * FROM Employee E
                  WHERE E.Salary > E.MngrSalary))
```

EXISTS(R) is a boolean function (called predicate)

- Returns true when R it not empty
- Return false otherwise

NOT EXISTS(R) ≡ isEmpty(R) ≡ (R = Φ)

Assertions and Inclusion Dependency

```
CREATE ASSERTION  NoEmptyCourses
   CHECK  (NOT  EXISTS (
                SELECT *  FROM Teaching T
                   WHERE T.roster() = Φ)
             )
```

Idea: search those courses in Teaching such that they have no registered students.

But how to write T.roster() = Φ in SQL?

Assertions and Inclusion Dependency

```
CREATE ASSERTION  NoEmptyCourses
   CHECK  (NOT  EXISTS (
                  SELECT *  FROM Teaching T
                     WHERE   -- for each row T check the following condition
                      NOT  EXISTS (
                      SELECT * FROM Transcript  R
                         WHERE R.CrsCode = T.CrsCode
                            AND R.Semester = T.Semester )
                 ) )
```

Idea: search those courses in Teaching <u>such that they have no registered students</u>.

User-Defined Types

- **create type** construct in SQL creates user-defined type

  create type *Dollars* **as numeric (12,2) final**

- Example:

  create table *department*
  (*dept_name* **varchar** (20),
  building **varchar** (15),
  budget Dollars);

Domains

- **create domain** construct in SQL-92 creates user-defined domain types

  create domain *person_name* **char**(20) **not null**

- Types and domains are similar. Domains can have constraints, such as **not null**, specified on them.
- Example:

  create domain *degree_level* **varchar**(10)
  constraint *degree_level_test*
  check (**value in** ('Bachelors', 'Masters', 'Doctorate'));

MySQL: Enumeration Values

- Syntax: **ENUM**
- https://www.mysqltutorial.org/mysql-enum/

Index Creation

- Many queries reference only a small proportion of the records in a table.
- It is inefficient for the system to read every record to find a record with particular value
- An **index** on an attribute of a relation is a data structure that allows the database system to find those tuples in the relation that have a specified value for that attribute efficiently, without scanning through all the tuples of the relation.
- We create an index with the **create index** command

  create index <name> **on** <relation-name> (attribute);

Index Creation Example

- **create table** *student*
  (*ID* **varchar** (5),
  name **varchar** (20) **not null**,
  dept_name **varchar** (20),
  tot_cred **numeric** (3,0) **default** 0,
  primary key (*ID*))
- **create index** *studentID_index* **on** *student*(*ID*)
- The query:

  select *
  from *student*
  where *ID* = '12345'

  can be executed by using the index to find the required record, without looking at all records of *student*

Authorization

- We may assign a user several forms of authorizations on parts of the database.
  - **Read** - allows reading, but not modification of data.
  - **Insert** - allows insertion of new data, but not modification of existing data.
  - **Update** - allows modification, but not deletion of data.
  - **Delete** - allows deletion of data.
- Each of these types of authorizations is called a **privilege**. We may authorize the user all, none, or a combination of these types of privileges on specified parts of a database, such as a relation or a view.

Authorization (Cont.)

- Forms of authorization to modify the database schema
  - **Index** - allows creation and deletion of indices.
  - **Resources** - allows creation of new relations.
  - **Alteration** - allows addition or deletion of attributes in a relation.
  - **Drop** - allows deletion of relations.

Authorization Specification in SQL

- The **grant** statement is used to confer authorization

  grant <privilege list> **on** <relation or view > **to** <user list>
- <user list> is:
  - a user-id
  - **public**, which allows all valid users the privilege granted
  - A role (more on this later)
- Example:
  - **grant select on** *department* **to** Amit, Satoshi
- Granting a privilege on a view does not imply granting any privileges on the underlying relations.
- The grantor of the privilege must already hold the privilege on the specified item (or be the database administrator).

Privileges in SQL

- **select**: allows read access to relation, or the ability to query using the view
  - Example: grant users U_1, U_2, and U_3 **select** authorization on the *instructor* relation:

    grant select on *instructor* **to** U_1, U_2, U_3
- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **all privileges**: used as a short form for all the allowable privileges

Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization.

  revoke <privilege list> **on** <relation or view> **from** <user list>

- Example:

  revoke select on *student* **from** U_1, U_2, U_3

- <privilege-list> may be **all** to revoke all privileges the revokee may hold.
- If <revokee-list> includes **public,** all users lose the privilege except those granted it explicitly.
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation.
- All privileges that depend on the privilege being revoked are also revoked.

Roles

- A **role** is a way to distinguish among various users as far as what these users can access/update in the database.
- To create a role we use:

  create a role <name>
- Example:
  - **create role** instructor
- Once a role is created we can assign "users" to the role using:
  - **grant** <role> **to** <users>

Roles Example

- **create role** instructor;
- **grant** *instructor* **to** Amit**;**
- Privileges can be granted to roles:
  - **grant select on** *takes* **to** *instructor*;
- Roles can be granted to users, as well as to other roles
  - **create role** *teaching_assistant*
  - **grant** *teaching_assistant* **to** *instructor*;
    - *Instructor* inherits all privileges of *teaching_assistant*
- Chain of roles
  - **create role** *dean*;
  - **grant** *instructor* **to** *dean*;
  - **grant** *dean* **to** Satoshi;

View

- In SQL, a **view** is a virtual table based on the result-set of an SQL statement.
- A view contains rows and columns, just like a real table. The fields in a view are fields from one or more real tables in the database.
- A view is defined using the **create view** statement which has the form

  create view *v* **as** < query expression >

  where <query expression> is any legal SQL expression. The view name is represented by *v.*

View

- Once a view is defined, the view name can be used to refer to the virtual relation that the view generates.

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

View Definition and Use

- A view of instructors without their salary

```
create view faculty as
    select ID, name, dept_name
    from instructor
```

- Find all instructors in the Biology department

```
select name
from faculty
where dept_name = 'Biology'
```

- Create a view of department salary totals

```
create view departments_total_salary(dept_name, total_salary) as
    select dept_name, sum (salary)
    from instructor
   group by dept_name;
```

View - Substitution

When used in an SQL statement, the view definition is substituted for the view name in the statement. As SELECT statement nested in FROM clause

```
SELECT  S.Name, C.Cum
FROM (SELECT  T.StudId,  AVG (T.Grade)
        FROM Transcript T
        GROUP BY T.StudId) C,  Student S
WHERE  C.StudId = S.StudId AND C.Cum > 3.5
```

View Benefits

- *Access Control*: Users not granted access to base tables. Instead they are granted access to the view of the database appropriate to their needs.
  - *External schema* is composed of views.
  - View allows owner to provide SELECT access to a subset of columns (analogous to providing UPDATE and INSERT access to a subset of columns)

Views – Limiting Visibility

Grade projected out

```
CREATE VIEW PartOfTranscript (StudId, CrsCode, Semester) AS
    SELECT T. StudId, T.CrsCode, T.Semester      -- limit columns
     FROM Transcript T
     WHERE T.Semester = 'S2000'                  -- limit rows
```

Give permissions to access data through view:

```
GRANT SELECT ON PartOfTranscript TO joe
```

This would have been analogous to:

```
GRANT SELECT (StudId,CrsCode,Semester)
                                ON Transcript TO joe
```

View Benefits (cont’d)

- *Customization*: Users need not see full complexity of database.
- View creates the illusion of a simpler database customized to the needs of a particular category of users
- A view is *similar in many ways to a subroutine* in standard programming
  - Can be reused in multiple queries

Views Defined Using Other Views

- **create view** *physics_fall_2017* **as**
  select *course*.*course_id*, *sec_id*, *building*, *room_number*
  from *course*, *section*
  where *course*.*course_id* = *section*.*course_id*
  and *course*.*dept_name* = 'Physics'
  and *section*.*semester* = 'Fall'
  and *section*.*year* = '2017';

- **create view** *physics_fall_2017_watson* **as**
  select *course_id*, *room_number*
  from *physics_fall_2017*
  where *building*= 'Watson';

Materialized Views

- Certain database systems allow view relations to be physically stored.
  - Physical copy created when the view is defined.
  - Such views are called **Materialized view**:
- If relations used in the query are updated, the materialized view result becomes out of date
  - Need to **maintain** the view, by updating the view whenever the underlying relations are updated.

Update of a View

create view *faculty* **as**
  select *ID*, *name*, *dept_name*
  from *instructor*

- Add a new tuple to *faculty* view which we defined earlier

  insert into *faculty*

    values ('30765', 'Green', 'Music');

- This insertion must be represented by the insertion into the *instructor* relation
  - Must have a value for salary.
- Two approaches
  - Reject the insert
  - Inset the tuple

    ('30765', 'Green', 'Music', null)

    into the *instructor* relation

Some Updates Cannot be Translated Uniquely

- **create view** *instructor_info* **as**
  select *ID*, *name*, *building*
  from *instructor*, *department*
  where *instructor*.*dept_name*= *department*.*dept_name*;
- **insert into** *instructor_info*
  values ('69987', 'White', 'Taylor');
- Issues
  - Which department, if multiple departments in Taylor?
  - What if no department is in Taylor?

And Some Not at All

- **create view** *history_instructors* **as**
  select *
  from *instructor*
  where *dept_name*= 'History';
- What happens if we insert

  ('25566', 'Brown', 'Biology', 100000)

  into *history_instructors?*

View Updates in SQL

- Most SQL implementations allow updates only on simple views
  - The **from** clause has only one database relation.
  - The **select** clause contains only attribute names of the relation, and does not have any expressions, aggregates, or **distinct** specification.
  - Any attribute not listed in the **select** clause can be set to null
  - The query does not have a **group** by or **having** clause.

Authorization on Views

- **create view** *geo_instructor* **as**
  (**select** *
  from *instructor*
  where *dept_name* = 'Geology');

- **grant select on** *geo_instructor* **to** *geo_staff*

End of Chapter 4