Úvod do databázových systémů

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- Relational algebra
- SQL
  - Inner Join
  - Self Join
  - Outer Join

Relational algebra

- Relational algebra - set of operators on relations
- Operator - takes one or more relations as its input and produce a new relation

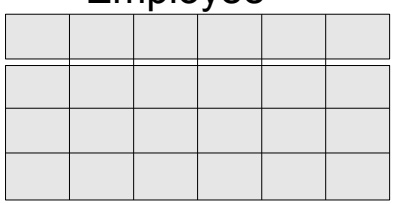
Selection	$\sigma_{condition}$
Projection	π
Cartesian product	$\times$
Join	$\bowtie$
Theta join	$\bowtie_{condition}$
Union	$\cup$
Intersection	$\cap$
Minus	$-$

Example

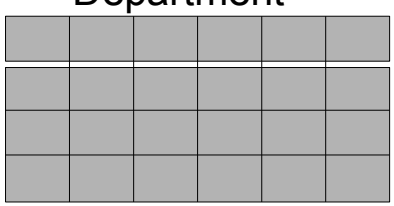
- Queries consist of elementary operations above relations, whose result is again a relation
- Example of a query:

Find name of those employees working at departments having sales at least 10 millions

Employee



Department



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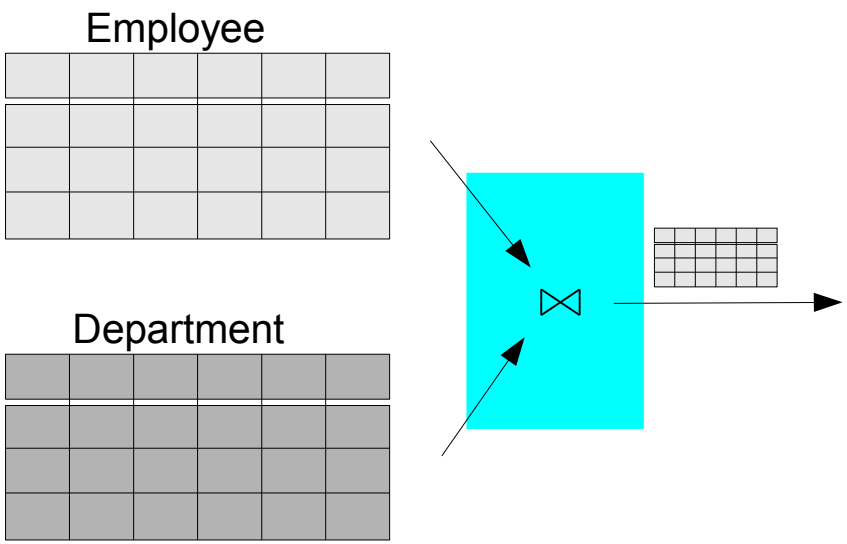

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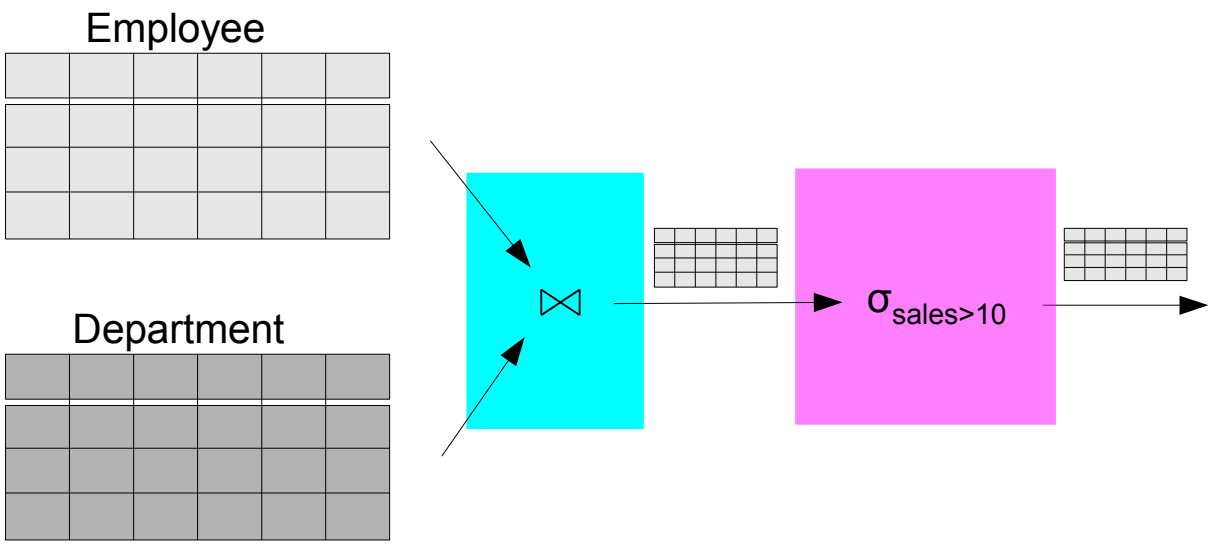

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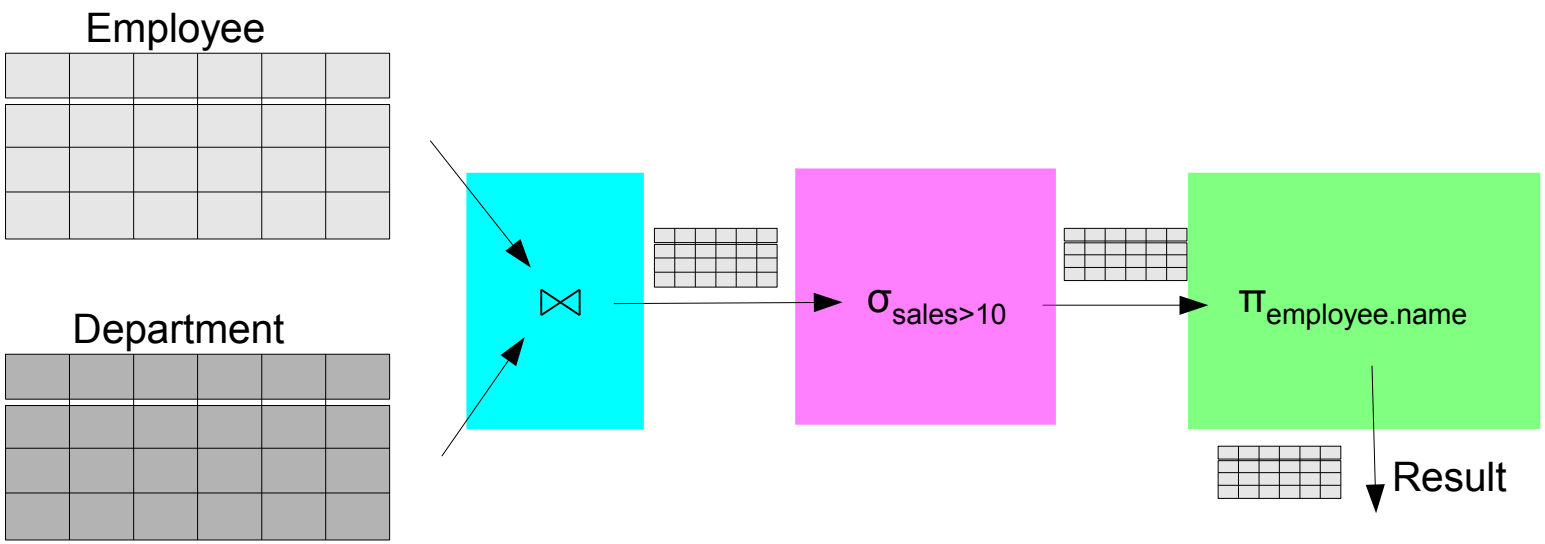

Restriction (selection)

- We select some rows from an input relation
- Notation: $\sigma_{condition}(Relation)$ - the condition defines rows that we want to pick
- *Example: Find all employees whose position is 'programmer'.*

Employee

eID	eName	passport no.	position
223	Newman	7905051111	programmer
124	Carter	6901112233	manager
154	Trier	7105029876	programmer

$\Downarrow \sigma_{position = 'programmer'}(Employee)$

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- *Example: Find IDs and names of all employees.*

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Duplications

- *Example: Find all positions of employees.*
  - **Relational algebra**: $\pi_{position}(Employee)$ - the resulting relation has two rows {(programmer),(manager)}
  - Duplications are automatically eliminated since we work with sets
  - **SQL**: `SELECT position FROM Employee` - the resulting relation has three rows
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Cartesian Product

- Cartesian product $R \times S$ is a "combination" of two relations R and S
- Each row of the relation R is combined with each row of S
- *Example:*

Employee

eID	eName	position	dID

Department

dID	dName	sales

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- *Example:*

Employee

eID	eName	position	dID

Department

dID	dName	sales

$\Downarrow$ *Employee* $\times$ *Department*

eID	eName	position	dID	dID	dName	sales

Combination of Operations

- *Example: To all employees with the position 'manager' add an information about department at which they work.*

$$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$$

$$\sigma_{Employee.dID=Department.dID}(\sigma_{position='manager'}(Employee) \times Department)$$

Employee

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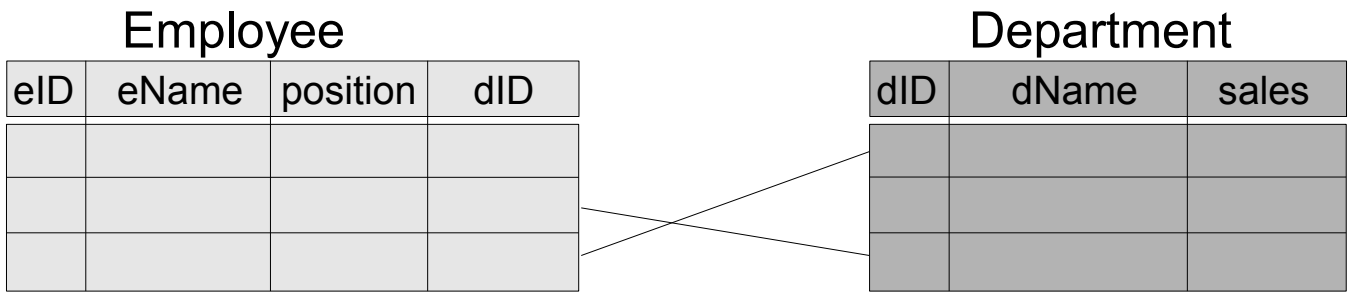


Natural Join

- Natural join $R \bowtie S$ - from the product $R \times S$ we pick only rows with the same values of attributes of the same name in both relations
- Having the natural join introduced, the situation from the last example is simplified
- *Example: To all employees the with position 'manager' add an information about department at which they work.*

Original version:

$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$

Natural join version:

$\sigma_{position='manager'}(Employee \bowtie Department)$

Theta Join (JOIN)

- Theta join (abbreviated to join) $R \bowtie_\Theta S$ - from the product $R \times S$ we pick only rows satisfying the Θ condition
- Once again, by using theta join, we simplify the notation
- *Example: To all employees the with position 'manager' add an information about department at which they work.*

Original version:

$$\sigma_{position='manager' \wedge Employee.dID=Department.dID}(Employee \times Department)$$

Theta join version:

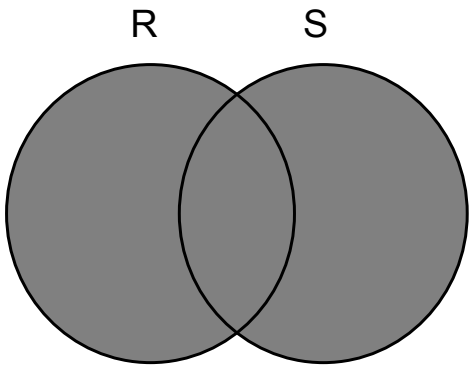
$$Employee \bowtie_{position='manager' \wedge Employee.dID=Department.dID} Department$$

Join Operation

- Although, when using joins, we do not improve the expressing capabilities of language, joins enable us to simplify notation of queries
- Theta join is implemented in SQL as the JOIN operation and it is a very frequent operation!

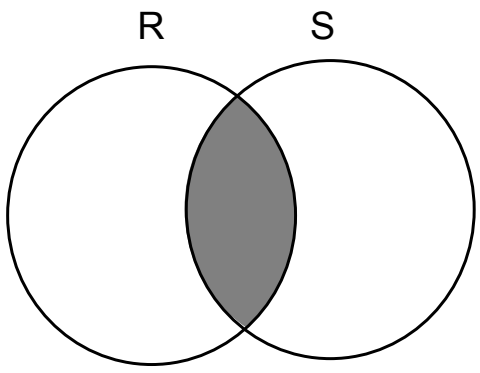
Standard Set Operations

Union



$R \cup S$

Intersection



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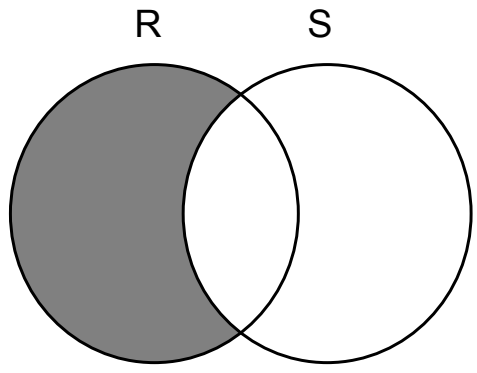
Difference



$R - S$

Intersection

- Intersection can be expressed by other set operations of relational algebra

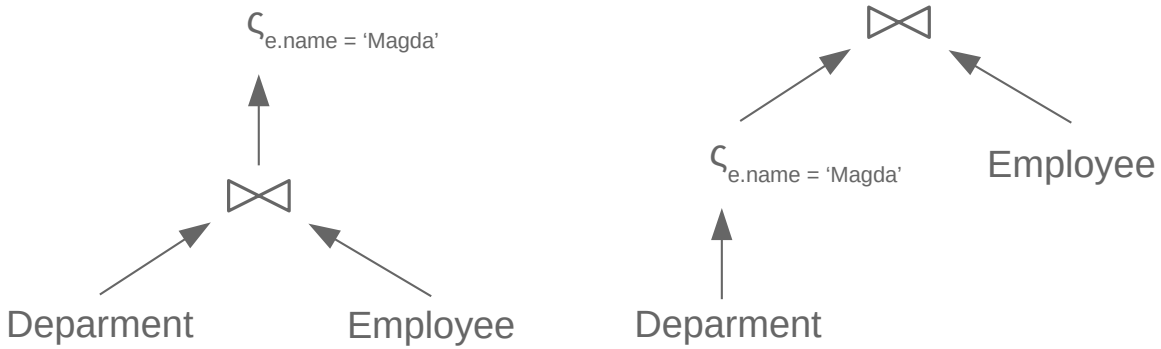
  $R \cap S = R - (R - S)$

  $R \cap S = R \bowtie S$ when schemes of R and S are the same

- So it again mainly simplifies the notation

Final Notes

- Some kind of relational algebra is often used as an internal representation of *query plans*
- Query plan describe how to execute the query
- To better understand a query plan or a relational algebra expression we usually use a tree.
- *Example: Find department names where an employee with name 'Magda' works.*



SQL

- Language for relational database systems
- Declarative
- SQL standards:
  - SQL-92 - Basic SQL constructs
  - SQL-99 - Regex, triggers, OO
  - SQL-2003 - XML, windows, sequences, auto-gen IDs
  - SQL-2008 - Truncate, offset/fetch
  - SQL-2011 - Temporal DB
  - SQL-2016 - JSON

SQL

- Data Definition Language (DDL) - alter database scheme
- Data Manipulation Language (DML) - alter database data & data retrieval
- Data Control Language (DCL) - configuration, access management, ...

SELECT Statement and Relational Algebra

- Basic structure of the SELECT statement:

  SELECT $A_1, \ldots, A_n$
  FROM $R_1, \ldots, R_m$
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WHERE *condition*	- which condition has to be satisfied by returned rows

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  $$\Updownarrow$$

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SELECT Statement and Relational Algebra (JOIN)

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SELECT $A_1, \ldots, A_n$
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Sakila Database

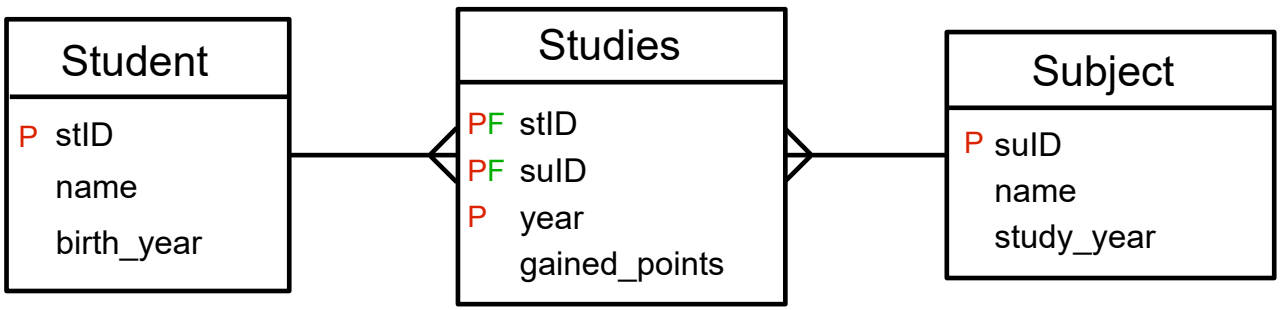
- Sakila database `https://github.com/ivanceras/sakila`
- Open-source, well-designed, support for more database systems
- One database for lectures and exercises

Database model

- Student(<u>stID</u>, name, birth_year)

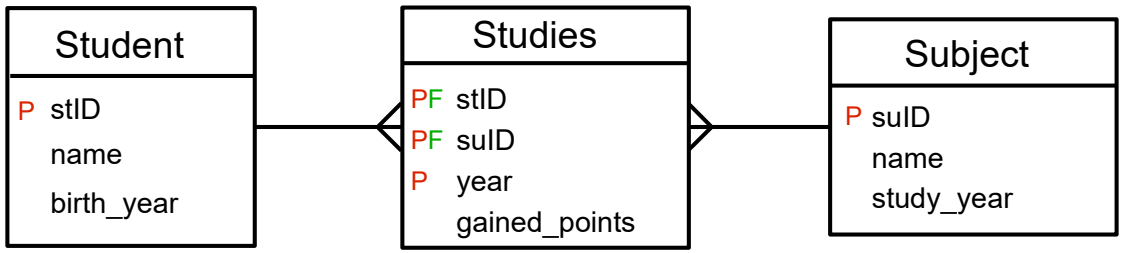
  Subject(<u>suID</u>, name, study_year)

  Studies(<u>stID</u>, <u>suID</u>, <u>year</u>, gained_points)



- The database stores students, subjects, and the information when a student studied given subject and how many points he/she gained

Example: Join of two tables



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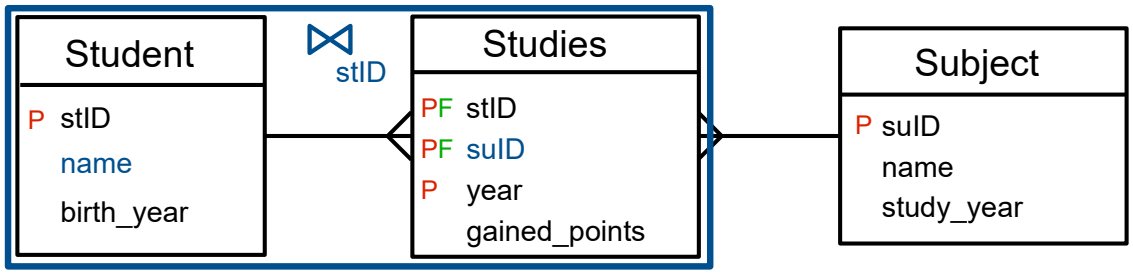

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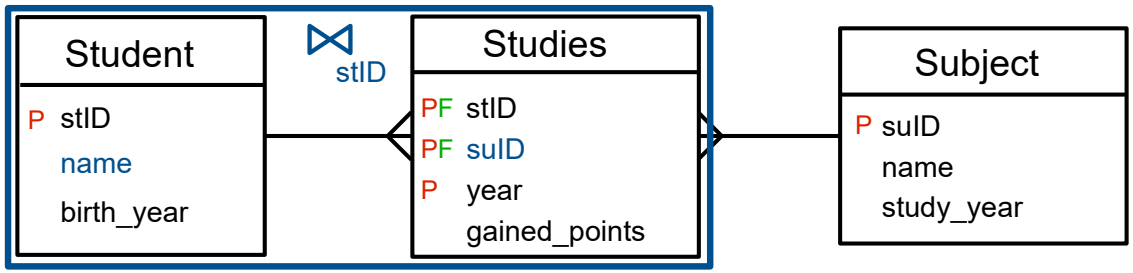

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  - `SELECT name, suID`
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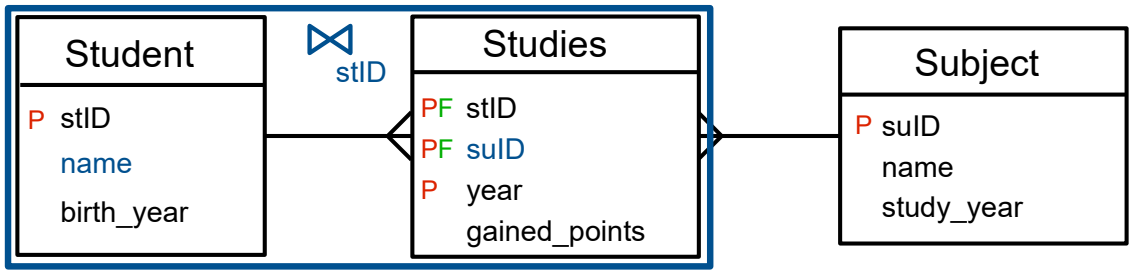

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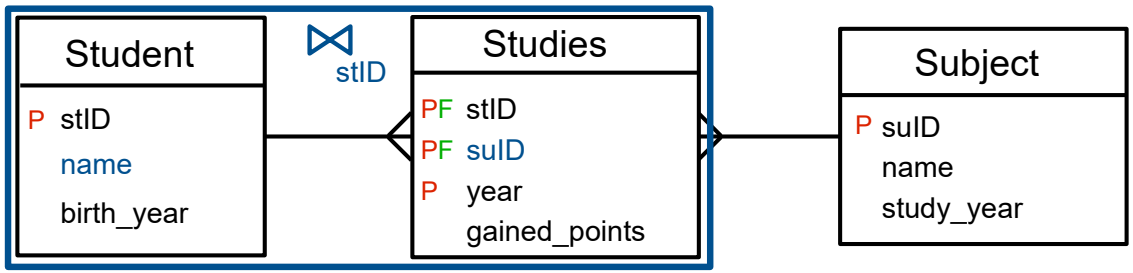

- *Find suIDs of all subjects, which students called Petr studied in 2010.*
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    SELECT name, suID
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    WHERE year = 2010 and name = 'Petr'
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  - $\pi_{suID}\left(\sigma_{year=2010 \wedge name='Petr'}(Student \bowtie Studies)\right)$
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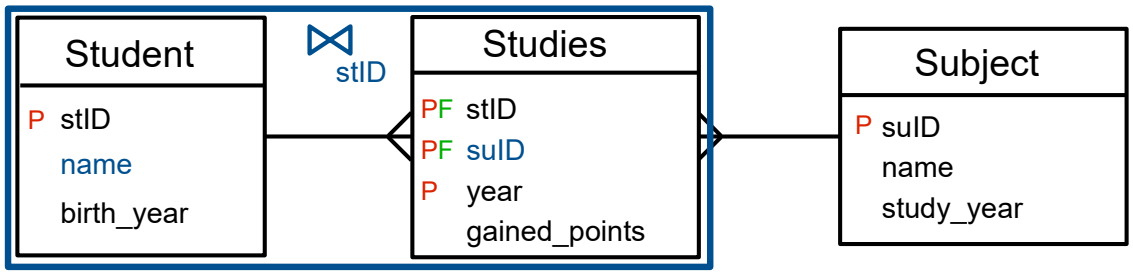

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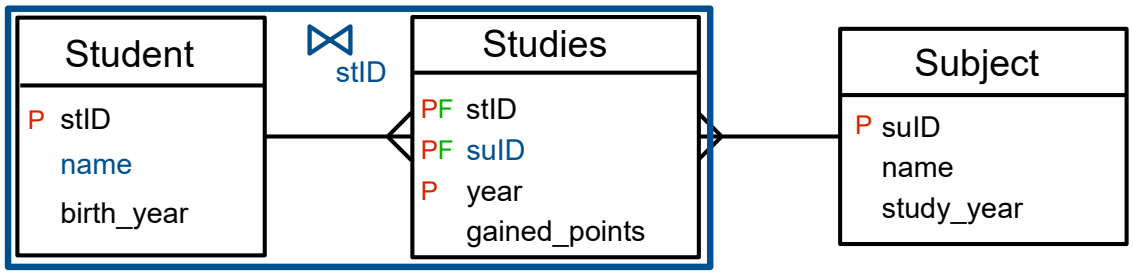

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Example: Join of Two Tables with Condition

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SELECT distinct pID
FROM Student
JOIN Study On Student.sID = Study.sID
WHERE year = 2011 and name = 'Petr'
```

π_{pID}

$\sigma_{year=2011 \wedge name='Petr'}$

$Student \bowtie Study$

Student

sID	name	birth_date
1	Petr	1990
2	Pavel	1991
3	Ivana	1990

Study

sID	pID	year	points
1	35	2010	23
1	35	2011	55
1	21	2010	89
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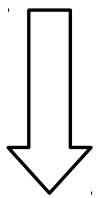

Student_Study

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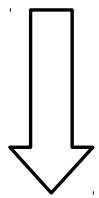

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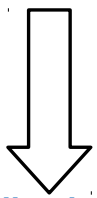

Student Study **Duplication!**

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Student_Study

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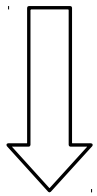

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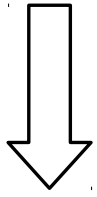
sID	name	birth_date	sID	pID	year	points
1	Petr	1990	1	35	2011	55

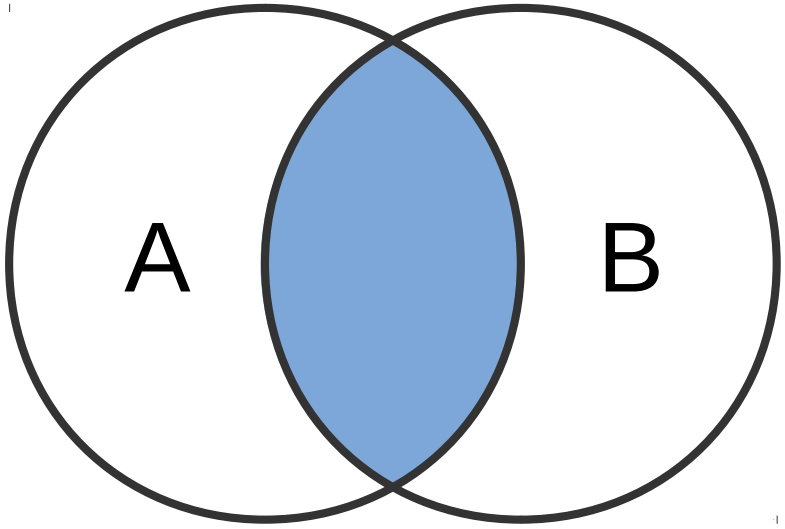


Student_Study

pID
35

Inner Join Observation

```
SELECT *
FROM A
JOIN B ON A.k = B.k
```



Inner Join Observation

```
SELECT *
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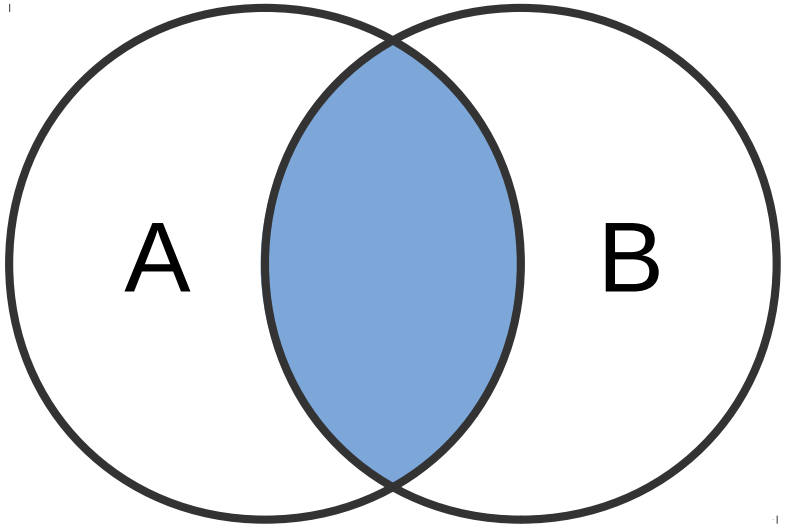
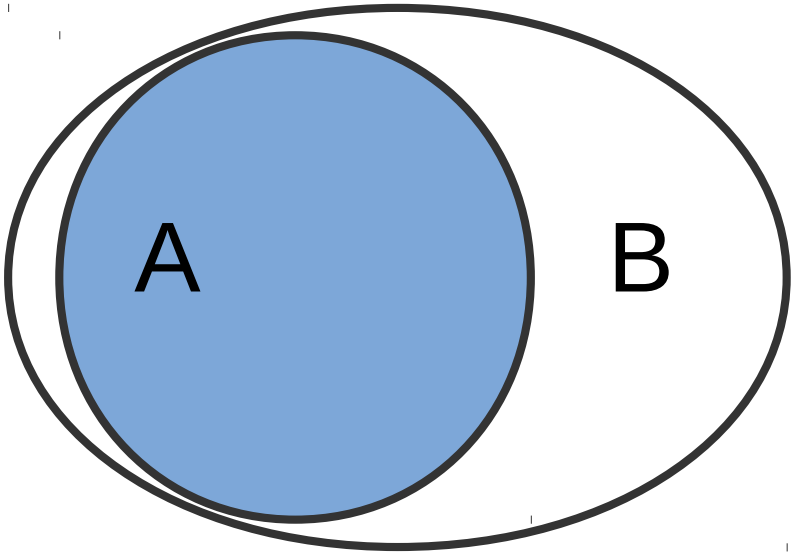
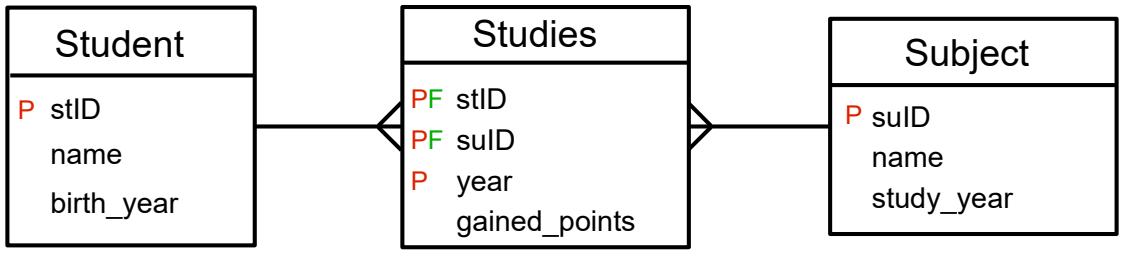
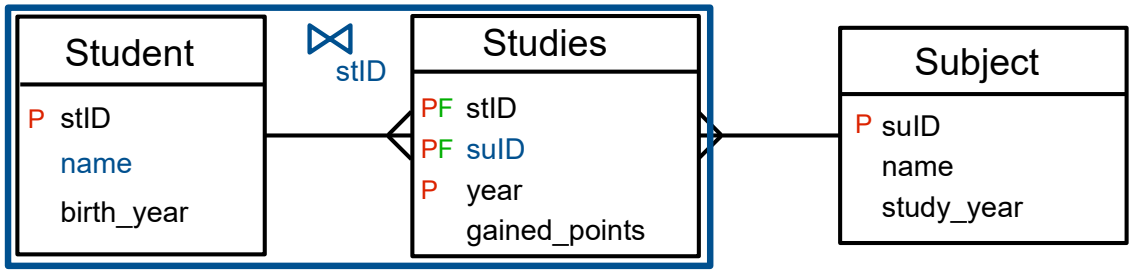
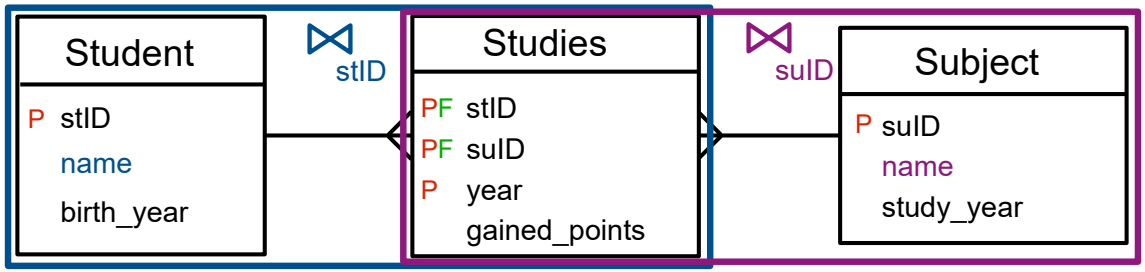
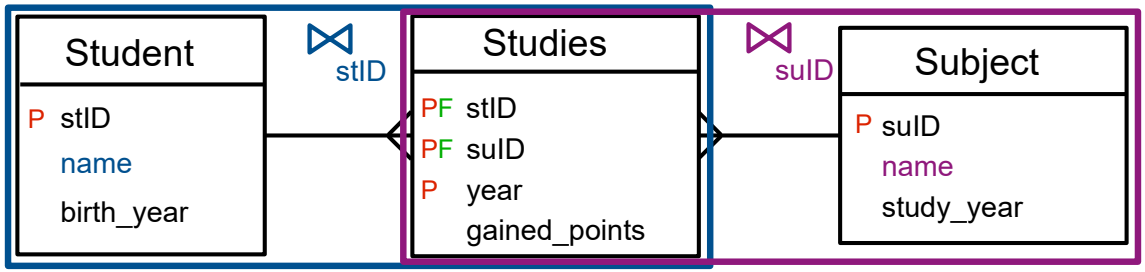
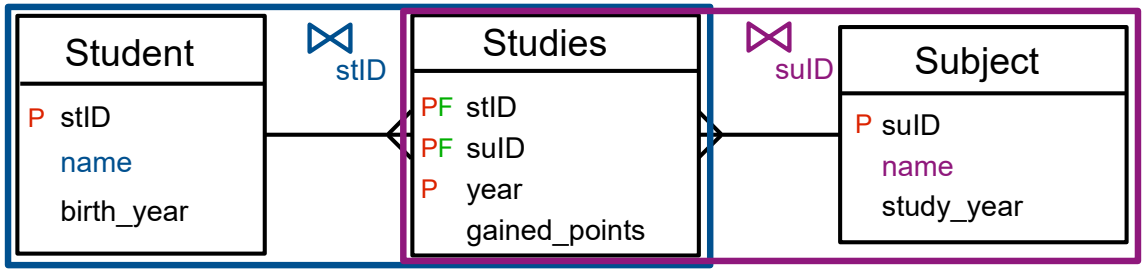
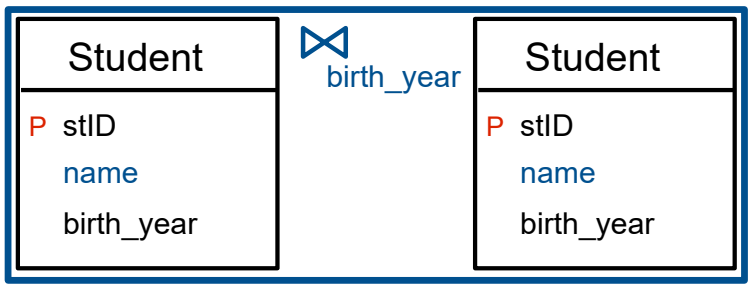
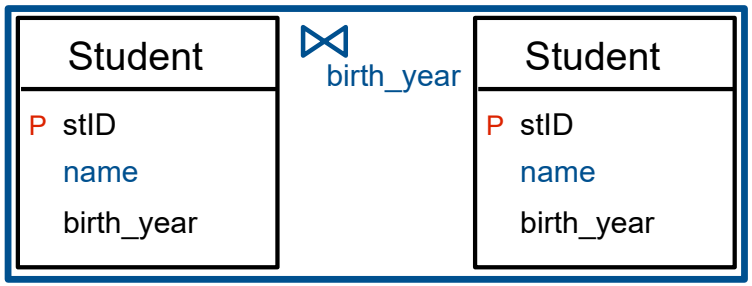
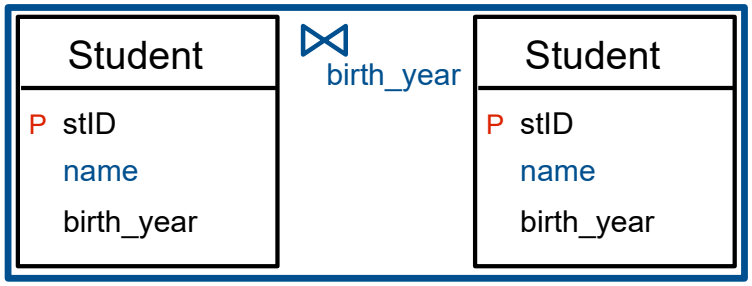
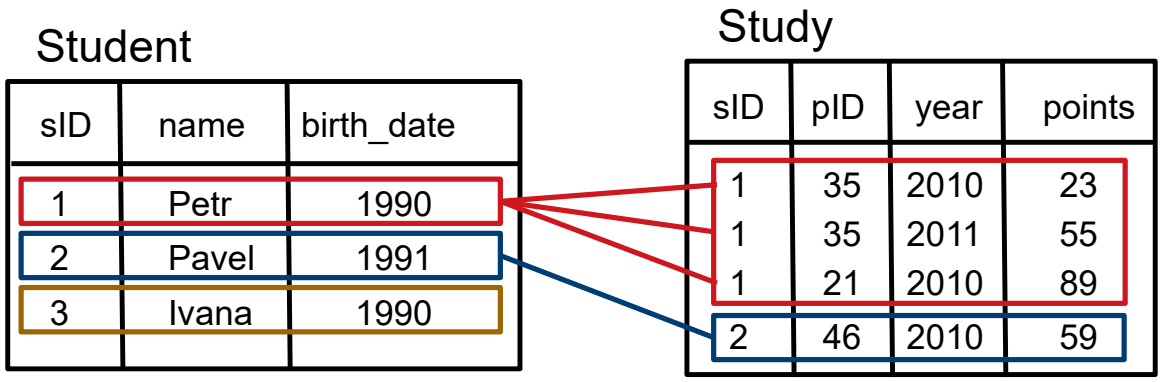
JOIN B ON A.k = B.k
```



What if `A.k` is foreign key and `B.k` is a primary key?

Inner Join Observation

```
SELECT *
FROM A
JOIN B ON A.k = B.k
```



Note that set `B` is usually smaller (i.e. the visualization is not very accurate)

Example: Join of Three Tables



- *To each name of subject find name of student who studies or studied this subject.*

Example: Join of Three Tables



- *To each name of subject find name of student who studies or studied this subject.*
  - `SELECT distinct Studies.suID, Student.name FROM Student JOIN Studies ON Student.stID = Studies.stID`

Example: Join of Three Tables



- *To each name of subject find name of student who studies or studied this subject.*
  - `SELECT distinct Subject.name,Student.name`
    `FROM Student`
    `JOIN Studies ON Student.stID = Studies.stID`
    `JOIN Subject ON Studies.suID = Subject.suID`

Example: Join of Three Tables



- *To each name of subject find name of student who studies or studied this subject.*
  - `SELECT distinct Subject.name, Student.name FROM Student JOIN Studies ON Student.stID = Studies.stID JOIN Subject ON Studies.suID = Subject.suID`
  - $\pi_{Subject.name, Student.name}\ (Student \bowtie Studies \bowtie Subject)$

Example: Join of Three Tables + Renaming a Relation



- *To each name of subject find name of student who studies or studied this subject.*
  - `SELECT distinct su.name, st.name`
    `FROM Student st`
    `JOIN Studies se ON st.stID = se.stID`
    `JOIN Subject su ON se.suID = su.suID`
  - $\pi_{Subject.name,Student.name}\ (Student \bowtie Studies \bowtie Subject)$
  - For the sake of clarity, we can rename the relations

Example: Self Join



- *Find all pairs of students having the same birth year.*
  - ```
    SELECT s1.name, s2.name
    FROM Student s1
    JOIN Student s2
            ON s1.birth_year = s2.birth_year
    ```
    ```

Example: Self Join



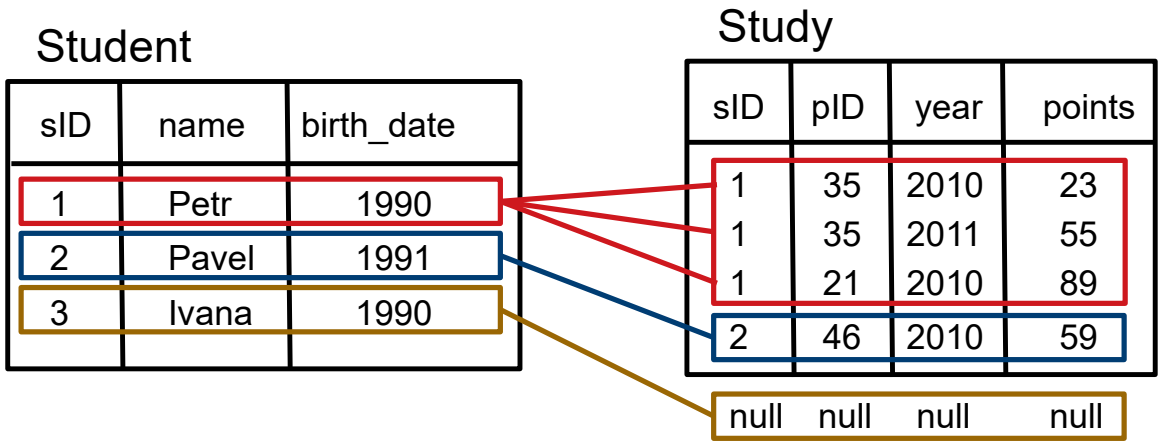
- *Find all pairs of students having the same birth year.*
  - ```
    SELECT s1.name, s2.name
    FROM Student s1
    JOIN Student s2
            ON s1.birth_year = s2.birth_year
    ```
  - Not quite correct solution!
    ```

Example: Self Join



- *Find all pairs of students having the same birth year.*
  - ```
    SELECT s1.name, s2.name
    FROM Student s1
    JOIN Student s2
            ON s1.birth_year = s2.birth_year
             AND s1.stID > s2.stID
    ```
    ```

Inner Join Rules



- **Multiplication** - Every student is repeated as many times as is the number of his studies
- **Elimination** - A student is eliminated if he did not study anything

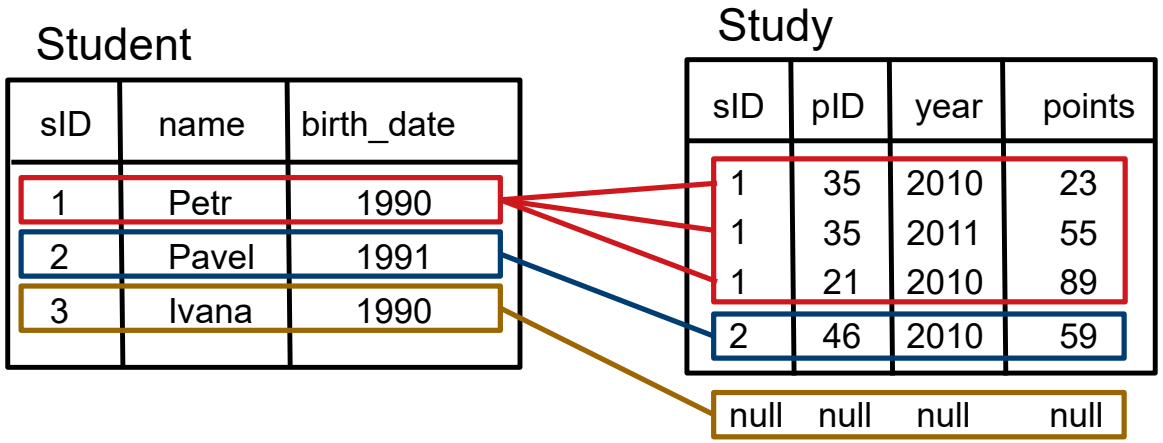
Inner Join Rules



- **Multiplication** - Every student is repeated as many times as is the number of his studies
- **Elimination** - A student is eliminated if he did not study anything

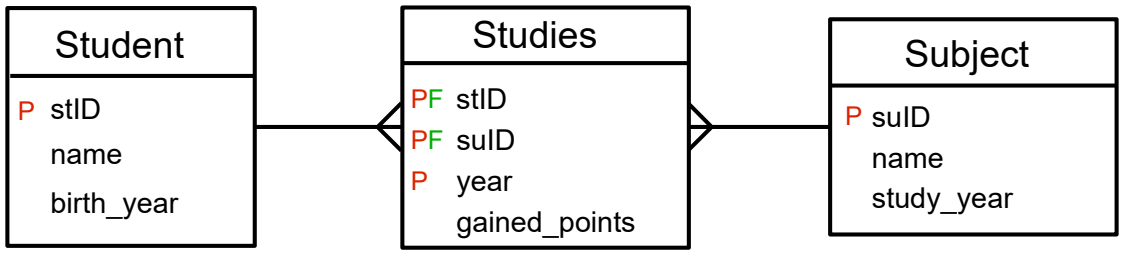
However, sometimes we do not want to eliminate!

Outer Join



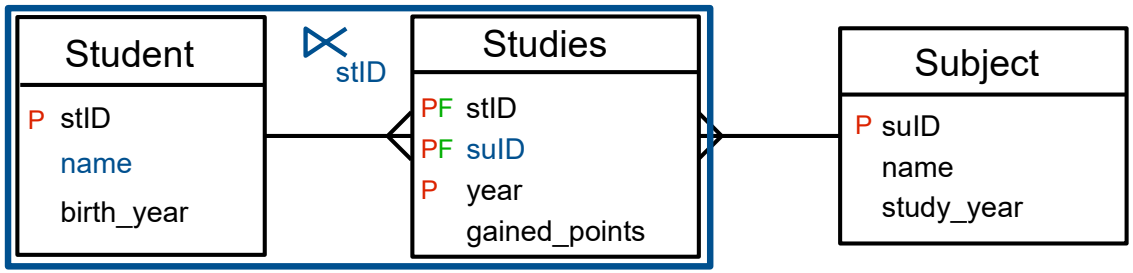
- This is called outer join
- We have more types of outer joins:
  - Left/Right outer join
  - Full outer join

Example: Left Outer Join



- *List names of students and suIDs of subjects studied by them; if a student does not study any subject, write NULL to his/her name.*

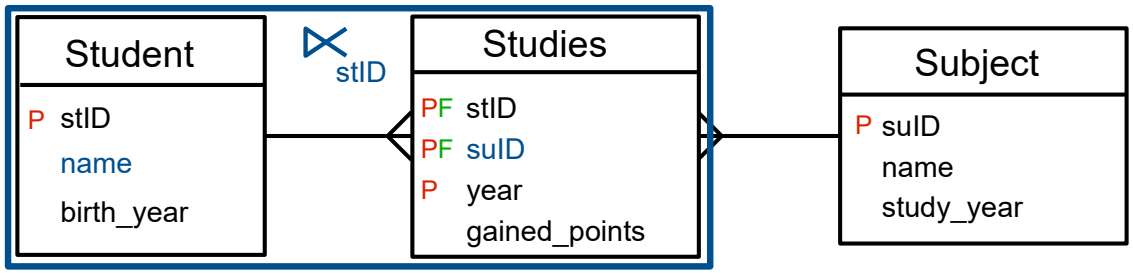
Example: Left Outer Join



- *List names of students and suIDs of subjects studied by them; if a student does not study any subject, write NULL to his/her name.*

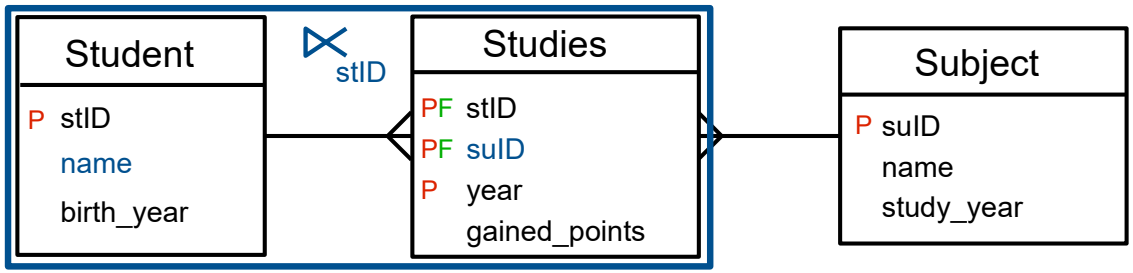
```
SELECT name, suID
FROM Student
LEFT JOIN Studies ON
      Student.stID = Studies.stID
```

Example: Left Outer Join with Condition

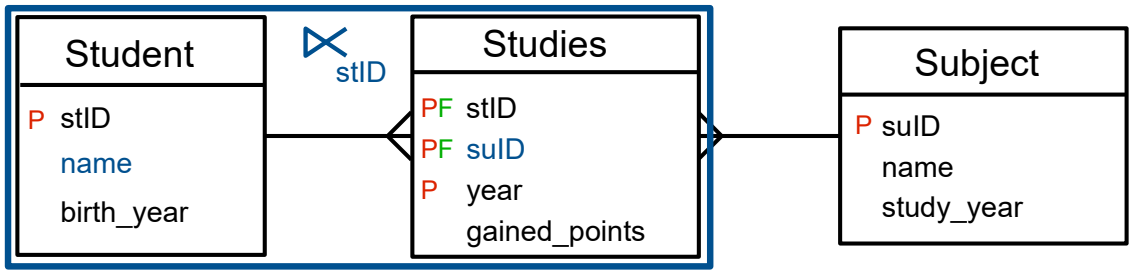


- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

Example: Left Outer Join with Condition



- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

  - ```
    SELECT name, suID
    FROM Student
    LEFT JOIN Studies ON
          Student.stID = Studies.stID
    WHERE year = 2011
    ```
  - Is this correct?
    ```

Example: Left Outer Join with Condition



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    ```
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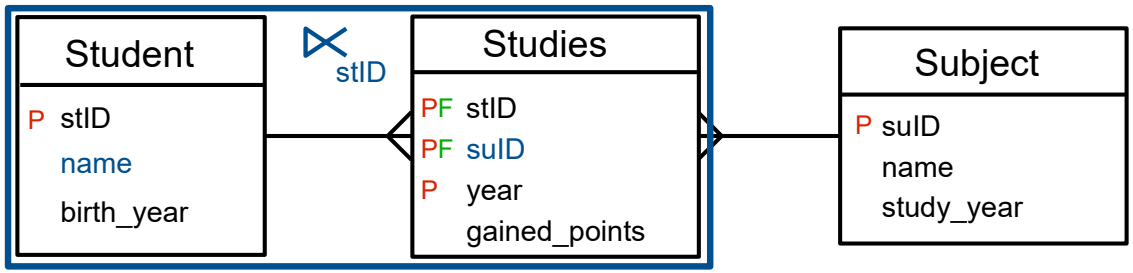
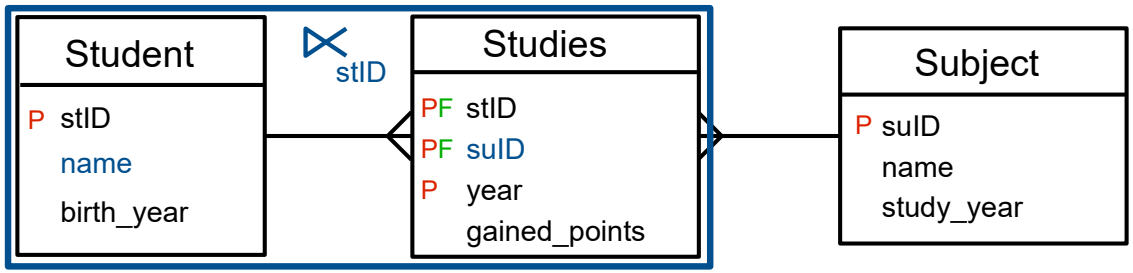
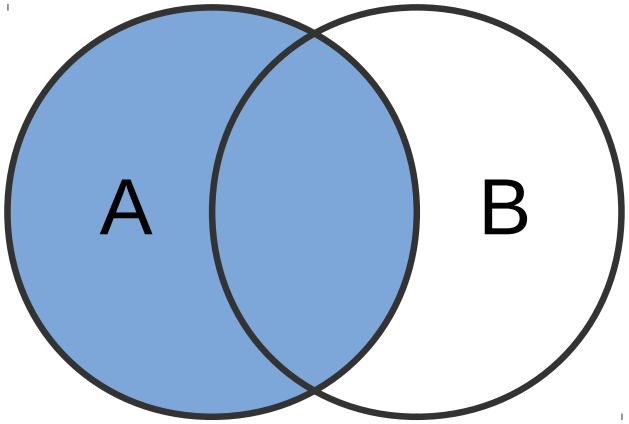
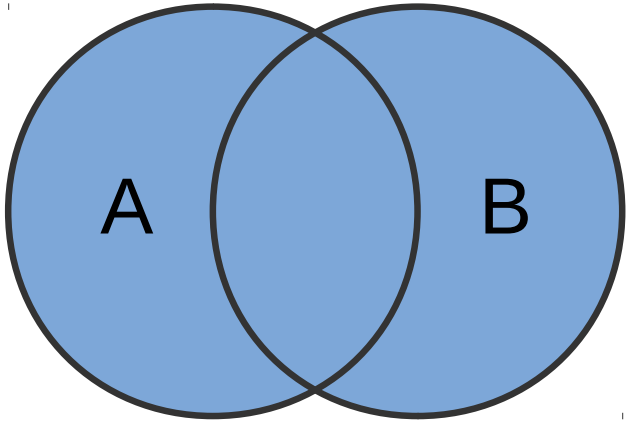
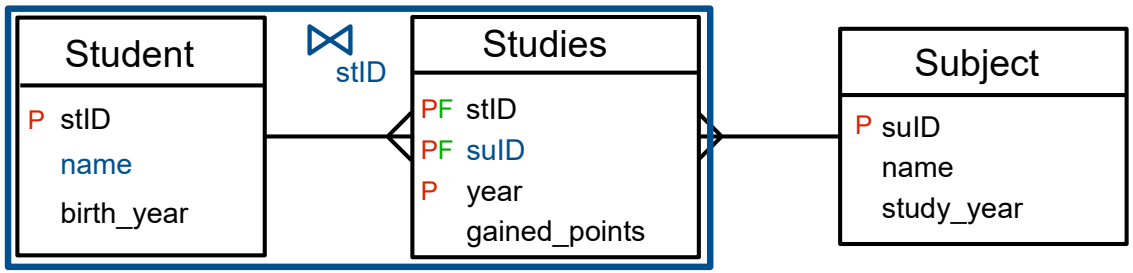
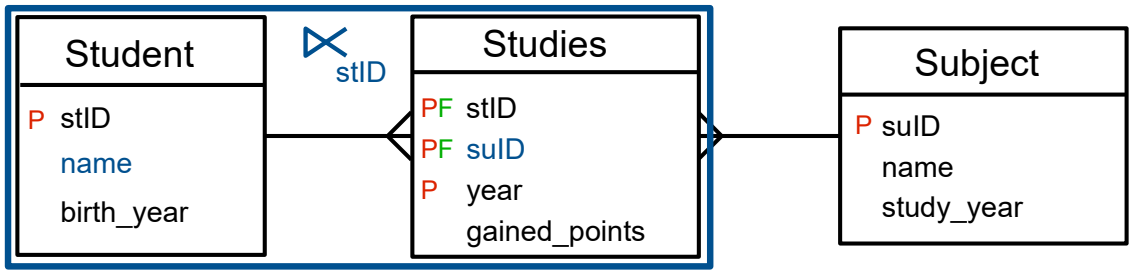
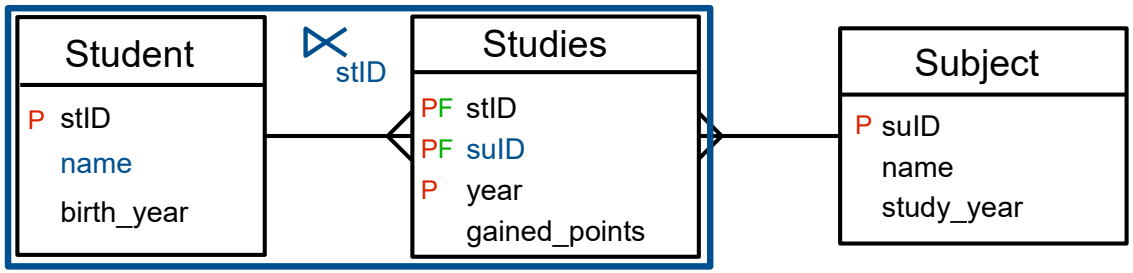
    ```

Example: LEFT OUTER JOIN with Condition



- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

  - ```
    SELECT name, suID
    FROM Student
    LEFT JOIN Studies ON
          Student.stID = Studies.stID
    WHERE year = 2011
    ```
  - No, join is correct, however, the WHERE condition removes all students which does not study anything in 2011
    ```

Example: LEFT OUTER JOIN with Condition



- *List student names and suIDs of subjects studied by them in 2011; if a student does not study a subject, write NULL to his name.*

  - ```
    SELECT name, suID
    FROM Student
    LEFT JOIN Studies ON
          Student.stID = Studies.stID
        AND year = 2011
    ```
    ```

SQL Clausule Priority

1. `FROM`
2. `JOIN`
3. `WHERE`
4. `SELECT`
5. `...`

- Semantic order
- Not a query processing order!

Outer Join Visualization

```
SELECT *
FROM A
LEFT JOIN B
      ON A.k = B.k
```




```
SELECT *
FROM A
FULL JOIN B
      ON A.k = B.k
```



Example: Difference



- *List names of students who did not studied anything*

Example: Difference



- *List names of students and suIDs of subjects studied by them; if a student does not study any subject, write NULL to his/her name.*

```
SELECT name
FROM Student
LEFT JOIN Studies ON
      Student.stID = Studies.stID
WHERE Studies.stID IS NULL
```

- We will show other ways how to implement the difference later

Example: Difference



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WHERE Studies.stID IS NULL
```

- We will show other ways how to implement the difference later

References

- Stránky UDBS na `http://dbedu.cs.vsb.cz`
- Andrew Pavlo, CMU Database systems
  `https://www.youtube.com/watch?v=KG-mqHoXOXY`