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Organization of data and knowledge bases

Lecture 5. Relational Data Structure

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Lecture 5. Relational Data Structure

CONTENT

- Relation in mathematics
- Relation definition
- Domains, attributes, schemas and instances of relations in RDM
- Relations and tables
- Keys of relations

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Nonformal introduction to relations

Relation is an association between any number of entities.

Like subject			Is more			Supply	
Who	What	First	Second	Who	Whom	What	Q-ty
John	DBMS	5	3	Π1 K7 table			200
Peter	C	17	5	Π3 K14 door			150
AnnXML		2	1	Π18	K9 window		1000

Form of representation:

- As a table
- By using a condition

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Relation definition

Let's given sets D_1, D_2, \dots, D_n (does not obligatory distinct). **Relation** R , defined on these sets, is a set of ordered n -tuples (d_1, d_2, \dots, d_n) , such that $d_1 \in D_1, \dots, d_n \in D_n$

Lets given sets D_1, D_2, \dots, D_n (does not obligatory distinct). **Cartesian product** of these sets, denoted as $D_1 \times D_2 \times \dots \times D_n$, is a set of all possible tuples (d_1, d_2, \dots, d_n) , such that $d_i \in D_i, i = 1, n$.

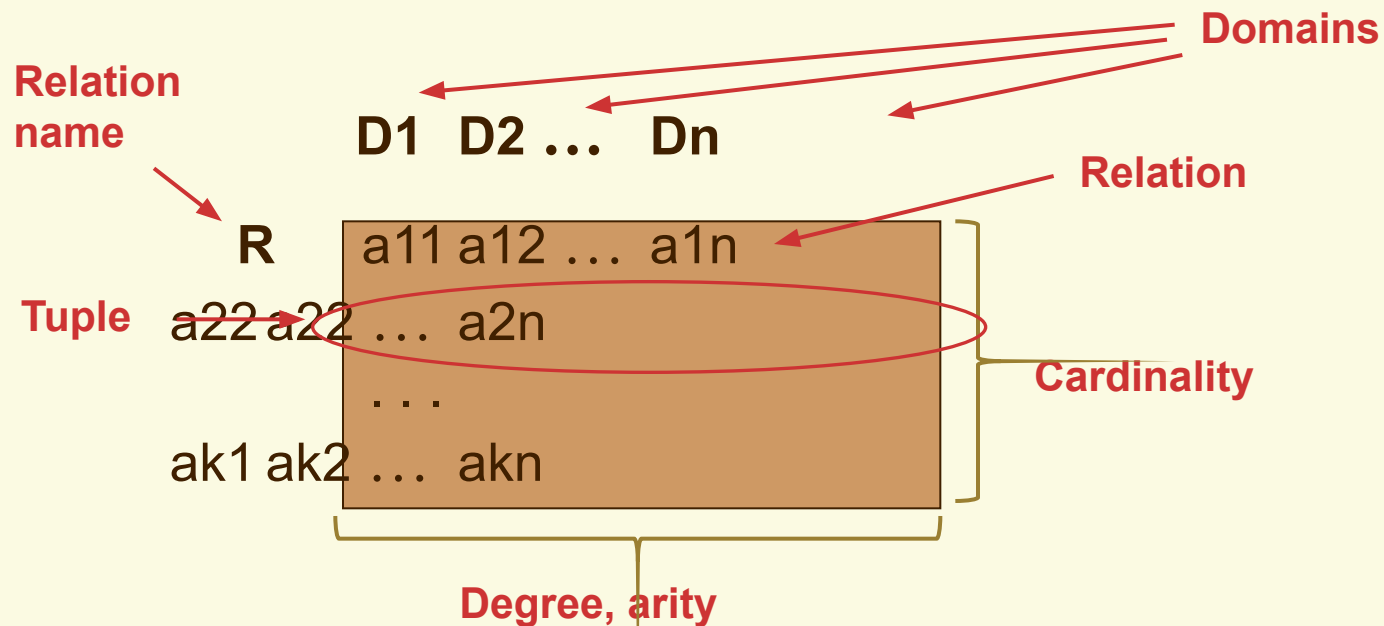
R is a **relation** on the sets D_1, D_2, \dots, D_n , if:

$$R \subseteq D_1 \times D_2 \times \dots \times D_n = \{(d_1, d_2, \dots, d_n) \mid d_i \in D_i, i = 1, 2, \dots, n\}$$

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Additional terms

- Sets D_1, D_2, \dots, D_n are called **domains** of the relation R .
- n is a **degree** of the relation R or its **arity**.
- Number of tuples in a relation is called **cardinality**.
- **Tuple** is a row of the relation.



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Representation of binary relations

As a matrix

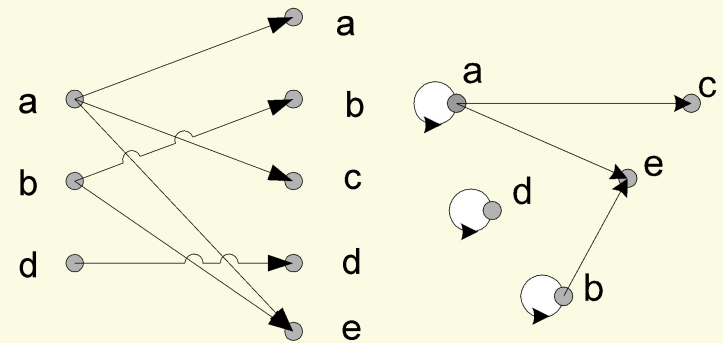
$R =$

a	a
a	c
a	e
b	b
b	e
d	d

As a table

R	a	b	c	d	e
a	*		*		*
b		*			*
d				*	

Graphical



As a logical condition: $R(x,y,\dots,z) = \{(x,y,\dots,z) \mid \varphi(x,y,\dots,z)\}$

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Basic operations

Union: $R \cup S = \{t \mid t \in R \vee t \in S\}$

Intersection: $R \cap S = \{t \mid t \in R \ \& \ t \in S\}$

Negation: $\neg R = \{t \mid t \notin R\}$

Cartesian product: $R \times S = \{(r,s) \mid r \in R \ \& \ s \in S\}$

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Property of binary relations

Reflexivity: Relation R is reflexive if:

$$\forall a R(a, a).$$

Symmetry: Relation R is symmetric if

$$\forall a \forall b (R(a, b) \Rightarrow R(b, a))$$

Transitivity: Relation R transitive if:

$$\forall a \forall b \forall c (R(a, b) \& R(b, c) \Rightarrow R(a, c)).$$

Antisymmetry: Relation R is antisymmetric if:

$$\forall a \forall b (R(a, b) \& R(b, a) \Rightarrow a = b).$$

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Examples of binary relations

Relation **Look-Like**(x,y) is reflexive (any person looks like himself), symmetric (if b looks like d , then d looks like b), but not transitive (if have chain of pairs of similar persons it does not mean that persons at the ends of this chain are similar).

Relation **Is-Higher**(x,y) is transitive but not reflexive and symmetric.

Relation **Is-Equal** ($=$) is reflexive, symmetric and transitive.

Relation **Teach**(x,y) is not reflexive, symmetric and transitive.

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Schema of a relation

In mathematics order of columns is essential.

Is More

5 3
17 5

Is More

3 ~~5~~
5 ~~17~~

In relational data structure order of “columns” is not essential. It is achieved at the expense of introducing of the concept “attribute”.

Attribute – is semantically sensible names of the relation columns.

Attribute names

Domain names

$R(A_1: D_{i1}, A_2: D_{i2}, \dots, A_n: D_{in})$ ← **Schema of relation in RDM**

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Property of attributes and schemas

- **Properties of the relation attributes:**
 - Each attribute of a relation has a name.
 - The set of allowed values for each attribute is called the domain of the attribute.
 - Different attributes may have the same domain.
 - Attribute values are required to be atomic, that is, indivisible.

Properties of the relation schema:

- Every schema has a name.
- Attribute names in schema must be unique.
- Order of attributes in schema is not fixed

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Relation instance

Relation instance corresponds to the relation in mathematics with the only difference – the order of columns in the relation is not important.

Properties of a relation instance:

- Order of attributes is arbitrary, but it is defined by a relation schema.
- Order of tuples is arbitrary
(tuples may be located in an arbitrary order)
- Tuples must be unique within the instance

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Relational data structure

As **relational structure** the set of the *relational schema* and its *instance* (state).

The **relational schema** is a set of the schemas of relations:

$$\begin{aligned} &R_1 (A_1, \dots, A_n) \\ &R_2 (B_1, \dots, B_k) \\ &\dots \\ &R_n (K_1, \dots, K_m) \end{aligned}$$

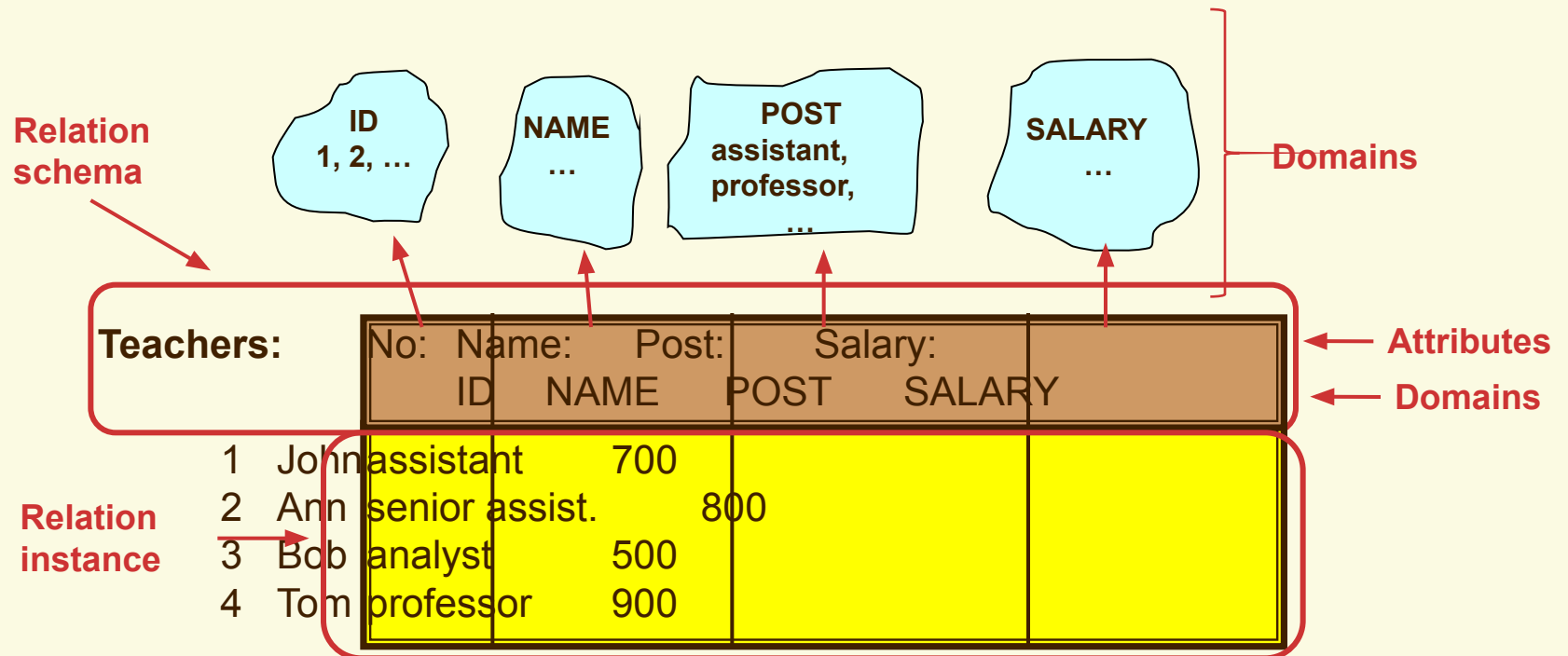
Instance of relational schema is a set of instances of the relations in relational schema .

The relational schema and its instance have the following properties:

- Name of the relations in relational schema must be unique

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Relations and tables



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Term correspondence

Formal term	Nonformal equivalent
domain allowed values	
attribute	column, field
relation	table
tuple	row, record
cardinality	number of rows
degree, arity,	number of columns
key unique identifier	

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Keys

The **key** is a set of relation attributes that uniquely identify the tuples of the relation.

Assertion. Any relation has a key.

Example: In the relation **STUDENT(No, Name, Course)** set of attributes (**No, Name, Course**) are key because tuples of any relation are unique.

Assertion. Any relation may has many keys.

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Simple and compound keys

The key is *simple*, if it consists of one attribute.

The key *compound* if it consists of several attributes.

Example. In the relation:

STUDENT(ID-No, Name, Pasp-ser, Pasp-No, Course)

ID-No is a simple key and pair of attributes

(Pasp-ser, Pasp-No) is a compound key.

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Redundant and minimal keys

Compound key is **redundant** (*not minimal*) if there is a subset of this key that is also a key. Redundant key is also called **superkey**.

Example. In the relation:

STUDENT(ID-No, Name, Pasp-ser, Pasp-No, Course)

key (Pasp-ser, Pasp-No, Course) is redundant key because its subset (Pasp-ser, Pasp-No, Course) is also a key

Nonredundant key is called **minimal**.

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Primary key

A relation may have many minimal keys. All of them are called *candidate keys*.

Example. Relation:

STUDENT (ID-No, Name, Pasp-ser, Pasp-No, Course)

has two minimal (that is why candidate) keys:

- ID-No
- Pasp-ser, Pasp-No

Among set of all candidate (minimal) keys only one is selected as a *primary key*.

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Properties of a primary key

Main properties (integrity constraints):

- Primary key values must never be duplicated. That is they are unique within a relation. But there may be duplicates in parts of compound primary key.
- Primary key cannot have NULL values.

Additional properties:

- Every relation must have one and only one primary key.
- Primary key do not influence attribute order.
- Primary keys do not influence tuple order.

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Example of a primary key

Teachers:

No	Name	Past-Ser	Pasp-No
1	John	CH	951945
2	Ann	CH	917327
3	Bob	CK	917327
4	Tom	BO	111223
5	Alber	BO	111223
6	Ben	MK	NULL
7	Dick	NULL	457328

Primary key

Components of a primary may not be unique

This tuple violates primary key constraint because it contains duplicate value of the primary key

The last two tuples violate primary key constraint because they contain NULL values

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Foreign key

In a relational model relationships between relations are defined “by values”.

Foreign key is one or more attributes of a relation that are used to reference to tuples of other relation.

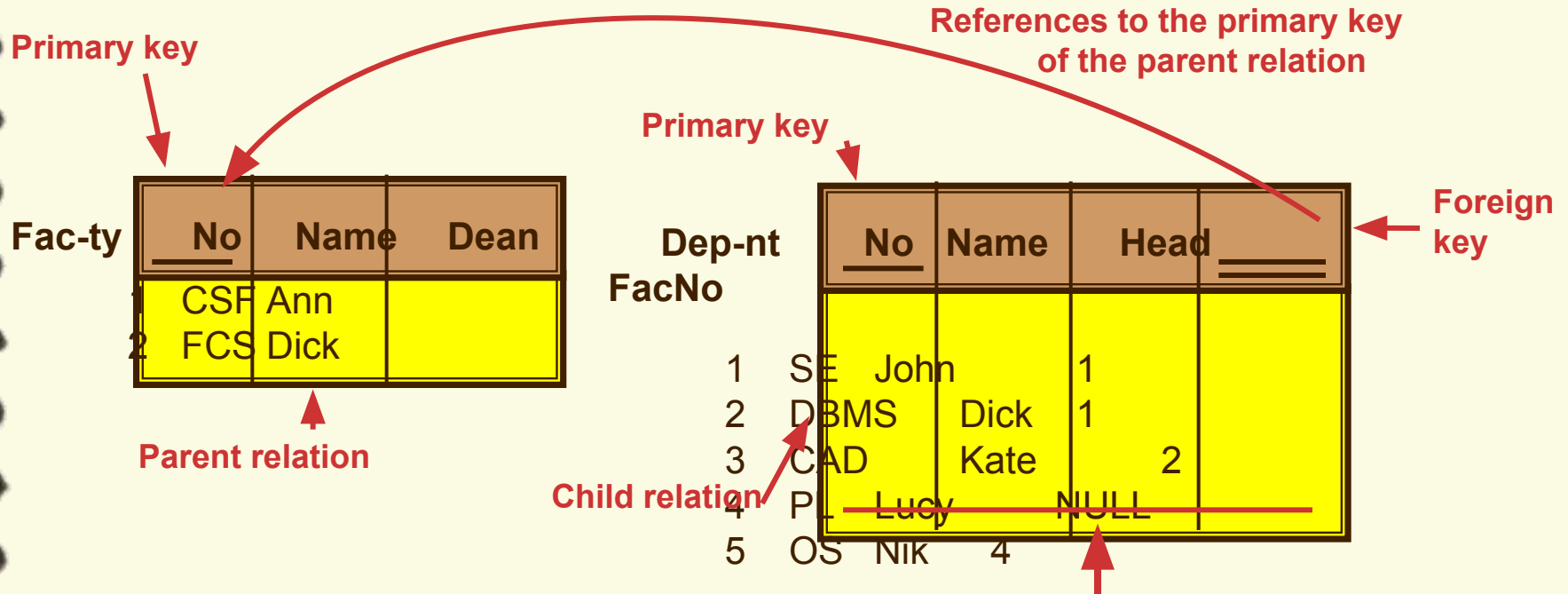
Relation that is references to other relation is called **child relation**.

Relation that is referenced by other relation is called **parent relation**.

Child relation may references only to primary key (or unique key) of the parent relation.

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Example of a foreign key



This tuple violates foreign key integrity constraint (referential integrity constraint) : it is referenced to the absent value of the primary key of the parent table

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Property of foreign key

Main property (integrity constraint):

- Value of a foreign key cannot reference to absent values of the primary key of the parent relation.
It is so called ***referential*** integrity constraint of the foreign key.

Additional properties:

- Foreign key can contain duplicate values.
- Foreign key can contain NULL values.

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Supporting referential constraint

Manipulating by tuples of a child relation:

- When a tuple is added or updated referential constraint is tested and if it is violated the corresponding action (adding/updating) is rejected.
- When a tuple is deleted referential constraint cannot be violated.

Manipulating by tuples of a parent relation :

- When a tuple is added referential constraint cannot be violated.
- When deleting or updating:
 - Tuple deleting/updating is not done if there are references from child relation, that violate referential integrity constraint.
 - Deleting/updating tuple of parent relation causes deleting/updating tuples of a child relation that references the tuple of the parent relation.
 - Deleting/updating tuple of parent relation causes setting NULL values to corresponding tuples of a child relation .
 - Deleting/updating tuple of parent relation causes setting DEFAULT values to corresponding tuples of a child relation.

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Supporting referential integrity constraints in SQL

Supporting referential integrity constraints in standard SQL:

```
ON DELETE {RESTRICT | CASCADE | SET NULL | SET DEFAULT}  
ON UPDATE {RESTRICT | CASCADE | SET NULL | SET DEFAULT}
```

Supporting referential integrity constraints in SQL Oracle:

```
[ON DELETE {CASCADE | SET NULL}]
```

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Supporting referential constraint – RESTRICT

ON DELETE RESTRICT

This tuple cannot be deleted because it is referenced by tuples of a child relation

This tuple may be deleted because it is not referenced

Fac-ty

<u>No</u>	Name	Dean
1 CSF	Ann	
2 CEF	Dick	
3 CTF	Peter	

Department
FacNo

	<u>No</u>	Name	Head	<u>HeadNo</u>
1	SE	John	1	
2	DBMS	Dick	1	
3	CAD	Kate	2	
4	PL	Lucy	NULL	

This tuple may be changed including “No” attribute

The “No” attribute of these tuples cannot be updated because they are referenced by foreign keys of a child relation

ON UPDATE RESTRICT

CSF NAU

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Supporting referential constraint – CASCADE

ON DELETE CASCADE

When deleting this tuple the following tuples of parent relation are also deleted.

	<u>No</u>	Name	Dean
1	CSF	Ann	
2	SEF	Dick	
3	CTF	Peter	

Department
FacNo

	<u>No</u>	Name	Head	<u>Head</u>
1	SE	John	1	
2	DBMS	Dick	1	
3	CAD	Kate	2	
4	PL	Lucy	NULL	

When “No” attribute of this tuple is changed the following values of “FacNo” attribute are also changed.

ON UPDATE CASCADE

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Supporting referential constraint – SET NULL

ON DELETE SET NULL

On deleting this tuple the following values of “FacNo” attribute are set to NULL.

Fac-ty	<u>No</u>	Name	Dean
1	CSF	Ann	
2	SEF	Dick	
3	CTF	Peter	

Department	<u>No</u>	Name	Head	<u>FacNo</u>
1	SE	John	1	
2	DBMS	Dick	1	
3	CAD	Kate	2	
4	PL	Lucy	NULL	

When “No” attribute of this tuple is changed the following values of “FacNo” attribute are set to NULL.

ON UPDATE SET NULL

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Supporting referential constraint – SET DEFAULT

ON DELETE SET DEFAULT

On deleting this tuple the following values of “FacNo” attribute are set to default value.

Fac-ty	<u>No</u>	Name	Dean
1	CSF	Ann	
2	SEF	Dick	
3	CTH	Peter	

Department	<u>No</u>	Name	Head	<u>FacNo</u>
1	SE	John	1	
2	DBMS	Dick	1	
3	CAD	Kate	2	
4	PL	Lucy	NULL	

When “No” attribute of this tuple is changed the following values of “FacNo” attribute are set to default value.

ON UPDATE SET DEFAULT

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Recursive foreign key

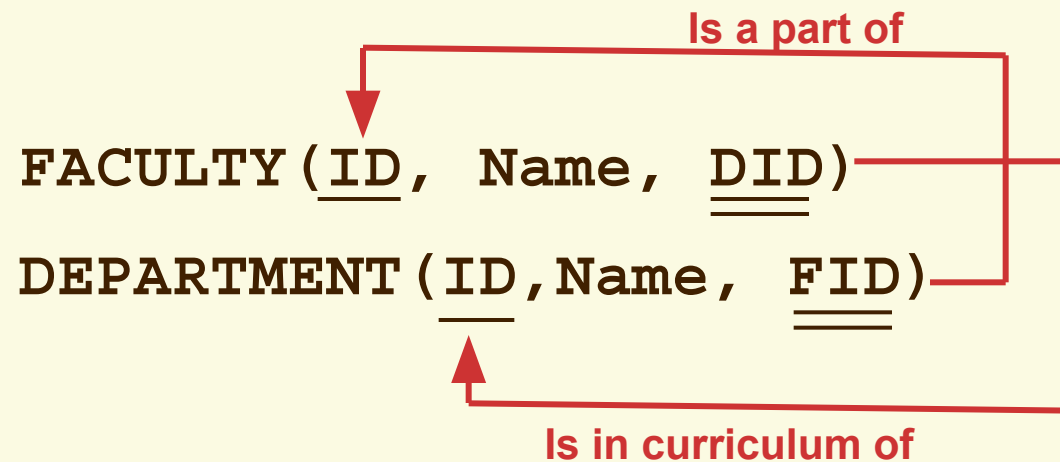
Foreign key is *recursive* if it references to the primary key of the relation where it is defined.

Teacher	<u>No</u>	Name	Pasp-Ser	Pasp-No	<u>ChiefNo</u>
1 Ann	CH	951945	4		
2 Dick	CH	917327	4		
3 Peter	CK	917327	7		
4 John	BO	111223	7		
5 Kate	BO	111224	4		
6 Lucy	MK	NULL	7		
7 Mary	NULL	457328	NULL		

It allows to model hierarchy structure that is defined on one relation.

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Cross-reference foreign keys



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Foreign key as a part of primary key

TEACHER (ID, Name)

SUBJECT (ID, Name)

LECTURE (TID, SID, Hours)

