Università degli Studi di Trieste

Corso di Laurea Magistrale in
INGEGNERIA CLINICA

RICHIAMI DI BASI DI DATI

Corso di Informatica Medica

Docente Sara Renata Francesca MARCEGLIA

Dipartimento di Ingegneria e Architettura

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DATABASE DEFINITION AND PROPERTIES

A **database** is a collection of **related data** with **an implicit meaning** that:

- Is **logically coherent** (random assortments are not a database)
- Is designed, built, and populated with a **specific purpose** and intended users
- Represents some aspects of the real world (**miniworld**)

EXAMPLE

PATIENT	Name	Surname	Address	Location	Unique_ID
	Jack	White	17	MI01	1
	Anna	Green	1	MI03	2
	Herbert	Brown	7	MI01	3

ADDRESS	Street	Number	City	ZIP	State	AddressNumber
	Rockville Pike	3800	New York	19003	NY	1
	Walnut Street	17	Albany	21187	NY	7
	Chestnut Road	17977	Cherry Hill	80087	NJ	17

OPERATIVE UNIT	Unit_Number	Name	Specialty	n.beds
	1	Cardiology 1	Cardiology	55
	2	G.Washington	Oncology	37
	3	M. Montessori	Pediatrics	47

DOCTORS	Name	Surname	Specialty	Unique_ID
	Jane	Smith	Surgery	1
	Anne	Powell	Neurology	2
	Henry	Doe	Pharmacology	3

PRESCRIPTIONS	Patient	Operative Unit	Doctor	Drug name
	3	1	3	Paracetamol
	3	2	1	Antibiotics
	1	3	2	Melatonin

DATABASE APPROACH VS FILE PROCESSING APPROACH (1)

PATIENT	Name	Surname	Address	Location	Unique_ID
	Jack	White	17	MI01	1
	Anna	Green	1	MI03	2
	Herbert	Brown	7	MI01	3

ADDRESS	Street	Number	City	ZIP	State	AddressNumber
	Rockville Pike	3800	New York	19003	NY	1
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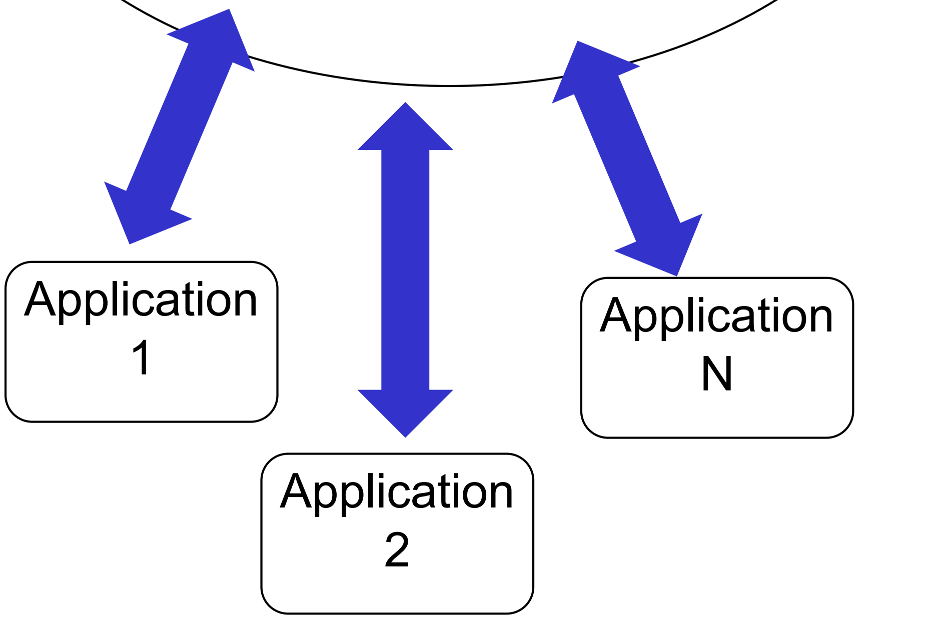

Application 1

```
struct Patient {
   char Name[30];
   char Surname[30];
   address Address;
   char location[5];
   char uniqueID [21];
   ....
};
```

→ Patient FindPatient (char Name[30]);

Application N

```
struct Patient {
   char Name[30];
   char Surname[30];
   address Address;
   char location[5];
   char uniqueID [21];
   ....
};
```

→ CreateNewPrescription (Patient pat);

DATABASE APPROACH VS FILE PROCESSING APPROACH (2)

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DATABASE	FILE PROCESSING
• A single repository of data is mainteined that is defined once and then accessed by various users • The database system contains a complete definition or description of the database itself **(self-contained nature)** • Database access programs are written independently of any specific file **(independence between programs and data)** • Provide a conceptual representation of data **(data abstraction)** • Has many users with different perspectives **(multiple views)**	• Each user defines and implements the files needed for a specific application **(redundancy)** • Data definition is part of the application program **(data definitions embedded)** • The structure of the data files is embedded in the application program **(dependency between programs and data)** • Data are represented by the memory occupation/record length • Each different user needs a different application **(unique view)**

SCHEMAS AND INSTANCES IN A DATABASE

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- The **DATABASE SCHEMA** is the description of the database that is specified during database design and is not expected to change frequently.
- When we define a new database, we **define the schema**.

ADDRESS	Street	Number	City	ZIP	State	AddressNumber

OPERATIVE UNIT	Unit_Number	Name	Specialty	n.beds

- The **DATABASE INSTANCE** is composed by the data in a database at a certain time point (occurrence or state)
- A new database is an "empty istance". When we populate the database, we **load data**

OPERATIVE UNIT	Unit_Number	Name	Specialty	n.beds
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	2	G.Washington	Oncology	37
	3	M. Montessori	Pediatrics	47

DATA BASE MANAGEMENT SYSTEM

- A DBMS is a collection of programs that enables users to create and maintain database.
- It is a generalized software package for implementing maintaining a computerized database:
  - –DEFINING a database involves specifying the data types, structures and constraints for the data to be stored in the database;
  - –CONSTRUCTING the database is the process of storing the data itself on some storage medium that is controlled by the DBMS
  - –MANIPULATING a database includes such functions as query the database to retrieve specific data, updating the database to reflect changes in the miniworld, and generating reports from the data.

DBMS PROPERTIES

1. Management of huge amount of data
2. Providing persistent storage for program objects and data Structures
3. Sharing of Data (and Concurrency control)
4. Controlling redundancy
5. Providing Backup & Recovery
6. Restricting Unauthorized Access
7. Providing multiple interfaces
8. Representing complex relationships among data
9. Enforcing integrity constraints

ENFORCING INTEGRITY CONSTRAINTS

- Data should be consistent → the same data has to be represented by the same datatype
- Relationships can be constraints → a certain record has to be related to another record
- Unique values are constraints → these can be checked directly by the system
- Semantic constraints are more difficult to be automatically checked.

DBMS ARCHITECTURE

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- The advantages of a DBMS instead of a non-specific database system are:

1. Independency between data and applications
2. Multiple views
3. Use of a catalogue to store tha database schema independent from actual data

IMPLEMENTED THORUGH A THREE-LEVEL ARCHITECTURE

THE THREE LEVELS

- **INTERNAL LEVEL**

It has an internal schema that describes the physical storage structure of the database. The Internal schema includes the complete details of data storage and access paths of the database.

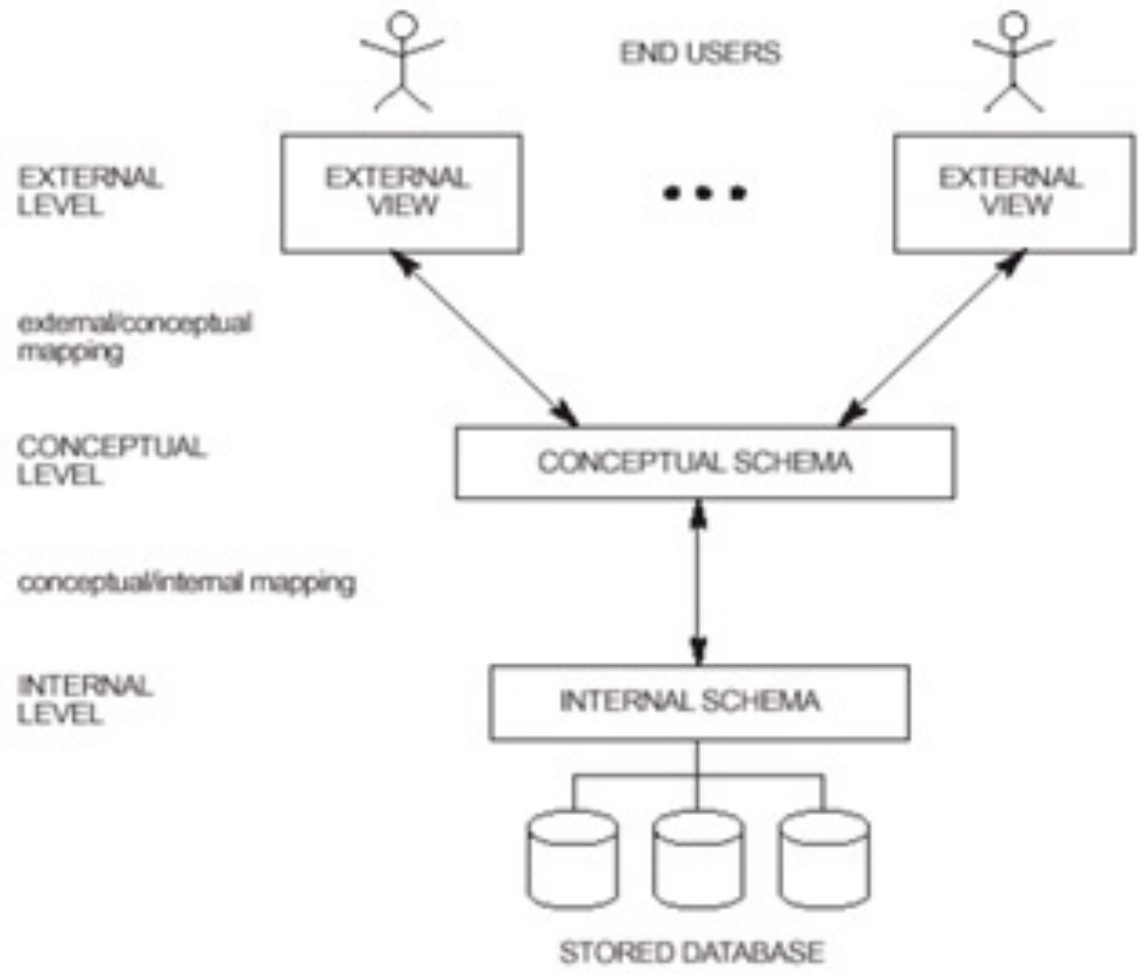
- **CONCEPTUAL LEVEL**

It has a conceptual schema that describes the structure of the whole database for a community of users, hiding the detais of the physical storage. A high-level data model can be used as conceptual schema.

- **EXTERNAL (VIEW) LEVEL**

Each external schema or user view describes the database view for a specific user group, hiding what is not interesting to the particular users.

THE THREE-SCHEMA ARCHITECTURE



DBMS LANGUAGES

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- **Data Definition Language (DDL).** Language for **data definition, the DDL** is used to specify conceptual schema for the database.
- **Storage Definition Language (SDL).** Language for **data storage, the SDL** defines the internal schema (physical storage of the data)
- **View Definition Language (VDL).** Language for **view defininition, the VDL** specifies user views and their mappings
- **Data Manipulation Language (DML).** Language for **data manipulation, the MDL** can be: high-level non procedural (does not define how the result is obtained but what is wanted) or low-level procedural (defines the procedure to obtain the result)

DEFINITION OF DATA MODEL

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A data model is a collection of concepts that can be used to describe the structure of a database

1. **Conceptual data models** → used to describe data independently from the logical model (e.g. entity-relationship model)

2. **Representational data models** → used to represent the data in a DBMS

3. **Physical data models** → describe how data are physically stored in the computer memory (how many files, their size, …)

DATA MODELS IN DBMS

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Representational Data models are used to provide the conceptual representation of data in a DBMS.

1. Hierarchical data model
2. Network data model
3. Relational data model
4. Object-oriented data model

DBMS CLASSIFICATIONS

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Data model

- Relational
- Network
- Hierarchical
- Object oriented

Number of contemporary users

- Single-user
- Multi-user

Number of sites where the database is distributed

- Centralized DBMS (the database is stored in a single site)
- Distributed DBMS (the database is distributed over many sites)
- Federated DBMS (local databases have a degree of autonomy)

Representational Data models are used to provide the conceptual representation of data in a DBMS.

1. Hierarchical data model
2. Network data model
3. **Relational data model**
4. Object-oriented data model

BASIC CONCEPTS

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- The relational model represents the data in a database as a collection of **relations**

- A relation resembles a **table** → we can introduce an informal definition

Table = rows, columns

Relation = tuples, attributes

RELATIONS, TUPLES, AND ATTRIBUTES

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Relational Model — Query Language

- Relation ←→ Table
- Tuple ←→ Row
- Attribute ←→ Column

Relation

Attribute

PATIENT	PHID	FirstName	LastName	Encounter Date	Therapy
	000ZZ000	John	Smith	2003-03-12	Flutamide
	111AA222	Mary	Brown	2004-10-14	Penicillin
	000EE999	Kevin	Green	2001-09-23	Leuprolide
	123XX456	Ann	Black	2002-05-11	Epinephrine

Tuple

RELATIONS: PROPERTIES

1. There is no order among the relationships between relations (tables) in a relational database.

2. There cannot be two identical tuples in a relation (non-redundancy)

3. Attributes in a relation are not ordered

4. A relation is characterized by:

   relation schema + relation instance

RELATION SCHEMA

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It represents the **Relation intension:**

- Relation Name (eg, PATIENT)
- Relation attributes (eg, PHID, FirstName, LastName, EncounterDate, Therapy)

PATIENT	PHID	FirstName	LastName	Encounter Date	Therapy
	000ZZ000	John	Smith	2003-03-12	Flutamide
	111AA222	Mary	Brown	2004-10-14	Penicillin
	000EE999	Kevin	Green	2001-09-23	Leuprolide
	123XX456	Ann	Black	2002-05-11	Epinephrine

RELATION INSTANCE

It represents the **Relation extension:**

- Tuples (=rows) containing actual data are the instance of the relation.

PATIENT	PHID	FirstName	LastName	Encounter Date	Therapy
	000ZZ000	John	Smith	2003-03-12	Flutamide
	111AA222	Mary	Brown	2004-10-14	Penicillin
	000EE999	Kevin	Green	2001-09-23	Leuprolide
	123XX456	Ann	Black	2002-05-11	Epinephrine

KEYS

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- **A Relation is a set of tuples in which two tuples cannot be identical (each tuple is unique)**

  - This property has to be valid for at least a subset of attributes →

- **There cannot be two or more tuples with the same combination of values for this subset**

PATIENT	Name	Surname	Address	Location	Unique_ID
	Jack	White	17	MI01	1
	Anna	Green	1	MI03	2
	Herbert	Brown	7	MI01	3
	Jack	White	17	MI02	4

SUPERKEYS

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PATIENT	PHID	FirstName	LastName	BirthDate	BirthPlace	GP	Diagnosis
	000ZZ000	John	Smith	1980-03-12	NewYork	Parker	Diabetes
	080JJ333	John	Smith	1945-11-08	Los Angeles	Jackson	Hepatitis
	111AA222	Mary	Brown	1955-10-14	San Antonio	Hart	Hypertension
	000EE999	Kevin	Green	1974-09-23	Sydney	Goldman	Cold
	123XX456	Ann	Black	1963-05-11	Frankfurt	O'Neill	Miocarditis

Superkey =

a subset of attributes in a relation that is unique for each tuple.

⬇

A **Superkey** univocally identifies a tuyple

KEYS

key = minimum superkey

(superkey for which it is not possible to identify a subset of attributes satisfying the unicity property)

⬇

- Example:

{FirstName, LastName, BirthDate, BirthPlace, GP} → it is not a key (it is a superkey)

{FirstName, LastName, BirthDate} → it is a key (it is minimal → I cannot exclude any of the attributes, otherwise the tuples are not unique)

{PHID} → superkey and minimal → it is another key of the same relation.

PRIMARY KEYS

- There is more than one possible key in a Relation
- **Primary Key = key chosen to identify the tuples in a relation**
- Notation → the attributes that constitute the primary key are followed by the **%** symbol

Primary key - examples

1) Primary key =

{FirstName, LastName, BirthDate}

For the PATIENT relation

PATIENT (PHID, FirstName%, LastName%, BirthDate%, BirthPlace, GP, Diagnosis)

2) Primary key =

{PHID}

For the PATIENT relation

PATIENT (PHID%, FirstName, LastName, BirthDate, BirthPlace, GP, Diagnosis)

Integrity constraints

The concept of integrity constraints derives from the observation that not all value combinations are able to represent the information correctly → the introduction of integrity constraints ensures that the information represented are correct

- Intra-relational constraints → within a relation
  - Tuple constraints → constraints on the values of each tuple (NOT NULL, valid interval,…) independent from the others (es. university marks are in the interval [18, 30] e 30 e lode); attribute NOT NULL.
  - Key constraints → no primary key value can be null.
- Inter-relational constraints → between relations
  - Referential integrity constraint → used to mantain the consistency among tuples of two relations

REFERENTIAL INTEGRITY CONSTRAINTS

- Based on the concept of "foreign key"

- A set of attributes FK in the relation R1 is foreign key of R1 if:
  1. The attributes in FK have the same domain as the primary key attributes PK of another relation R2
  2. A value of FK in a tuple t1 of R1 either occurrs as a value of PK in some tuple t2 in R2 or is null t1[FK] = t2[PK]

REFERENTIAL INTEGRITY CONSTRAINT: EXAMPLE

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Foreign key of PRESCRIPTIONS (FK)

PRESCRIPTIONS	Patient	Operative Unit	Doctor	Drug name
	1	3	1	Paracetamol
	3	2	1	Antibiotics
	1	3	2	Melatonin

1. The two attributes have the same domain
2. The values occurring in Operative Unit occur in Unit_Number and are Primary Keys

OPERATIVE UNIT	Unit_Number	Name	Specialty	n.beds
	1	Cardiology 1	Cardiology	55
	2	G.Washington	Oncology	37
	3	M. Montessori	Pediatrics	47

Primary key of OPERATIVE UNIT (PK)

THE NULL VALUE: MULTIPLE MEANINGS

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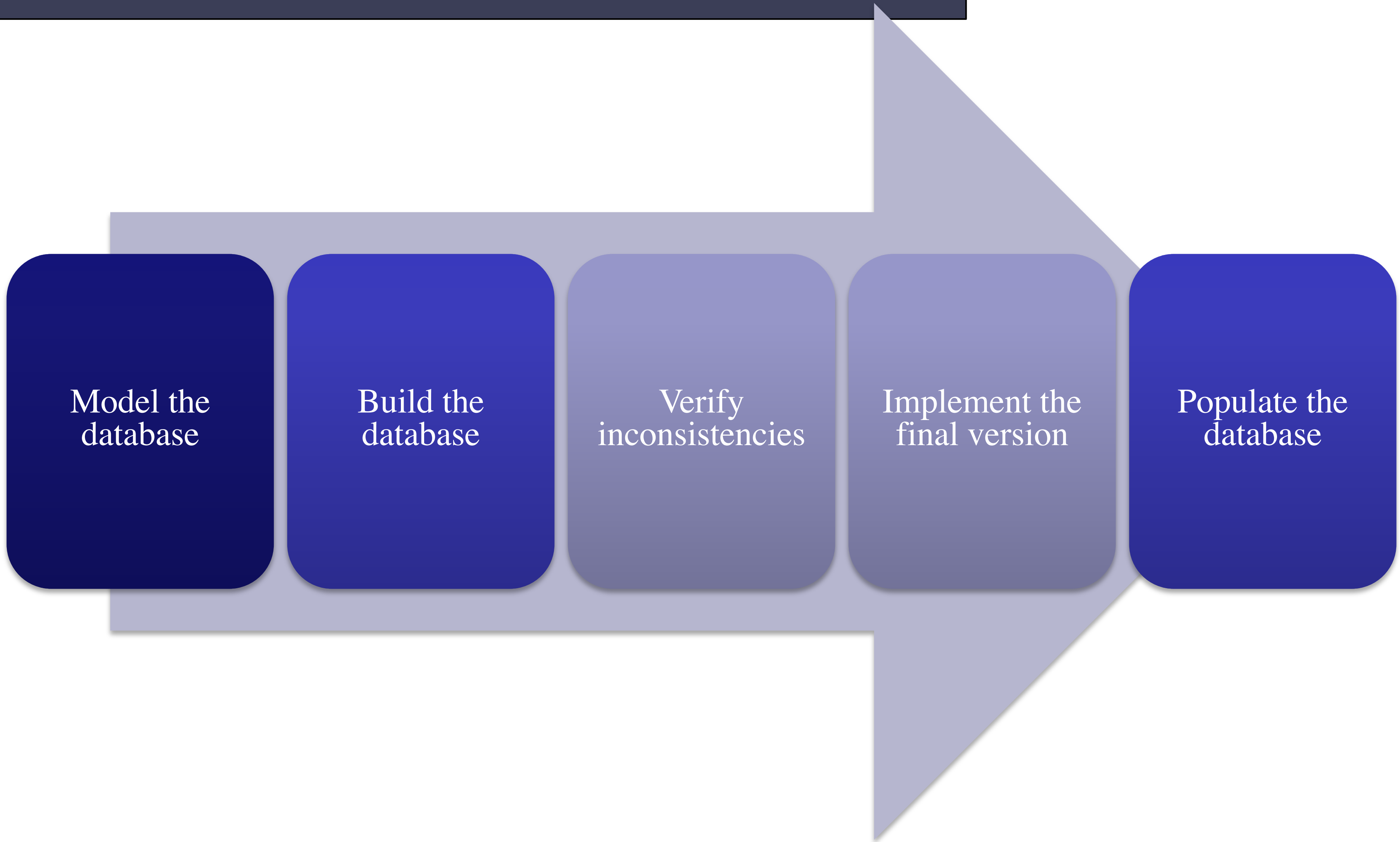
1. Not valid for the current instance (Husband surname for a male)
2. Valid but not yet existing (Husband surname for a non-martried woman)
3. Existing but it cannot be saved (patient's religion in some Countries cannot be stored to avoid discrimination)
4. Existing but unknown
5. Existing but not yet saved (patint's history noyt collected yet)
6. Stored and then deleted (erroneous information)
7. Available but in an updating phase (patient's therapy under modification)
8. Available but not reliable (a non final diagnosis)
9. Available but not valid (a blood parameter abovce the threshold of valid range)
10. Calculted from anothe NULL value (BMI if the weight is not present).

CONCEPTUAL & LOGICAL MODELING

To create a database…



DATABASE LIFECYCLE

The database lifecycle is a complex process, usually composed by the following main phases:

1. Requirements collection and analysis
2. Conceptual database design
3. Choice of a Data Base Management System
4. Logical database design
5. Physical database design
6. Database implementation
7. Use & maintenance

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CONCEPTUAL DATABASE DESIGN

High level and abstract view of the reality

Independent from the DBMS that will be used

→

Entity-Relationship (E-R) Data Model

THE ENTITY-RELATIONSHIP (E-R) DATA MODEL

- Entity is an independent object or entity of the real world.
- Relationship is an association between more entities

- As well as each entity is the instance of an entity type, each relationshi is and instance (relationship instance) of a certain relationship type.

- **WARNING**:
- RELATIONSHIPs in the ER model are DIFFERENT from RELATIONs in the relational model

THE ENTITY-RELATIONSHIP (E-R) DATA MODEL

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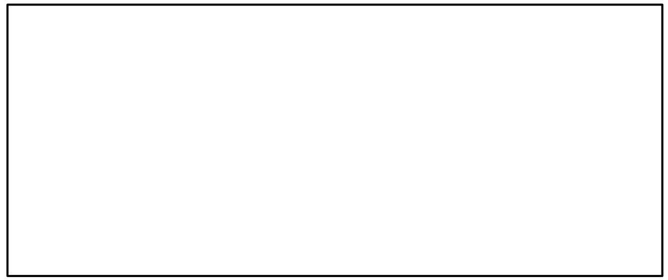
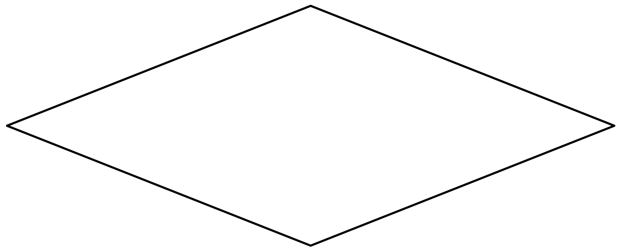
ENTITY

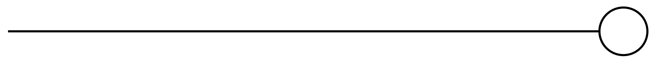


RELATIONSHIP

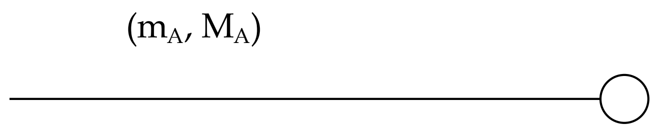


THE ENTITY-RELATIONSHIP (E-R) DATA MODEL

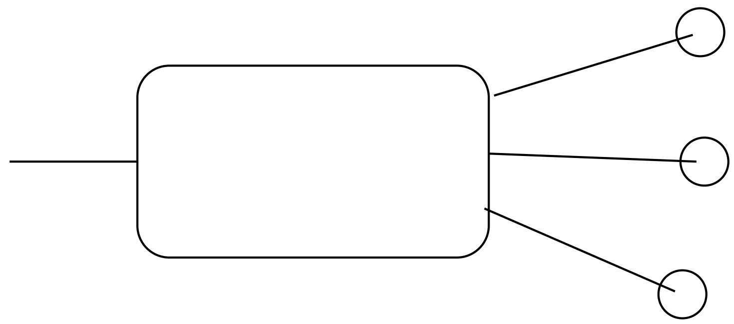
ATTRIBUTE



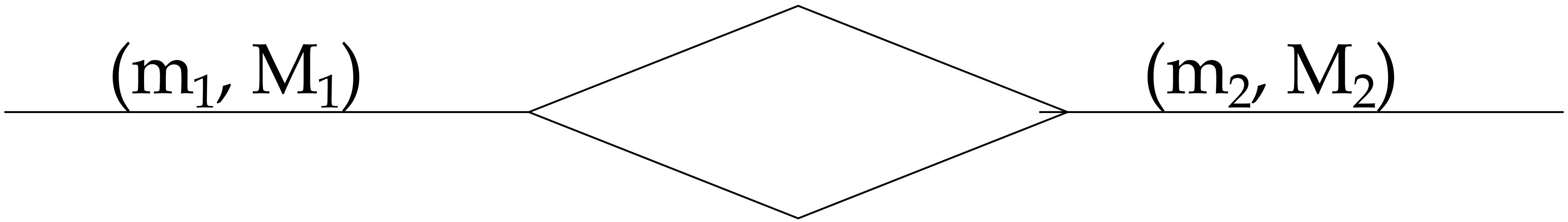
ATTRIBUTE WITH CARDINALITY



COMPOSITE ATTRIBUTE



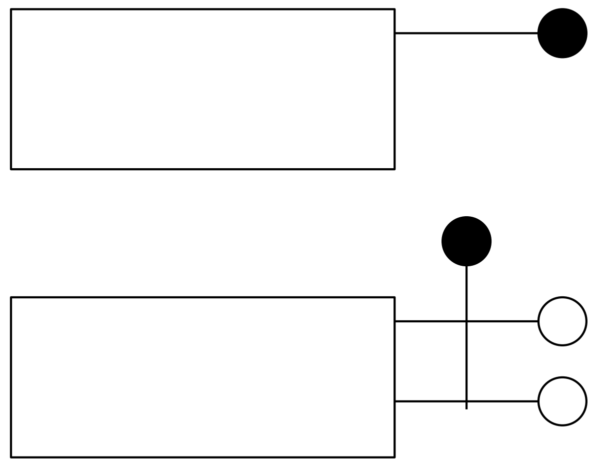
THE ENTITY-RELATIONSHIP (E-R) DATA MODEL



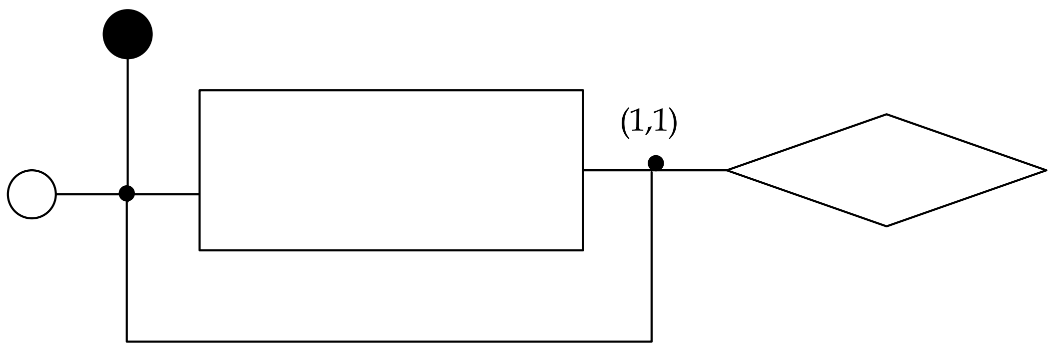
RELATIONSHIP CARDINALITY

THE ENTITY-RELATIONSHIP (E-R) DATA MODEL

KEY ATTRIBUTES



WEAK ENTITY (with foreign key)



THE ENTITY-RELATIONSHIP (E-R) DATA MODEL

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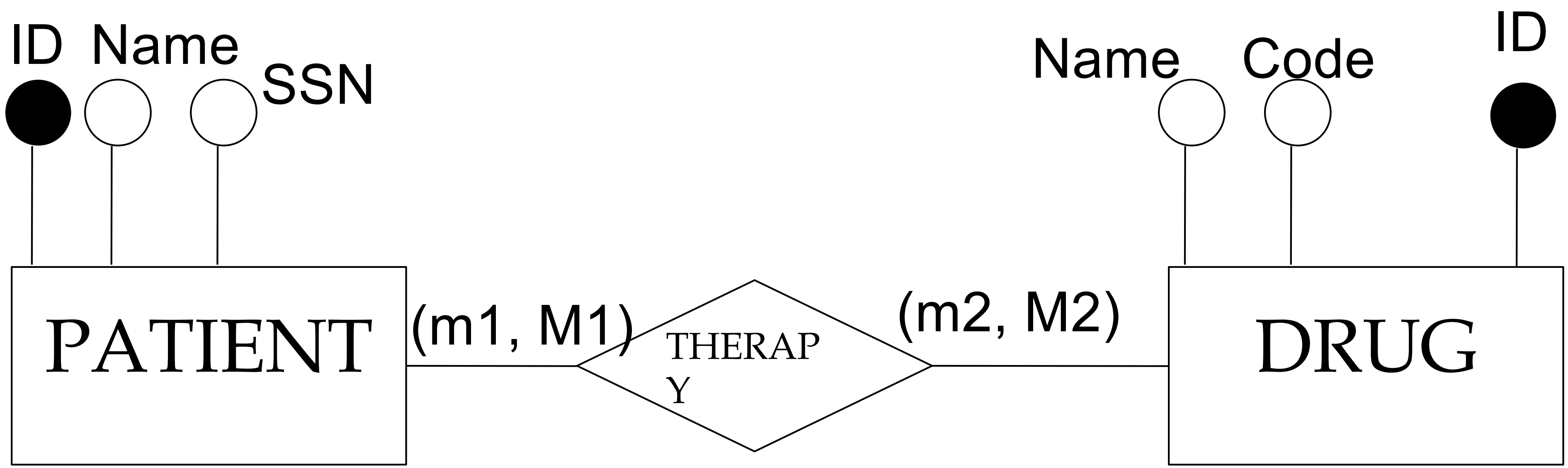

CARDINALITY

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- Have to be specified for each entity participating in a relationship;
- They describe the minimum and maximum occurrencies of each entity in a relationship
- They define how many times each entity can be involved with other entities through the specified relationship

CARDINALITY

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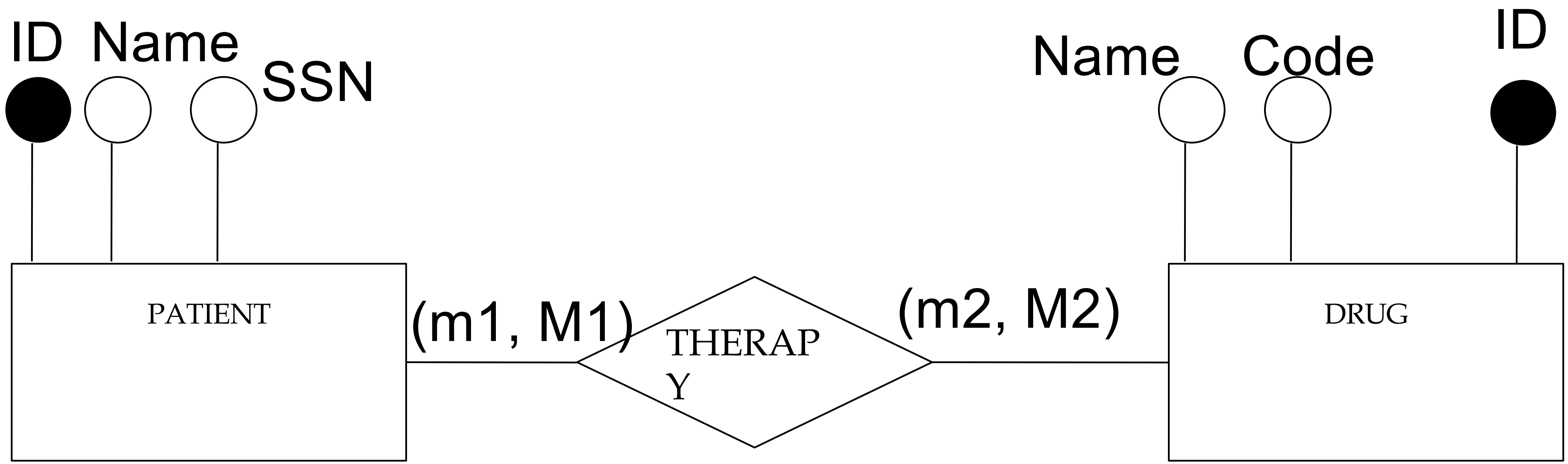
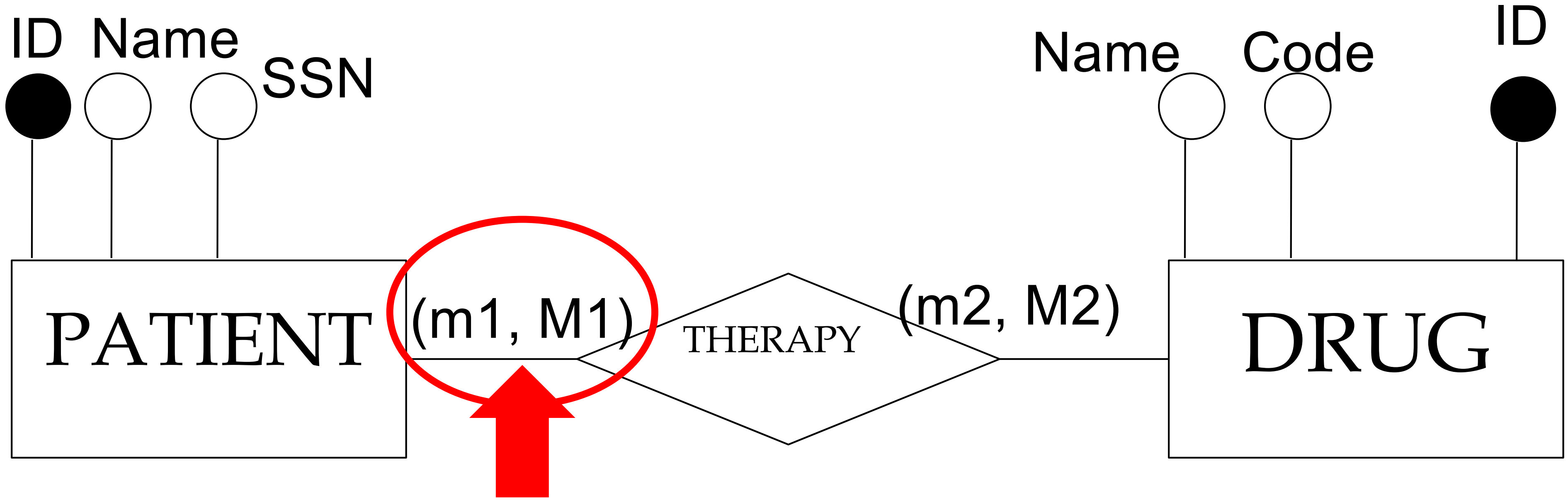


m1	M1	m2	M2	Cardinality
0	1	0	1	One-to-One
0	1	0	N	One-to-Many
0	N	0	N	Many-to-Many

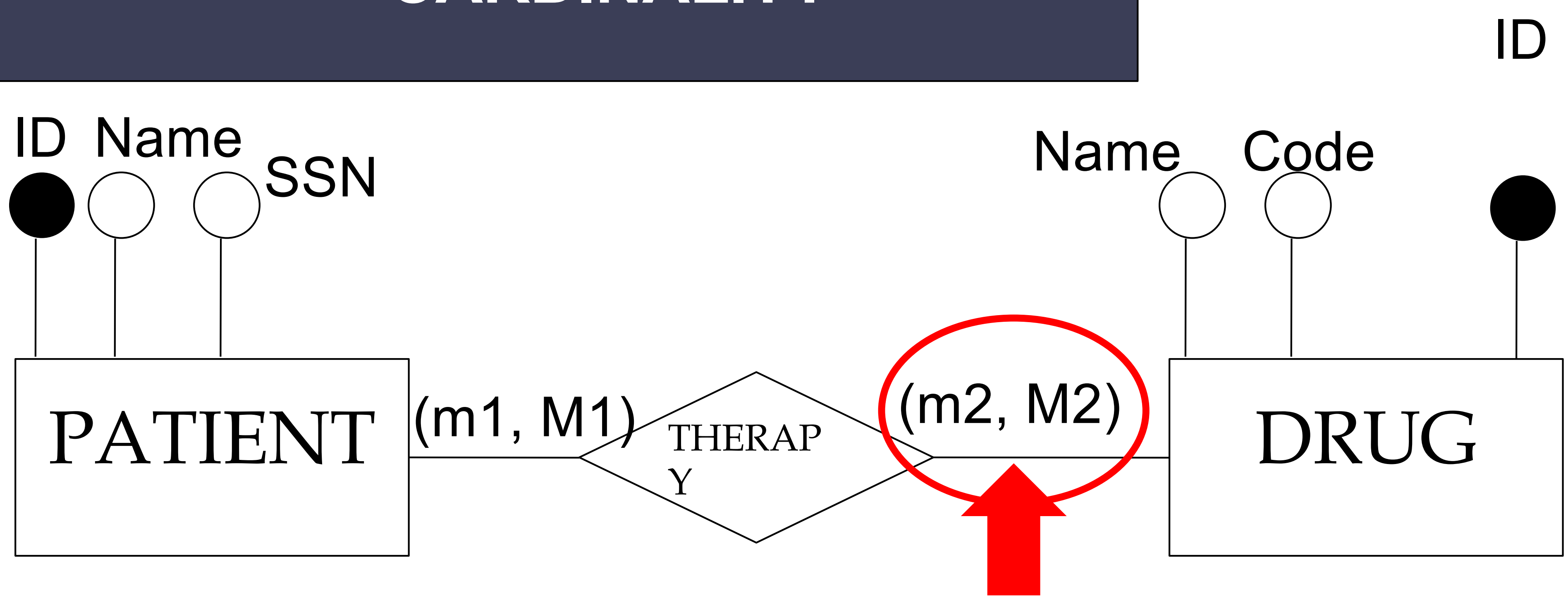
CARDINALITY



- If M1>m1>=0 → a patient has to (if m1>0) or can (if m1=0) participate to a minimum of m1 occurrences and a maximum of M1 occurrences of the THERAPY relationship.

- This implies that each patient has (or can have) at least m1 drugs assigned but no more than M1

CARDINALITY



- If M2>m2>=0 → a drug has to (if m2>0) or can (if m2=0) participate to a minimum of m2 occurrences and a maximum of M2 occurrences of the THERAPY relationship.

- This implies that each drug has to (or can be) assigned to at least m2 patients but no more than M2.

Entity-Relationship (E-R) Data Model: example

The entity-relationship diagram describing a centralized databank for neuronal bioelectrical signals recorded during stereotactic neurosurgery

Entity-Relationship (E-R) Data Model

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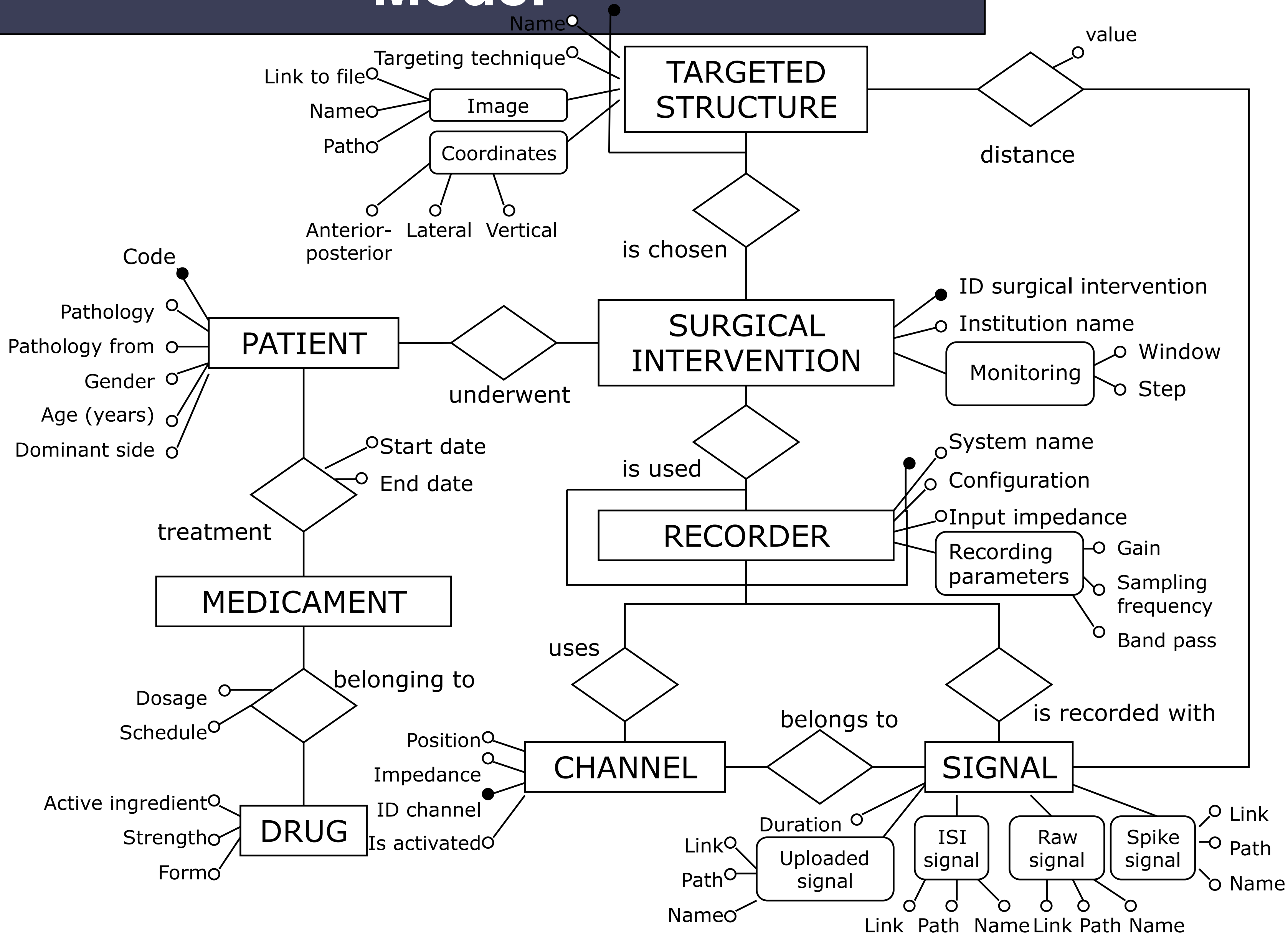

The NULL value: multiple meanings

1. Not valid for the current instance (Husband surname for a male)
2. Valid but not yet existing (Husband surname for a non-martried woman)
3. Existing but it cannot be saved (patient's religion in some Countries cannot be stored to avoid discrimination)
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LOGICAL DATABASE DESIGN

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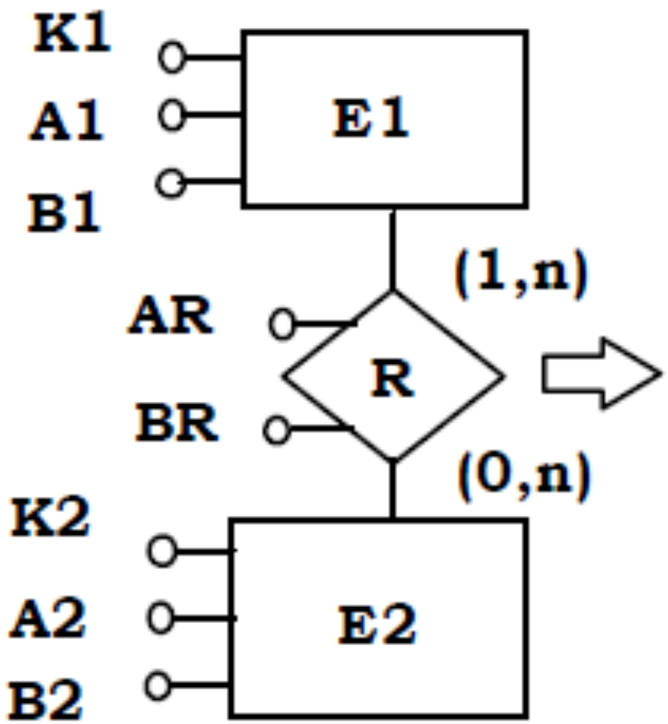
- Translates the abstract representation of the conceptual model in specifications that can be implemented thorugh a DBMS
- The result is the logical schema.

1. Translation from the conceptual schema to the logical schema using the DBMS data model;
2. Adaptation of the logical schema to the characteristics of the specific DBMS
3. Logical schema optimization→ Normalization

STANDARD TRANSLATION



E1 (K1, A1, B1,...)

E2 (K2, A2, B2,...)

R (K1,K2, AR, BR,...)

DATABASE QUERYING: RELATIONAL ALGEBRA AND SQL

DATABASE QUERYING: RELATIONAL ALGEBRA OPERATIONS

- SELECT
  - From all the rows in a table, this operation selects only those that satisfy a certain condition
- PROJECT
  - From all the columns in a table, this operation selects only a subset
- CARTESIAN PRODUCT
  - Given two tables, it creates all the possible combinations of the rows in each table
- JOIN
  - Selects only some rows satisfying a certain condition after a cartesian product

SELECT OPERATION - σ

- Is used to select a specific subset of tuples in a relation
- The selected tuples must satisfy a selection condition
- The result of the selection operation is a new relation with the same attributes as the starting relation and only the selected tuples

$$\text{New\_Relation} \leftarrow \sigma_{(\text{condition})} (\text{Relation\_Name})$$

Condition: usually a comparison operation with constant values and Boolean operators AND, OR, NOT

SELECT OPERATION – σ
Example (1/3)

We want to select the Cardiology patients

Patient (ID%, family_Name, Diagnosis_Date%,Diagnosis Physician_Name, Operative_Unit)

PATIENT	ID%	Family Name	Diagnosis Date%	Diagnosis	Physician Name	Operative Unit
	1123	White	12/11/85	Stroke	Ackerman	Cardoiology
	1123	White	4/4/87	Ventricular arrythmia	Fontelo	Emergency
	1763	Green	3/31/79	Stroke	Reds	Cardiology
	1763	Green	4/25/99	Angina	Grey	Medicine I
	1763	Green	11/18/03	Angina	Rome	Medicine II
	2156	Brown	2/27/01	SA nodal block	Hanna	Cardiology

ID and diagnosis date are the primary key

SELECT OPERATION – σ
Example (2/3)

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$$New\_Patient \leftarrow \sigma_{(Operative\_Unit = \text{“Cardiology”})}(Patient)$$

SELECT OPERATION – σ
Example (3/3)

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NEW_PATIENT	ID%	Family Name	Diagnosis Date%	Diagnosis	Physician Name	Operative Unit
	1123	White	12/11/85	Stroke	Ackerman	Cardoiology
	1763	Green	3/31/79	Stroke	Reds	Cardiology
	2156	Brown	2/27/01	SA nodal block	Hanna	Cardiology

New relation with:

- The **SAME ATTRIBUTES**
- Only the **TUPLES SATISFYING THE CONDITION**

PROJECT OPERATION - π

- Is used to select certain columns from the table and discard the other columns
- Used when you are interest only in a subset of attributes
- The result is a new relation with the same tuples but different attributes

$$\text{New\_Relation} \leftarrow \pi_{(\text{attribute\_list})} (\text{Relation\_Name})$$

PROJECT OPERATION – π Example (1/3)

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We want to select the Name, Surname, and Date of Birth

Patient (Name, Surname, Birthdate,Gender)

PATIENT	Name	Surname	Birthdate	Gender
	Jack	White	11/5/61	M
	Anna	Green	7/9/25	F
	Mary	Brown	3/16/80	F
	Jack	Reds	9/15/73	M

PROJECT OPERATION – π
Example (2/3)

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$$\text{New\_Patient} \leftarrow \pi_{(\text{Surname},\text{Name},\text{Birthdate})}(\text{Patient})$$

PROJECT OPERATION – π Example (3/3)

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NEW_PATIENT	Name	Surname	Birthdate
	Jack	White	11/5/61
	Anna	Green	7/9/25
	Mary	Brown	3/16/80
	Jack	Reds	9/15/73

New relation

- **SAME TUPLES**
- Only the **ATTRIBUTES LISTED** in the selection criterion

CARTESIAN PRODUCT

- It operates over two relations (R1 and R2)
- The result of this operation is a relation that (1) combines all the tuples from R1 and R2 and (2) has all the attributes of both R1 and R2

$$\text{New\_Relation} \leftarrow R1 X R2$$

CARTESIAN PRODUCT
Example (1/3)

PATIENT	Name	Surname	Birthdate
	Jack	White	11/5/61
	Anna	Green	7/9/25
	Mary	Brown	3/16/80

DIAGNOSIS	Diagnosis_name	System	Ref_Operative_Unit
	Stroke	Cardiovascular	Cardiology
	Asthma	Respiratory	Pneumology
	Parkinson's Disease	Nervous	Neurology
	Angina	Cardiovascular	Cardiology

We want to create the cartesian product between the patients and the diagnoses

CARTESIAN PRODUCT
Example (2/3)

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Pat_Dia ← $Patient X Diagnosis$

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CARTESIAN PRODUCT
Example (3/3)

PAT_DIA	Name	Surname	Birthdate	Diagnosis_name	System	Ref_Operative_Unit
	Jack	White	11/5/61	Stroke	Cardiovascular	Cardiology
	Jack	White	11/6/61	Asthma	Respiratory	Pneumology
	Jack	White	11/7/61	Parkinson's Disease	Nervous	Neurology
	Jack	White	11/8/61	Angina	Cardiovascular	Cardiology
	Anna	Green	7/9/25	Stroke	Cardiovascular	Cardiology
	Anna	Green	7/10/25	Asthma	Respiratory	Pneumology
	Anna	Green	7/11/25	Parkinson's Disease	Nervous	Neurology
	Anna	Green	7/12/25	Angina	Cardiovascular	Cardiology
	Mary	Brown	3/16/80	Stroke	Cardiovascular	Cardiology
	Mary	Brown	3/17/80	Asthma	Respiratory	Pneumology
	Mary	Brown	3/18/80	Parkinson's Disease	Nervous	Neurology
	Mary	Brown	3/19/80	Angina	Cardiovascular	Cardiology

New relation

- **ALL ATTRIBUTES**
- **ALL TUPLES**
- The result per se does **not have a real meaning** but it is a matematical tool

JOIN OPERATION

- It operates over two relations (R1 and R2)
- The result of this operation is a relation that (1) combines related tuples from R1 and R2 into single tuples and (2) it is a cartesian product followed by a selection

$$New\_Relation \leftarrow R1 \bowtie_{(condition)} R2$$

JOIN
Example (1/3)

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PATIENT	ID	Name	Surname	Birthdate
	1	Jack	White	11/5/61
	2	Anna	Green	7/9/25
	3	Mary	Brown	3/16/80
	4	Jack	Reds	9/15/73

DIAGNOSIS	Patient_ID	Diagnosis	Dia_Date
	1	Stroke	12/11/85
	2	Asthma	3/31/79
	3	Parkinson's Disease	2/27/01
	4	Angina	4/25/99

We want to calculate the result of the JOIN operation between these two relations

JOIN
Example (2/3)

UNIVERSITÀ DEGLI STUDI DI TRIESTE

$$Pat\_Dia \leftarrow Patient \bowtie_{(ID=Pat\_ID)} Diagnosis$$

JOIN
Example (3/3)

UNIVERSITÀ DEGLI STUDI DI TRIESTE

PAT_DIA	ID	Name	Surname	Birthdate	Patient_ID	Diagnosis	Dia_Date
	1	Jack	White	11/5/61	1	Stroke	12/11/85
	2	Anna	Green	7/9/25	2	Asthma	3/31/79
	3	Mary	Brown	3/16/80	3	Parkinson's Disease	2/27/01
	4	Jack	Reds	9/15/73	4	Angina	4/25/99

New relation

- **ALL ATTRIBUTES**
- **ALL TUPLES satisfying the condition**
- It is the same result as the selection of the tuples where ID=Pat_ID after a cartesian product of Patient and Diagnosis

$$\text{Pat\_Dia} \leftarrow \sigma_{(ID = Pat\_ID)} (\text{Patient X Diagnosis})$$

NATURAL JOIN

- It operates over two relations (R1 and R2)
- The result of this operation is a relation that (1) combines related tuples from R1 and R2 into single tuples, but the set of common attribute is unique (2) it is a cartesian product followed by a selection and a projection

$$New\_Relation \leftarrow R1 \bowtie R2$$

NATURAL JOIN
Example (1/3)

PATIENT	ID	Name	Surname	Birthdate
	1	Jack	White	11/5/61
	2	Anna	Green	7/9/25
	3	Mary	Brown	3/16/80
	4	Jack	Reds	9/15/73

DIAGNOSIS	Patient_ID	Diagnosis	Dia_Date
	1	Stroke	12/11/85
	2	Asthma	3/31/79
	3	Parkinson's Disease	2/27/01
	4	Angina	4/25/99

We want to calculate the result of the NATURAL JOIN operation between these two relations

NATURAL JOIN
Example (2/3)

$$\text{Pat\_Dia} \leftarrow \text{Patient} \bowtie \text{Diagnosis}$$

NATURAL JOIN
Example (3/3)

UNIVERSITÀ DEGLI STUDI DI TRIESTE

PAT_DIA	ID	Name	Surname	Birthdate	Diagnosis	Dia_Date
	1	Jack	White	11/5/61	Stroke	12/11/85
	2	Anna	Green	7/9/25	Asthma	3/31/79
	3	Mary	Brown	3/16/80	arkinson's Diseas	2/27/01
	4	Jack	Reds	9/15/73	Angina	4/25/99

New relation

- **The same as the one obtained by the JOIN but the patient ID is repeated only once**
- It is the same result as the selection of the tuples where ID=Pat_ID after a cartesian product of Patient and Diagnosis and projecting all the attributes except Pat_ID

NATURAL JOIN vs JOIN

PAT_DIA	ID	Name	Surname	Birthdate	Patient_ID	Diagnosis	Dia_Date
	1	Jack	White	11/5/61	1	Stroke	12/11/85
	2	Anna	Green	7/9/25		Asthma	3/31/79
	3	Mary	Brown	3/16/80		Parkinson's Disease	2/27/01
	4	Jack	Reds	9/15/73	4	Angina	4/25/99

PAT_DIA	ID	Name	Surname	Birthdate	Diagnosis	Dia_Date
	1	Jack	White	11/5/61	Stroke	12/11/85
	2	Anna	Green	7/9/25	Asthma	3/31/79
	3	Mary	Brown	3/16/80	arkinson's Diseas	2/27/01
	4	Jack	Reds	9/15/73	Angina	4/25/99

RENAME OPERATION

- It operates over SINGLE RELATIONS
- It allows giving new names to the attributes of a relation
- The result of this operation is a relation that has the same attributes as the original one but with different names

$$New\_Relation \leftarrow \rho_{(renaming\_criteria)}(Relation\_Name)$$

(renaming_criteria) are in the form:
B1,B2,…Bn ← A1,A2,…,An

RENAME OPERATION
Example

UNIVERSITÀ DEGLI STUDI DI TRIESTE

PATIENT	Name	Surname	Birthdate	Gender
	Jack	White	11/5/61	M
	Anna	Green	7/9/25	F
	Mary	Brown	3/16/80	F
	Jack	Reds	9/15/73	M

$$New\_Pat \leftarrow \rho_{(First\_Name,Family\_Name \leftarrow Name,Surname)}(Patient)$$

PATIENT	First Name	Family Name	Birthdate	Gender
	Jack	White	11/5/61	M
	Anna	Green	7/9/25	F
	Mary	Brown	3/16/80	F
	Jack	Reds	9/15/73	M

Set Theoretic Operations

- They operate over two relations (R1 and R2) **having the same schema**

- **UNION OPERATION -** The result of this operation is a relation that includes all the tuples that are either in R1 or in R2 (Duplicate tuples are eliminated)
- **INTERSECTION OPERATION- t**he result of this operation is a relation that includes all the tuples that are both in R1 and in R2
- **SET DIFFERENCE OPERATION -** The result of this operation is a relation that includes all tuples that are in R1 but NOT in R2 – the order of the relations is relevant (**not commutative**)

Relational algebra for set theoretic operations

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New_Relation ← $R1 \cup R2$

New_Relation ← $R1 \cap R2$

New_Relation ← $R1 - R2$

Example

UNIVERSITÀ DEGLI STUDI DI TRIESTE

PATIENT_UO1	ID%	Family Name	Diagnosis Date%	Diagnosis	Physician Name
	1123	White	12/11/85	Stroke	Ackerman
	1763	Green	3/31/79	Stroke	Reds
	2156	Brown	2/27/01	SA nodal block	Hanna

PATIENT_UO2	ID%	Family Name	Diagnosis Date%	Diagnosis	Physician Name
	1123	White	12/11/85	Stroke	Ackerman
	1763	Green	4/25/99	Angina	Grey
	1763	Green	11/18/03	Angina	Rome

Two relations **having the same schema**

Example

PATIENT_UNION	ID%	Family Name	Diagnosis Date%	Diagnosis	Physician Name
	1123	White	12/11/85	Stroke	Ackerman
	1763	Green	3/31/79	Stroke	Reds
	2156	Brown	2/27/01	SA nodal block	Hanna
	1763	Green	4/25/99	Angina	Grey
	1763	Green	11/18/03	Angina	Rome

PATIENT_INTER	ID%	Family Name	Diagnosis Date%	Diagnosis	Physician Name
	1123	White	12/11/85	Stroke	Ackerman

PATIENT_DIFF	ID%	Family Name	Diagnosis Date%	Diagnosis	Physician Name
	1763	Green	3/31/79	Stroke	Reds
	2156	Brown	2/27/01	SA nodal block	Hanna

Example

Surname	Name	BirthDate	Gender
Bianchi	Luca	1962-05-08	M
Mascheroni	Marinella	1965-12-02	F
Strozzi	Giulia	1964-02-11	F
Aldobrandi	Enrico	1960-02-29	M

1 Retrieve names and surnames of the male patients;

2 Retrieve all data of the patients whose surname is "Bianchi";

3 Retrieve names, surnames, and birth year of all patients.

Retrieve names and surnames of the male patients;

Retrieve all data of the patients whose surname is “Bianchi”;

Retrieve names, surnames, and birth year of all patients

Operating on relational databases: The SQL

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- SQL (Structured Query Language): query language for relational databases;
- SQL is an ISO standard: independent from the implementation system;
- It specifies the characteristics of the results (Declarative Langugе) instead of the operations needed to obtain the results (as in procedural languages);
- SQL uses the terms Table, Row, Column that correspond to Relation, Tuple, Attribute in the relational model.