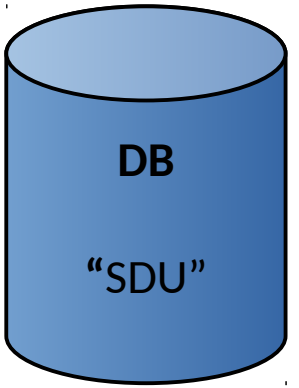
DM534: Introduction to Relational Databases

Slides by Christian Wiwie
(With edits by Rolf Fagerberg)

SDU
UNIVERSITY OF
SOUTHERN DENMARK

Some perspective …

What are Databases?

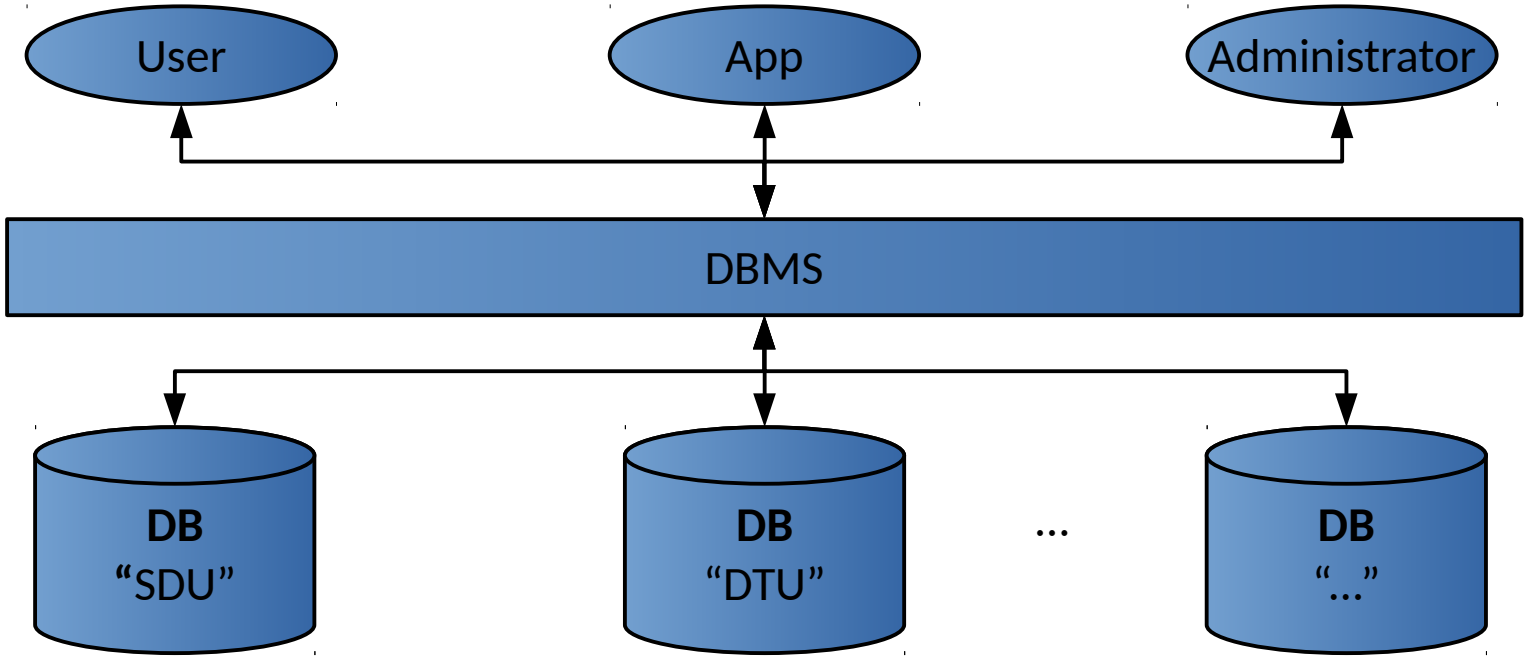


A large software tool that:

- Can store large amounts of data
- Describes a logical structure of contained data
- Guarantees data integrity by enforcing constraints
- Allows for efficient and flexible access
- Ensures Consistent and safe storage

Database Management System (DBMS)

- A DBMS manages databases
- Access to database only via DBMS



Why learn about Databases?

- Used almost everywhere
- Crucial for safety & integrity of stored data
- Jobs exist dealing specifically with databases
- Increasingly relevant as we generate and store more and more data

Where are Databases used?

Wherever large amounts of data are managed:

- Corporate data: payrolls, inventory, sales, customers, …
- University records of students, grades, courses,…
- Scientific and medical databases
- Data backend behind webpages

Often multiple DBMS in use that cater specific needs

- **Google** uses *Bigtable* for web indexing, Google Maps, …
- **Facebook** uses *MySQL; TAO* for graph search,…

Features of a modern DBMS

- Highly **efficient access** to stored data using *indexes*
- Backup/log mechanisms ensure **data safety**
- Security policies to manage access **permissions**
- Data **consistency**: Can enforce complex data constraints, including dependencies
- Flexible **searching, sorting, filtering**
- Ensures all the above with simultaneous multi-user access

Databases vs. storage in files

- File storage does not provide most of these features

  → Structure and constraints need to be imposed manually

- Complex operations
  - not trivial to do right → Error prone
  - are slow, e.g. searching, sorting

Types of DBMS / databases

- Data can be modeled and organized differently
- Optimized for specific kinds of operations
- **Relational DBMS (RDBMS) / databases** the most wide-spread

  Based on mathematical relations

  Basically, a database is a collection of relations

  e.g. MySQL, PostgreSQL, Oracle, …
- **Graph DBMS / databases**

  Data is a network, with entities and connections between them

  e.g. neo4j

Most widely used DBMS

- Ranking of most widely used DBMS

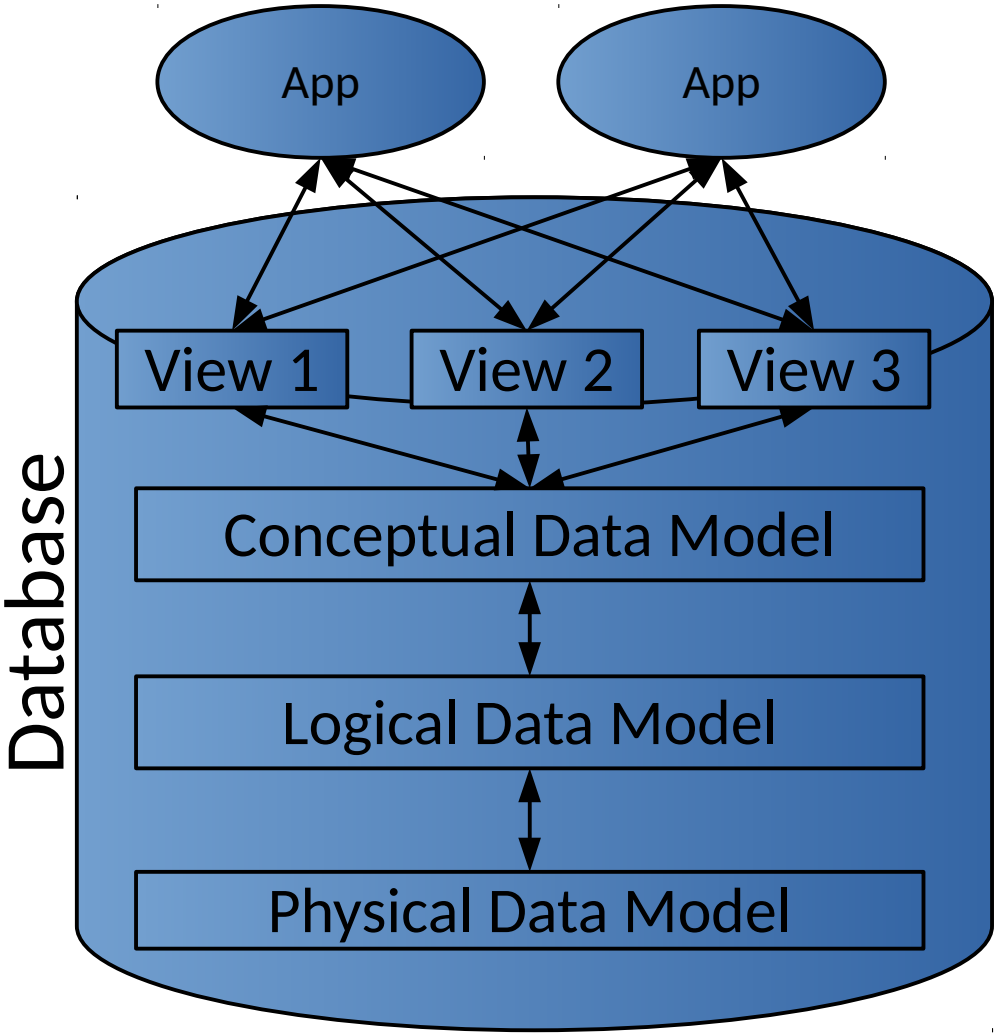
346 systems in ranking, October 2018

Rank			DBMS	Database Model	Score		
Oct 2018	Sep 2018	Oct 2017			Oct 2018	Sep 2018	Oct 2017
1.	1.	1.	Oracle	Relational DBMS	1319.27	+10.15	-29.54
2.	2.	2.	MySQL	Relational DBMS	1178.12	-2.36	-120.71
3.	3.	3.	Microsoft SQL Server	Relational DBMS	1058.33	+7.05	-151.99
4.	4.	4.	PostgreSQL	Relational DBMS	419.39	+12.97	+46.12
5.	5.	5.	MongoDB	Document store	363.19	+4.39	+33.79
6.	6.	6.	DB2	Relational DBMS	179.69	-1.38	-14.90
7.	↑ 8.	↑ 9.	Redis	Key-value store	145.29	+4.35	+23.24
8.	↓ 7.	↑ 10.	Elasticsearch	Search engine	142.33	-0.28	+22.09
9.	9.	↓ 7.	Microsoft Access	Relational DBMS	136.80	+3.41	+7.35
10.	10.	↓ 8.	Cassandra	Wide column store	123.39	+3.83	-1.40

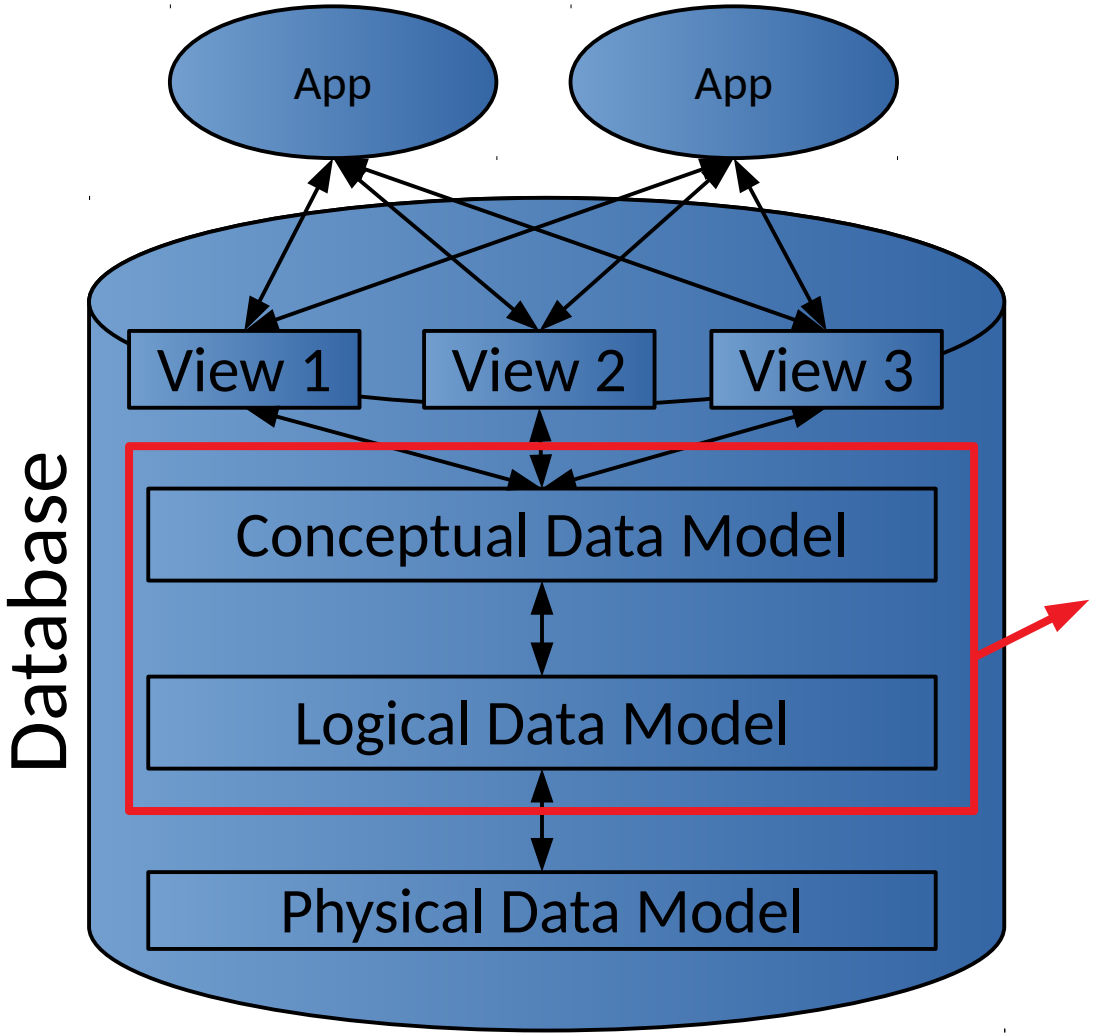
Source: https://db-engines.com/en/ranking

Internal Structure of a Database

- Multiple levels of abstraction
- Higher levels independent of lower levels
- Software independent of how data is logically and physically structured and stored



Internal Structure of a Database



We will be looking at this part

From here on we are exam relevant

Conceptual Data Model

- Semantics of stored data
- Which **entities** (concepts) are stored?
- Which **relationships** exist between entities?

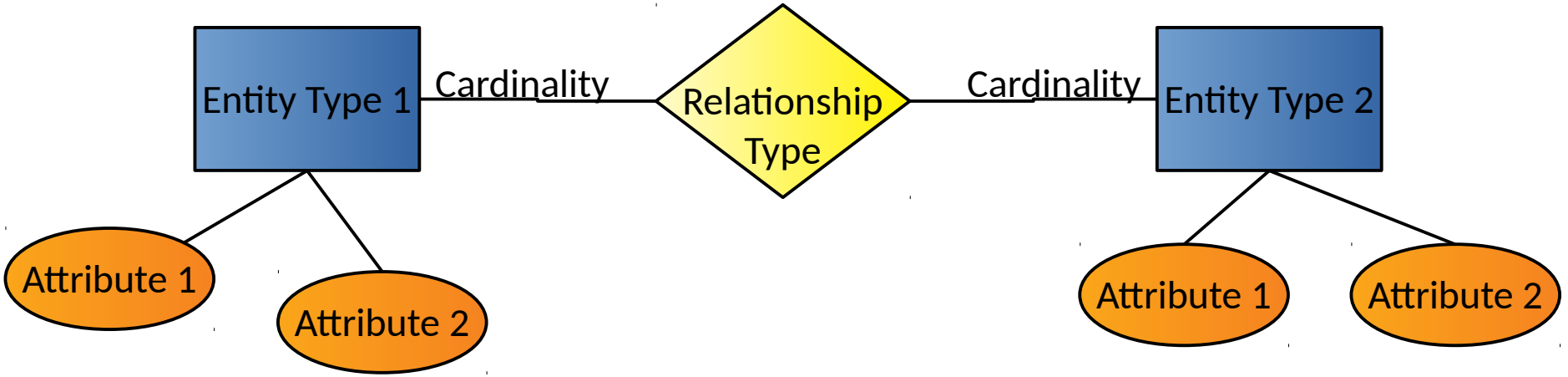
Is independent of DBMS type and specific DBMS used.
Is used for modelling/defining the structure of the data that can be stored.

SDU
UNIVERSITY OF SOUTHERN DENMARK

Conceptual Data Model

Most widely used conceptual model:

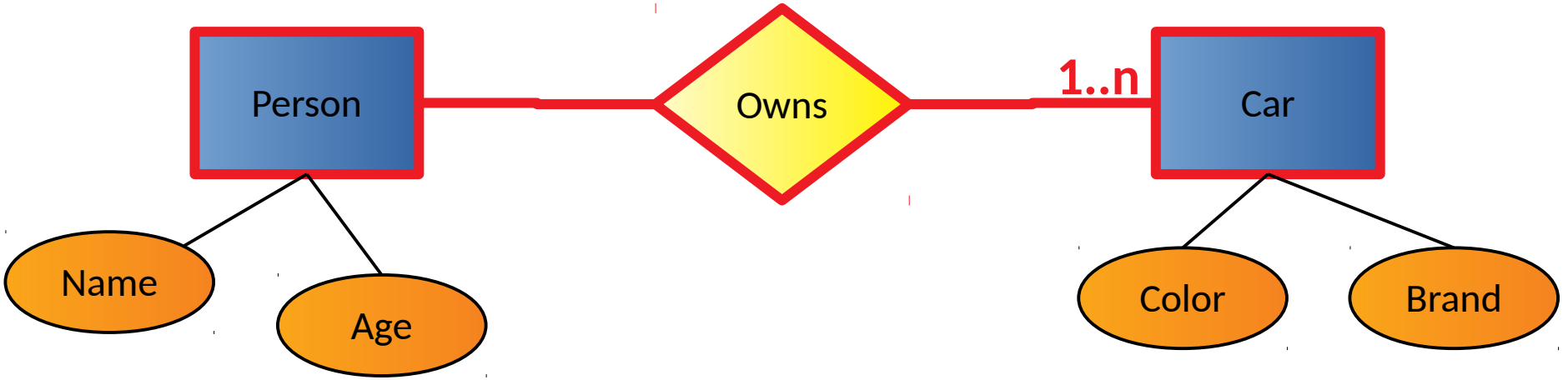
Entity-Relationship (ER) diagrams



Cardinality: How many entities are involved in a relationship?

Conceptual Data Model

- Example Cardinalities

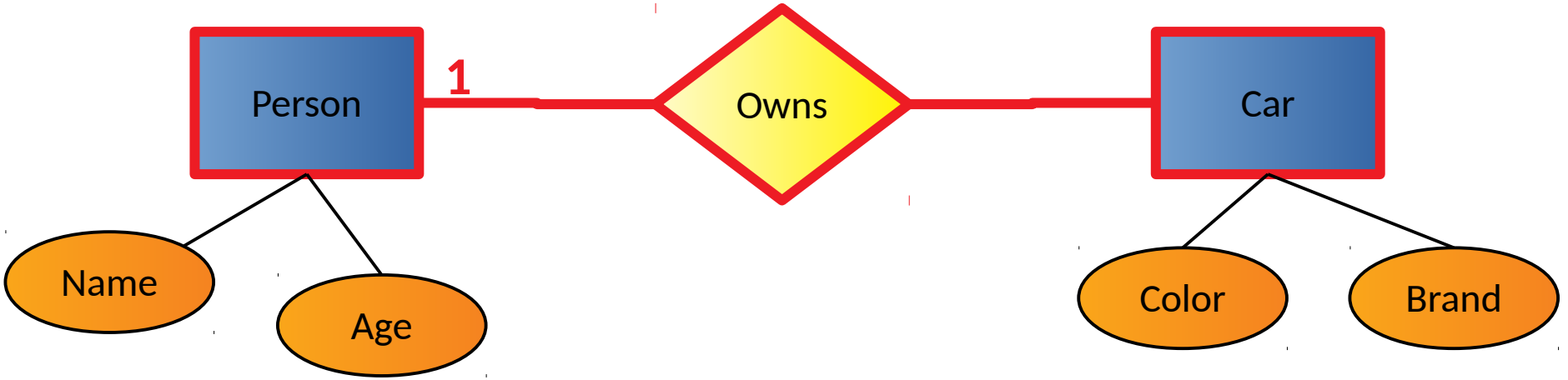


- Read:

  One person owns **one or more cars**

Conceptual Data Model

- Example Cardinalities



- Read:

  One car is owned by **exactly one person**

  → Constraints do not necessarily hold in reality (joint ownership)

Logical Data Model

- Usually derived from conceptual data model
- Expressed in terms of data structures specific to *type* of DBMS

  Relational DBMS: relational (logical) data model

  Graph DBMS: a graph structure

- But: Still independent of specific DBMS used

We focus on relational DBMS

Relational (Logical) Data Model

- Main structural concept: **relations**

  Is basically a fancy name for tables

name	age
'Henry'	36
'Thomas'	22

- A relation has a **relation schema**

  Specifies structure of data that *can be stored* in relation

- relations != relationship

  Relationship is part of conceptual data model

  There is a standard translation (see later slides) from the conceptual model to the relational model, i.e from ER-models to relation. In this translation, one relation will hold data for either an entity or a relationship.

Relational (Logical) Data Model

- A **relation schema** consists of:
  - a name
  - a set of attribute names
  - Optionally: attribute types

relation_name(*attribute*$_1$, *attribute*$_2$, …) or

relation_name(*attribute*$_1$: *type*$_1$, *attribute*$_2$: *type*$_2$, …)

Relation Schemas

- Example **relation schemas**:
  - *Car(color, brand)*
  - *Person(name: CHAR(20),age: INTEGER)*
  - *Owns(name, age, color, brand)*

Relation Instances

- A relation or relation schema does not specify which data is stored

- A **relation instance** is a realization of a relation with data

  Data must conform to relation's schema

- Many relation instances can exist for the same relation (similarly to classes vs. objects).

SDU
UNIVERSITY OF SOUTHERN DENMARK

Tuples

- A data entry in a relation instance is called **tuple**
- A **tuple** is a realization of the relation's schema
  - Assigns values to the attributes of the relation
  - Must conform to relation schema

SDU
UNIVERSITY OF SOUTHERN DENMARK

Tuples

- Example tuples of the relation *Car(color, brand)*:
  - (‘red’, ‘Ford’)
  - (‘blue’, ‘Mercedes’)

- Example tuples of the relation *Person(name, age)*:
  - (‘Henry’, 36)
  - (‘Thomas’, 22)

Relation Instance

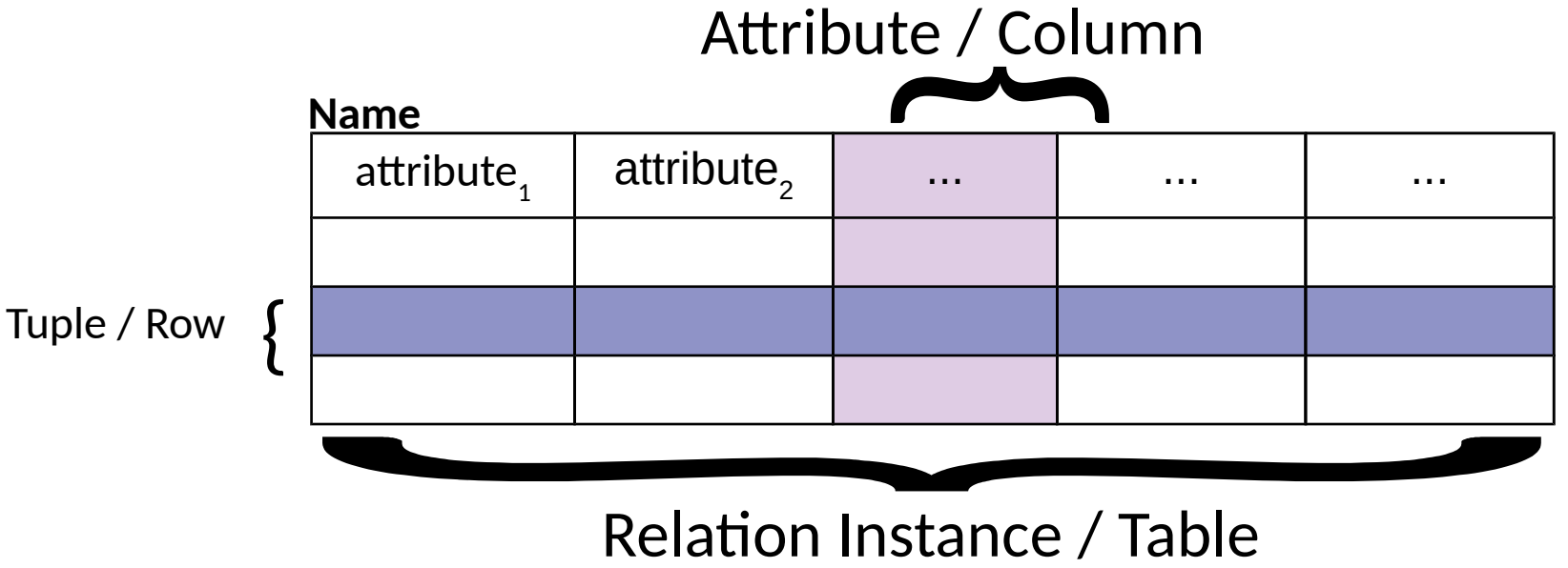
Example **relation instance** of the person relation

Person

name	age
‘Henry’	36
‘Thomas’	22

Relation Instances

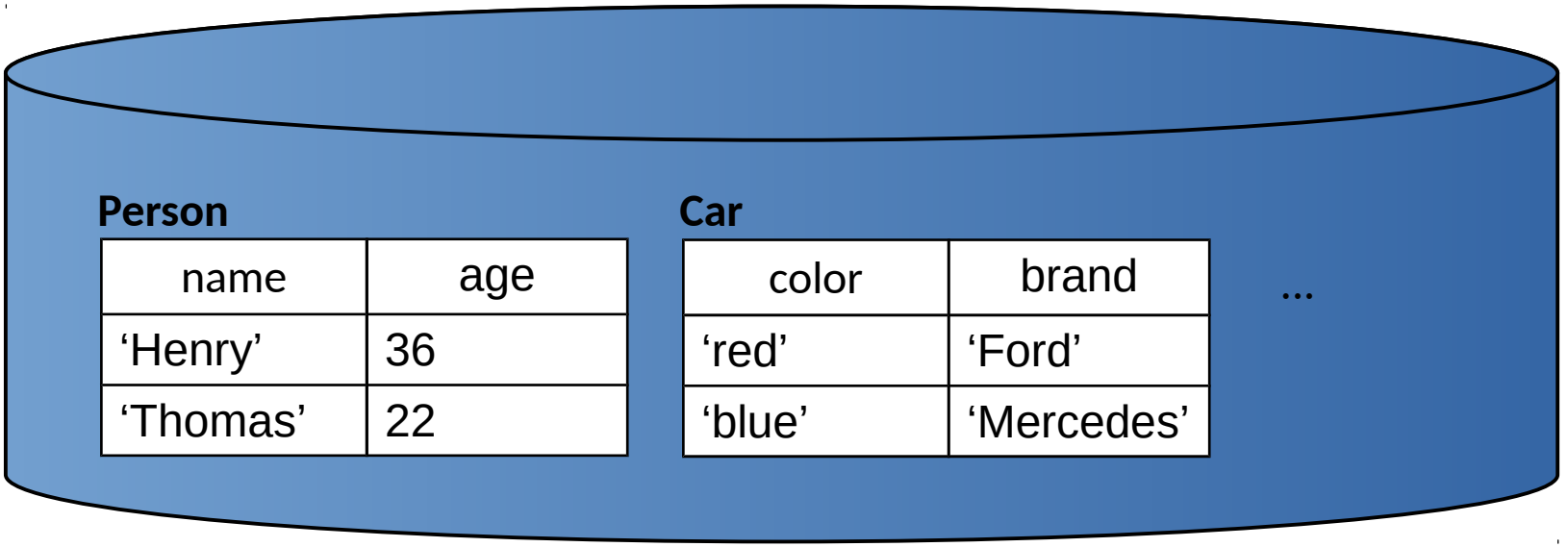
Summing up, the relational model is a set of fancy new names for the various parts of tables:



Database Instance

- A **database instance** is the collection of all its relation instances

  i.e. all relation schemas and their corresponding tuples



Person

name	age
‘Henry’	36
‘Thomas’	22

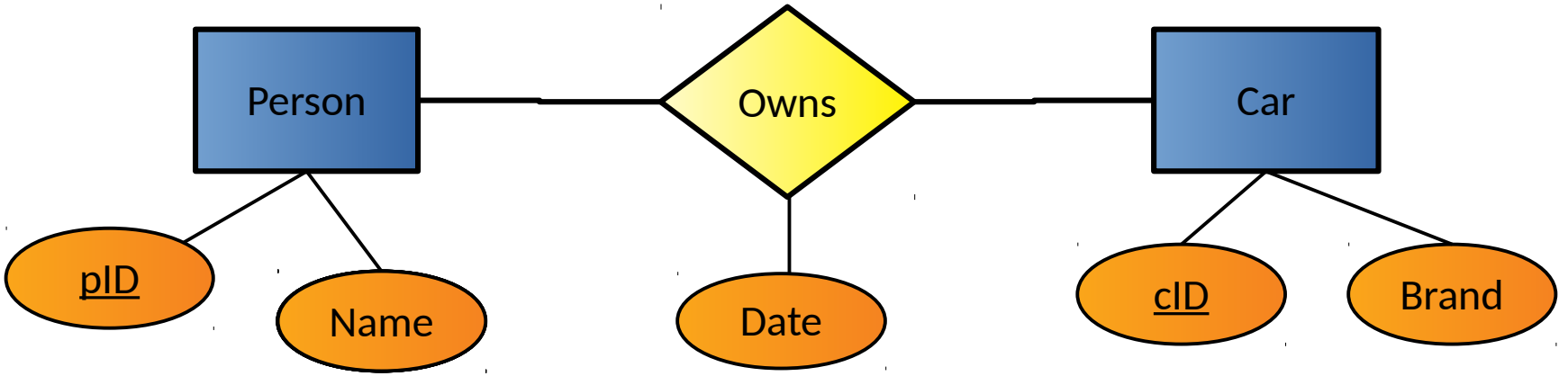
Car

color	brand
‘red’	‘Ford’
‘blue’	‘Mercedes’

...

From ER Diagrams to Relations

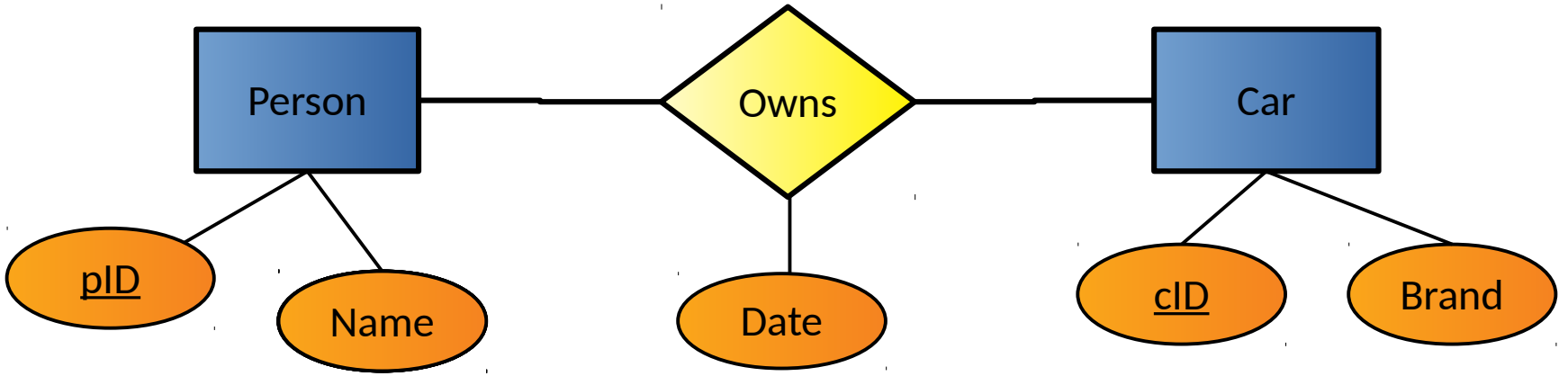
Standard translation:



- Each **entity** is converted directly to a relation (same attributes and keys).
- Each **relationship** is converted to a relation with attributes consisting of the keys of its related entities plus its own attributes (if any). More on keys later.

From ER Diagrams to Relations

Example:



Person(pID: INTEGER, Name: CHAR(20))

Car(cID: INTEGER, Brand: CHAR(20))

Owns(pID: INTEGER, cID: INTEGER, Date: CHAR(10))

Integrity Constraints (ICs)

Integrity Constraints (ICs)

- Condition that must be true for any database instance
- Specified when relation schemas are defined
- Checked whenever relation instances are modified

  i.e., when tuple is added, deleted, or modified

Domain constraints

- Domain of valid values for an attribute
  - e.g., INTEGER, FLOAT, CHAR(20), …
  - correspond to data types in programming languages
- Example relation schema:

  Person(name: CHAR(20),age: INTEGER)

name	age
‘Henry’	36
‘Mads’	‘Doe’

Domain constraint violation

→ DBMS will not allow insertion of this tuple

Semantic integrity constraints

- Semantic restrictions on the data

  e.g., age >= 18

- Example relation schema:

  Person(name: CHAR(20),age: INTEGER)

name	age
‘Henry’	36
‘Mads’	16

Constraint violation

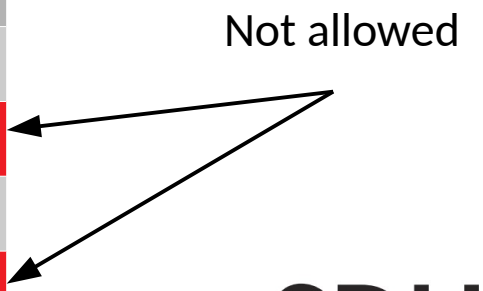
→ DBMS will not allow insertion of this tuple

Primary Keys

- Set of relation attributes
  - that uniquely identifies tuples of relation
  - all tuples need to have unique values for these attributes
- Example: CPR is primary key of relation **Person**

  → There cannot be two tuples with same CPR number

CPR	Name	Birthday	Address
...	...	...	...
1904651243	Svensson	19.04.1965	...
...	...	...	...
1904651243	...	...	...
...	...	...	...



SDU
UNIVERSITY OF SOUTHERN DENMARK

Primary Keys

- Primary key “points” to exactly one tuple

  → can be used to lookup corresponding tuple

  → e.g., person can be looked up using CPR

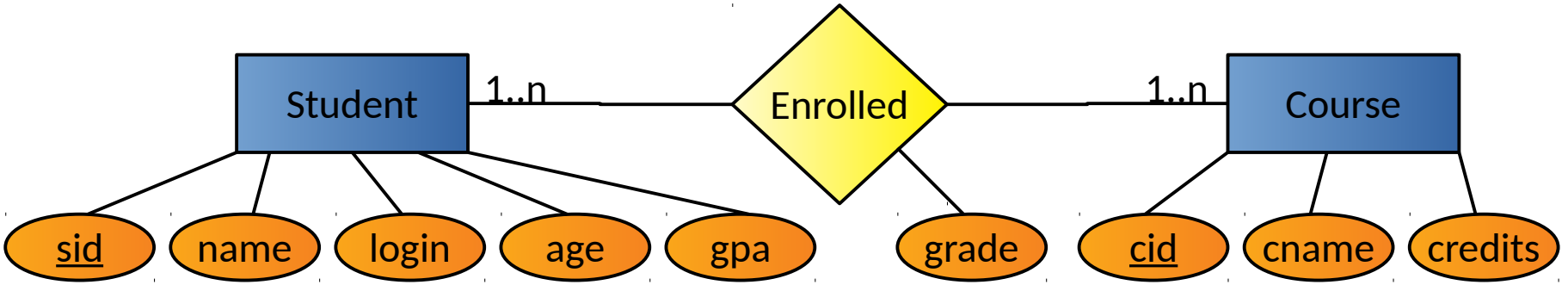
What is the name of the person with CPR=1904651243 ?

CPR	Name	Birthday	Address
...	...	...	...
1904651243	Svensson	19.04.1965	...
...	...	...	...

Foreign Keys

- Allow to associate tuples in different relations
- Tuple of source relation → tuple of target relation
  - Source and target relation can be the same
  - Can only point to a primary key in the target relation
  - Existence of a tuple with that primary key in target relation can be enforced by DBMS

Example: University Database



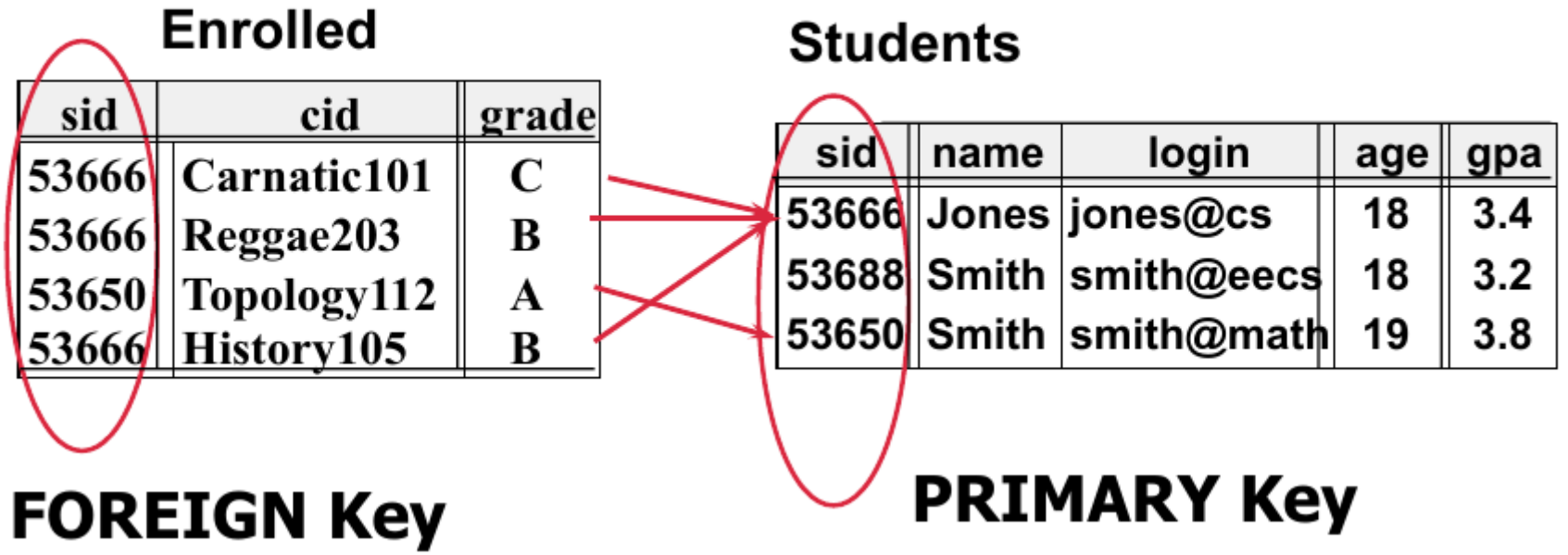
Relation schemas:

Students(sid: string, name: string, login: string, age: integer, gpa:real)

Courses(cid: string, cname:string, credits:integer)

Enrolled(sid:string, cid:string, grade:string)

Example: Foreign Keys



Query Languages

Query Languages

- Allow manipulation and retrieval of data from a database
- Query languages != programming languages
- not expected to be “turing complete”

  → i.e., not every algorithm can be expressed
- not intended to be used for complex calculations
- support easy, efficient access to large data sets

Relational Query Languages

- Based on relational algebra
- For relational databases, i.e. relational data model
- Relational model supports simple, powerful QLs:
  - Strong formal foundation based on logic
  - Allows for much optimization
- **SQL**: Most widely used relational query language

→ Understanding Relational Algebra is key to understanding SQL, query processing!

SDU
UNIVERSITY OF SOUTHERN DENMARK

Relational Query Languages

More on relational query languages and relational algebra at next lecture.