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# Databases

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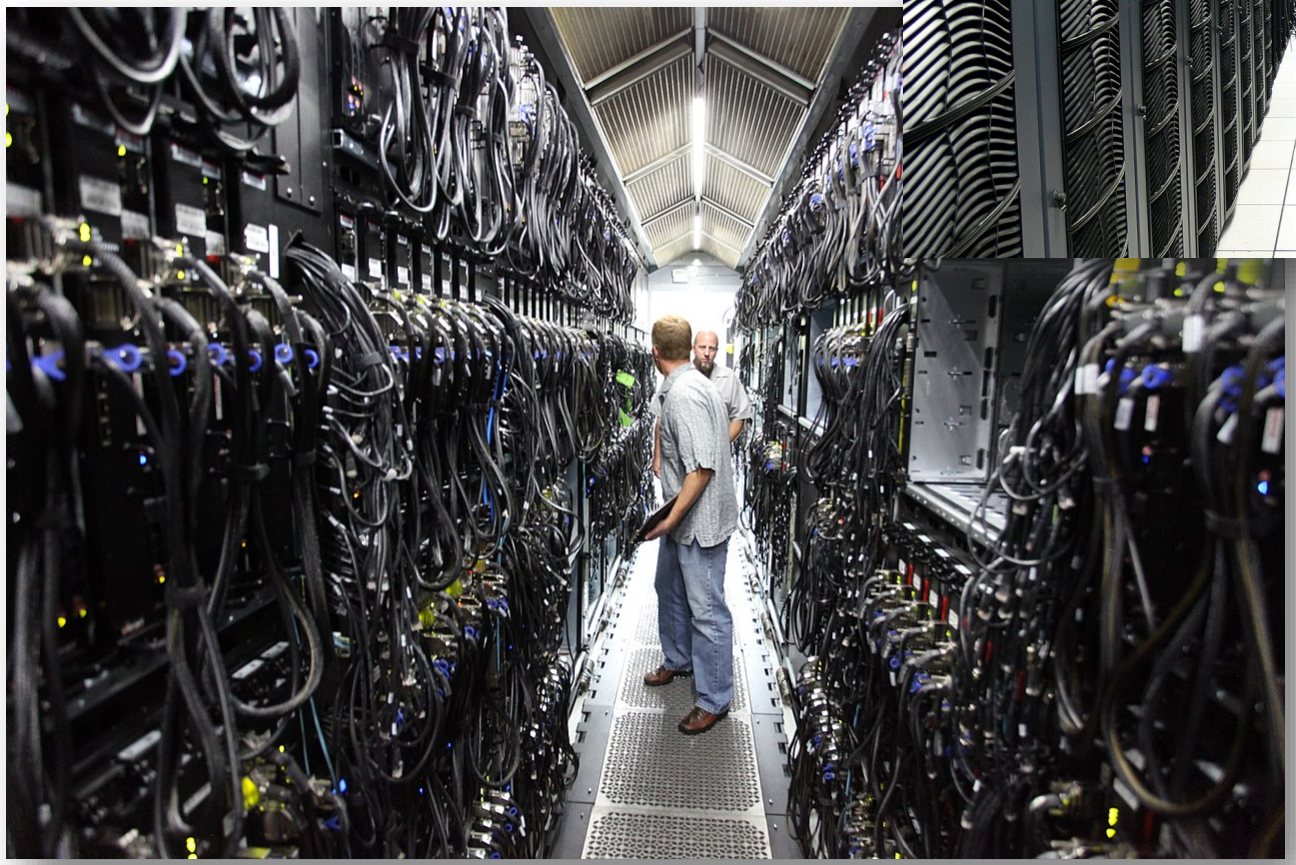

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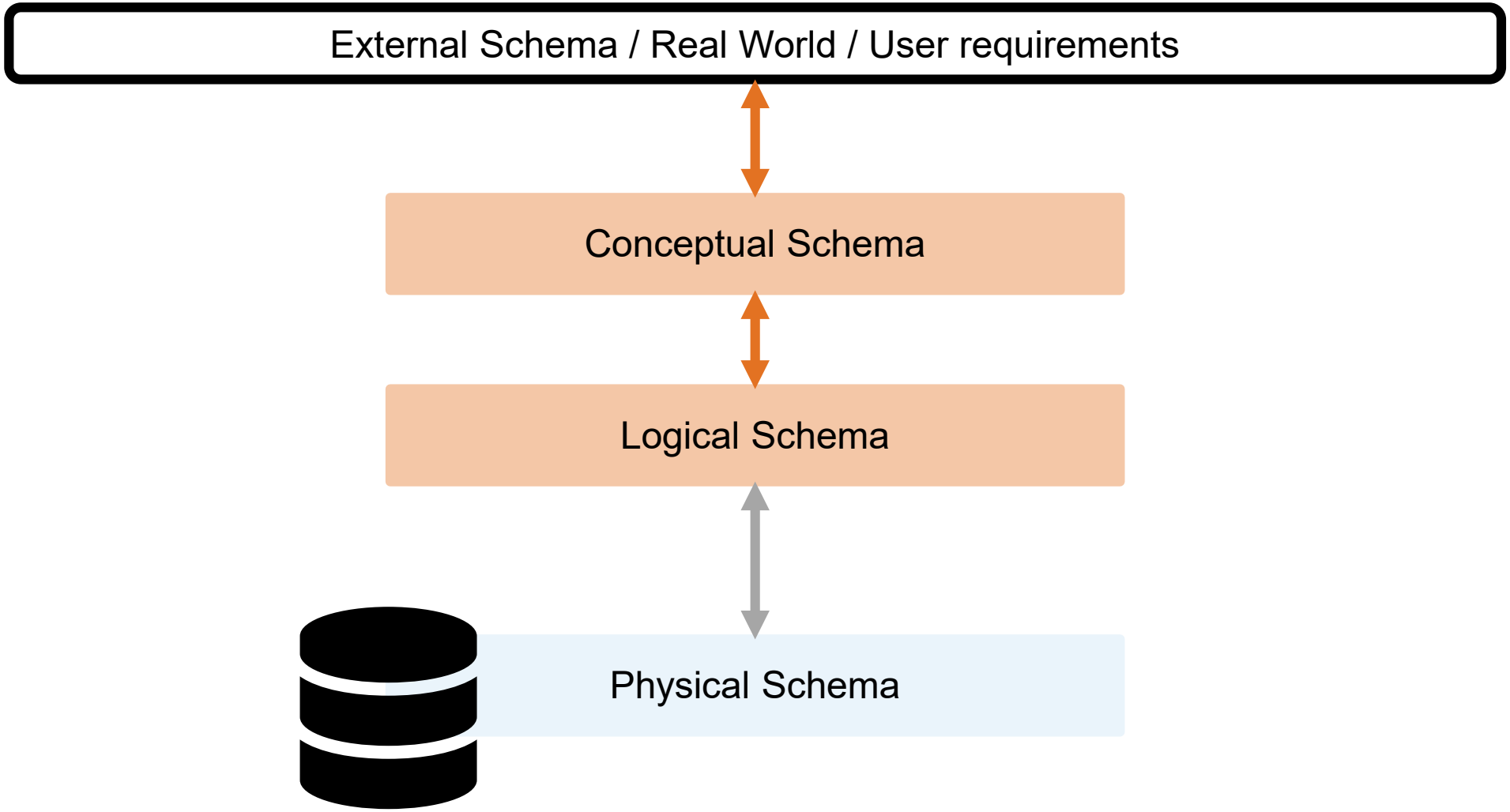
# Levels of Abstraction



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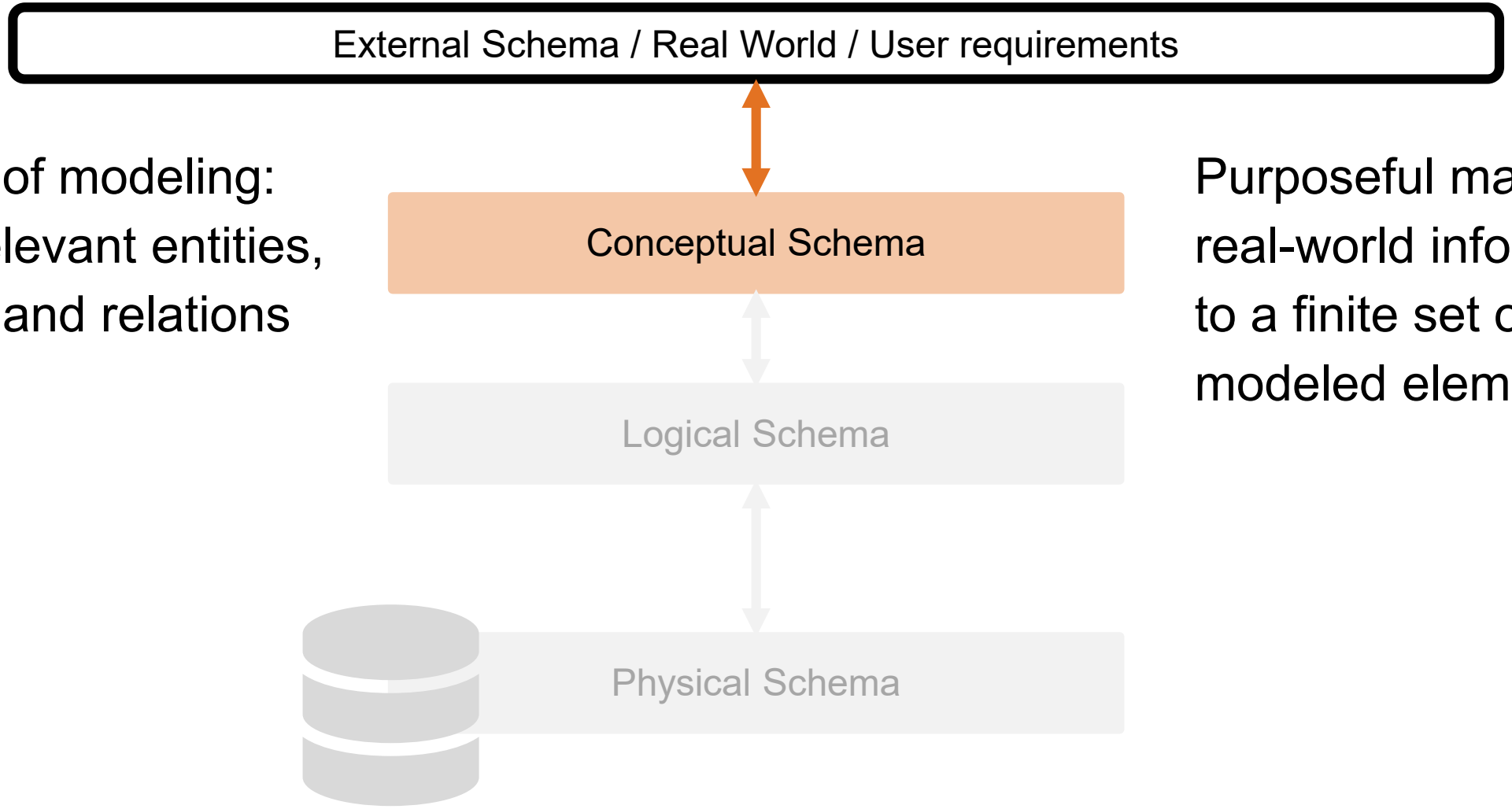
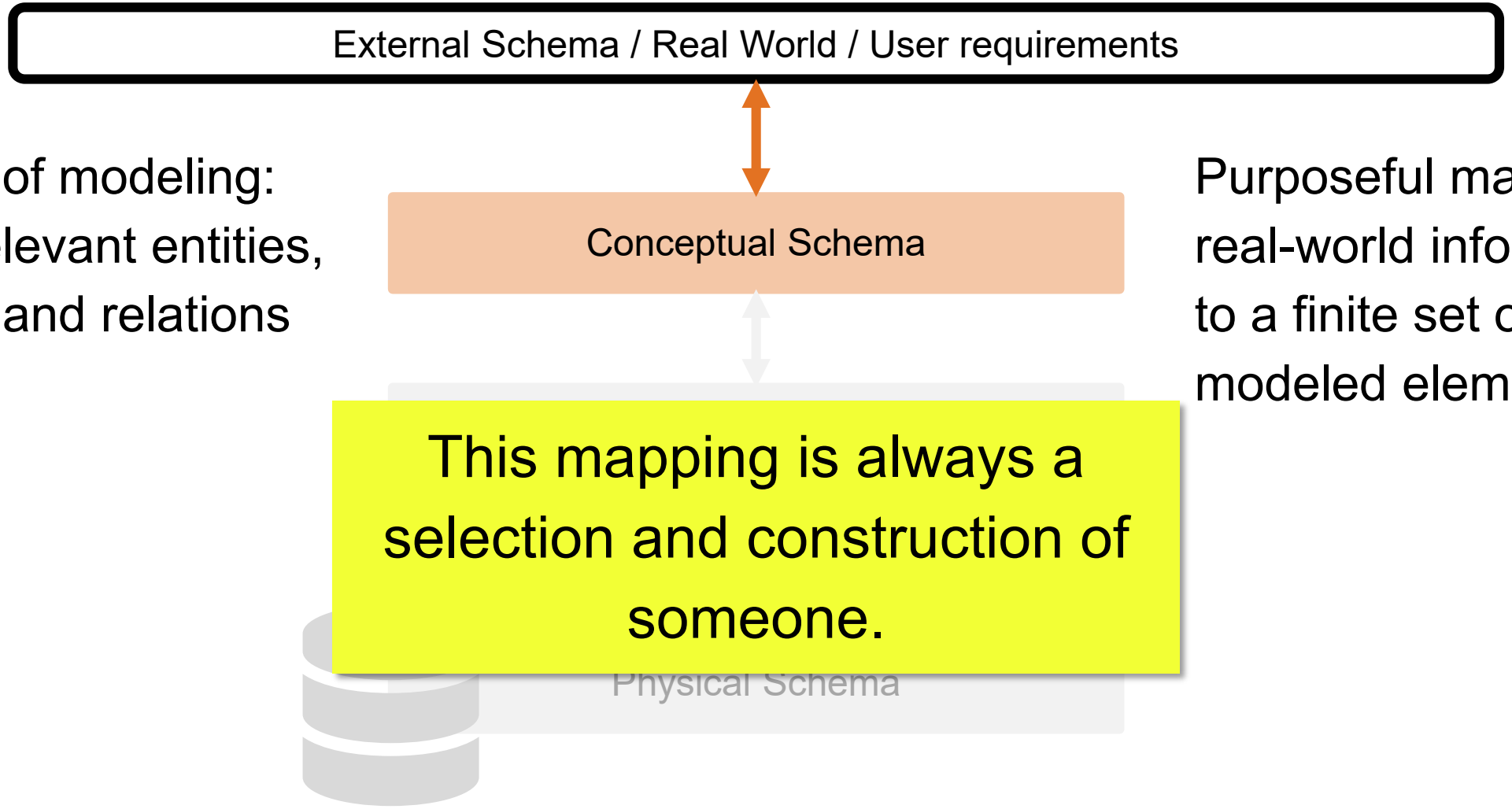



First step of modeling:
Identify relevant entities, attributes and relations

Purposeful mapping of real-world information to a finite set of modeled elements.

# Levels of Abstraction

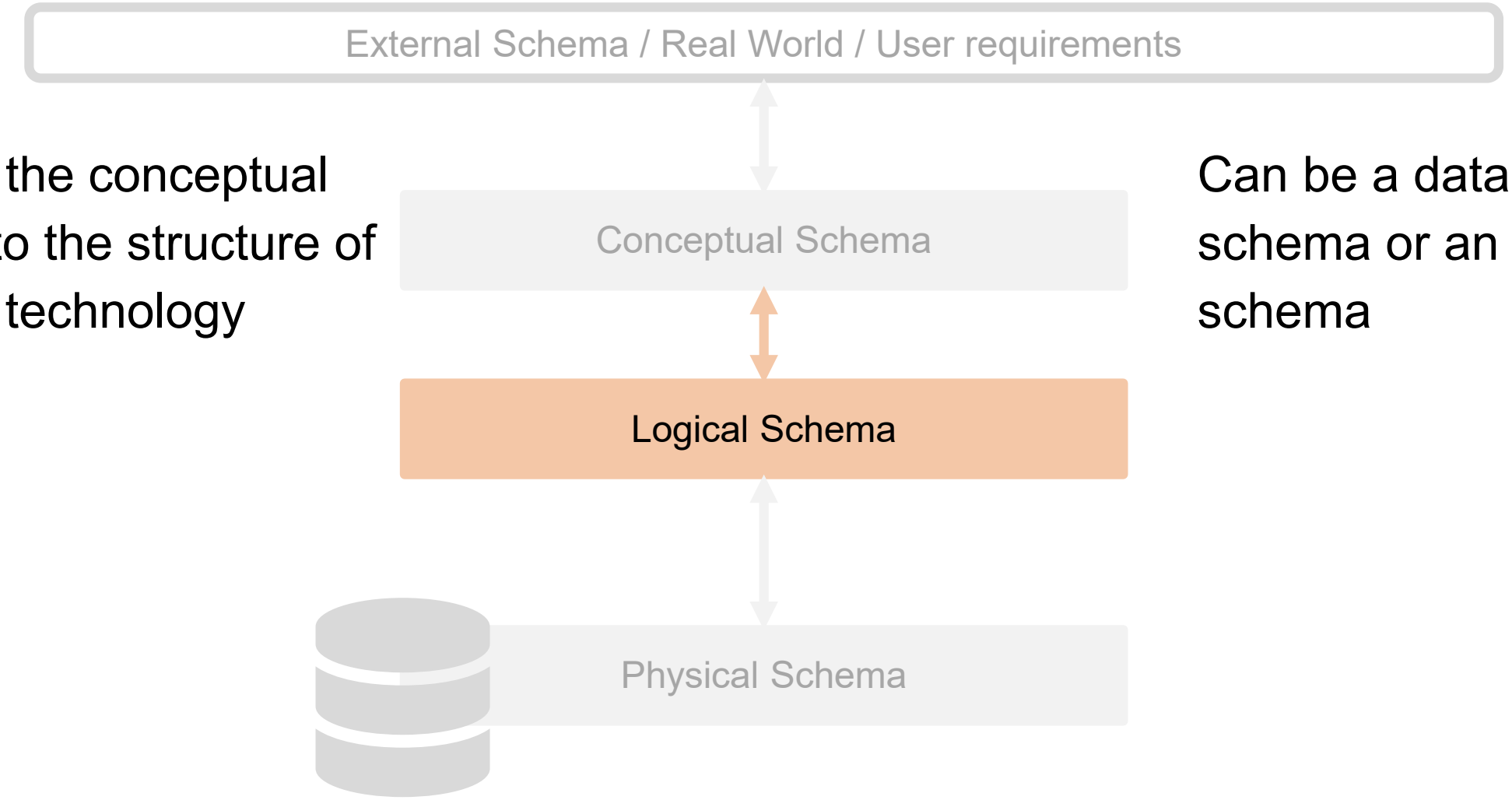



First step of modeling: Identify relevant entities, attributes and relations

This mapping is always a selection and construction of someone.

Purposeful mapping of real-world information to a finite set of modeled elements.

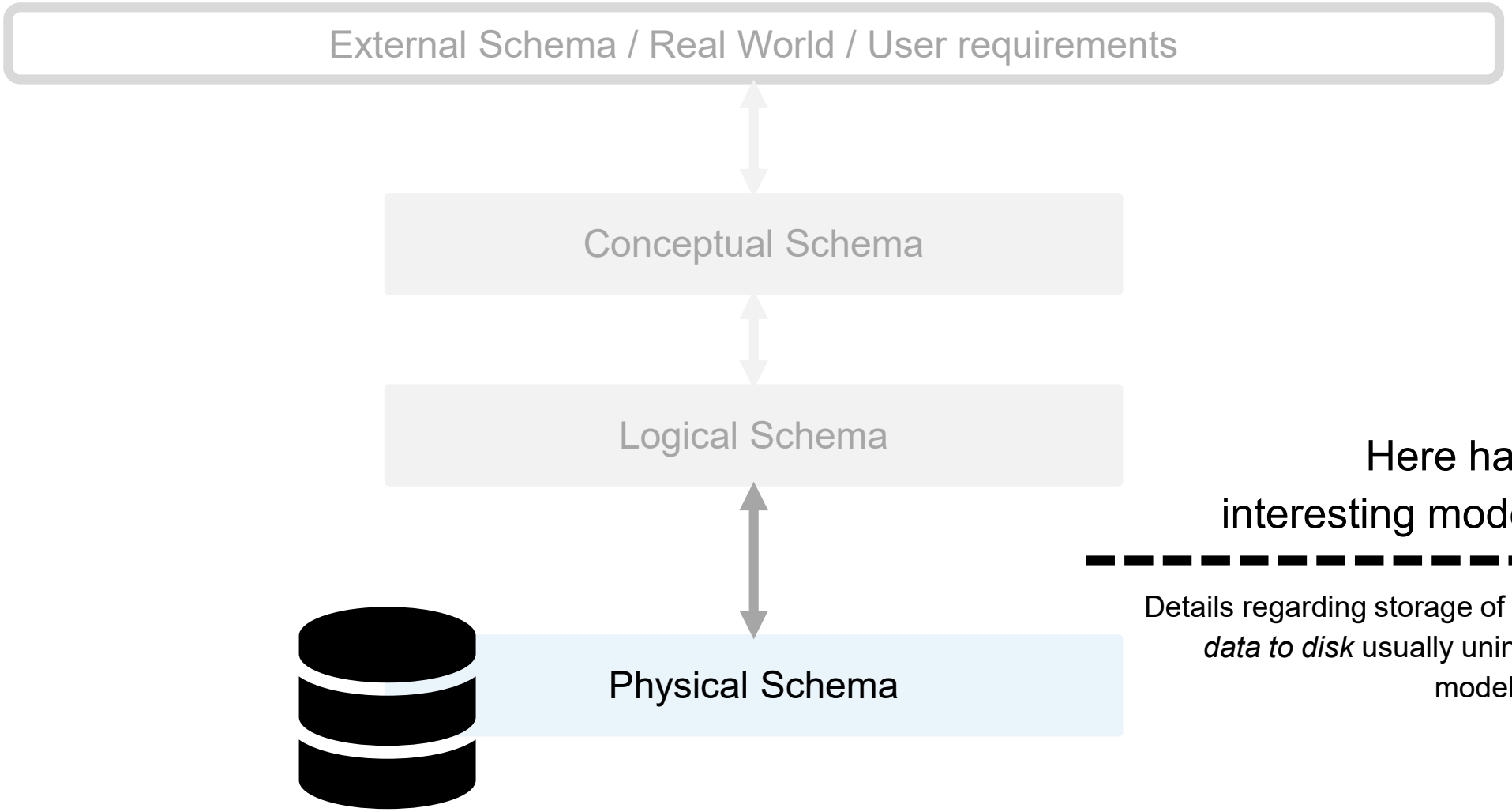
# Levels of Abstraction




Mapping the conceptual schema to the structure of a certain technology

Can be a database schema or an XML schema

# Levels of Abstraction



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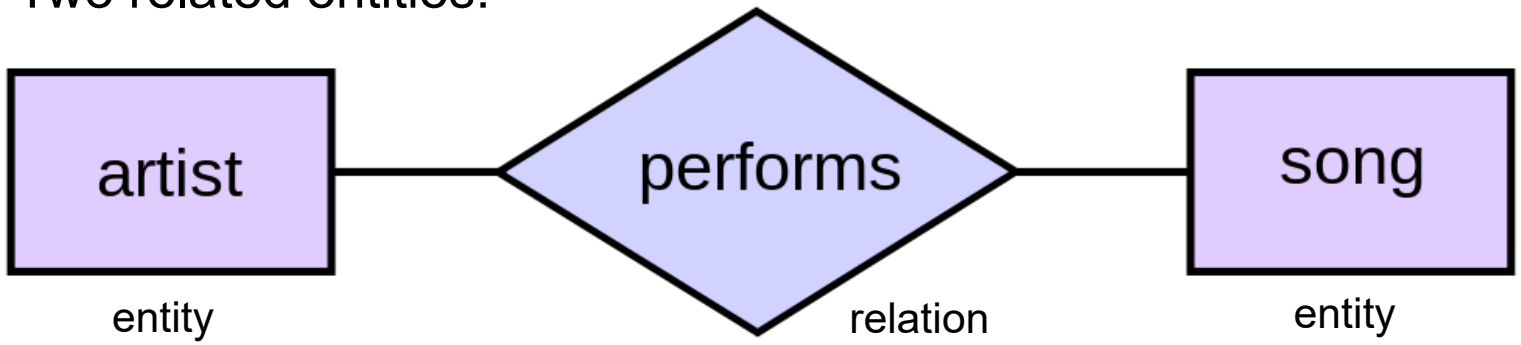
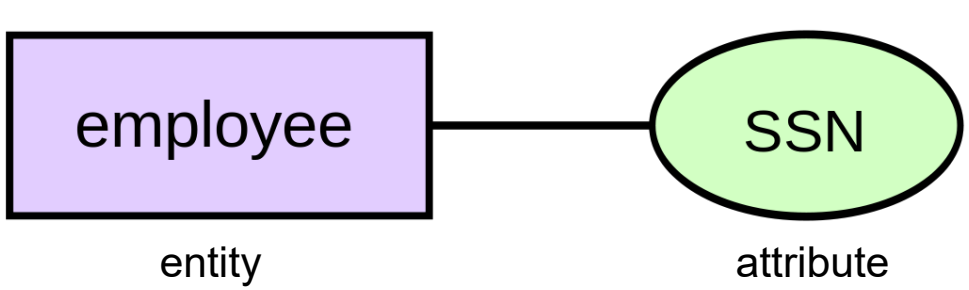
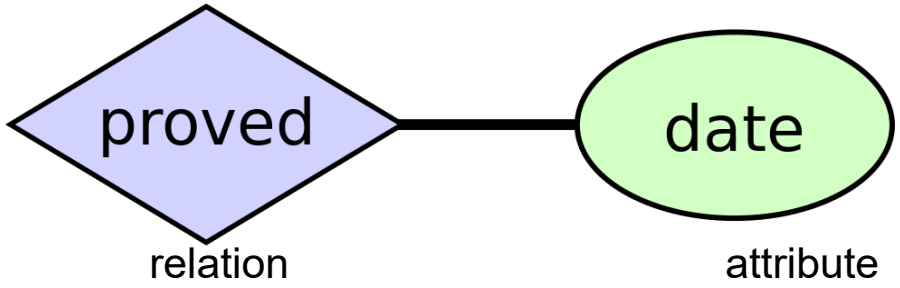
Two related entities:




Entities and relations with attributes:




Chen, Peter (1976). "The Entity-Relationship Model - Toward a Unified View of Data". ACM Transactions on Database Systems. 1 (1): 9–36.

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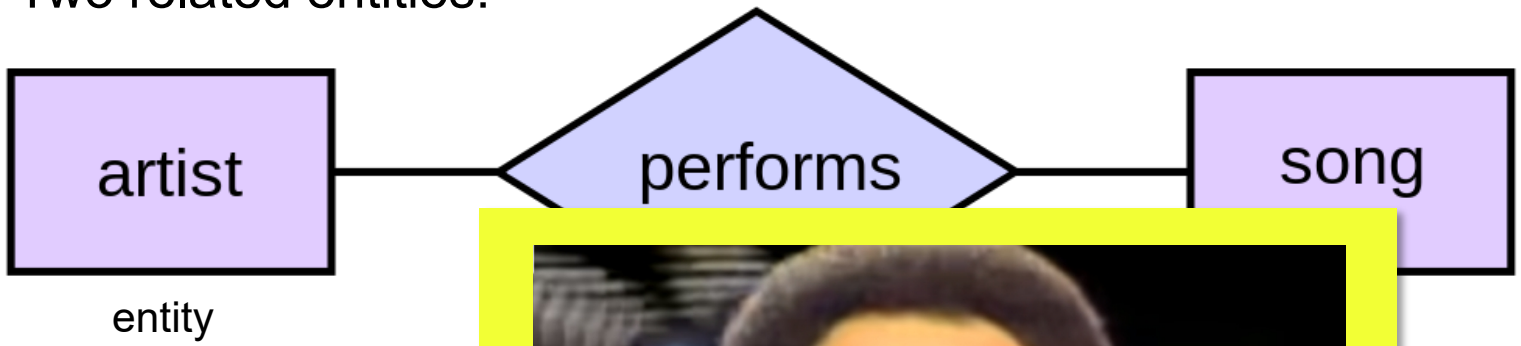
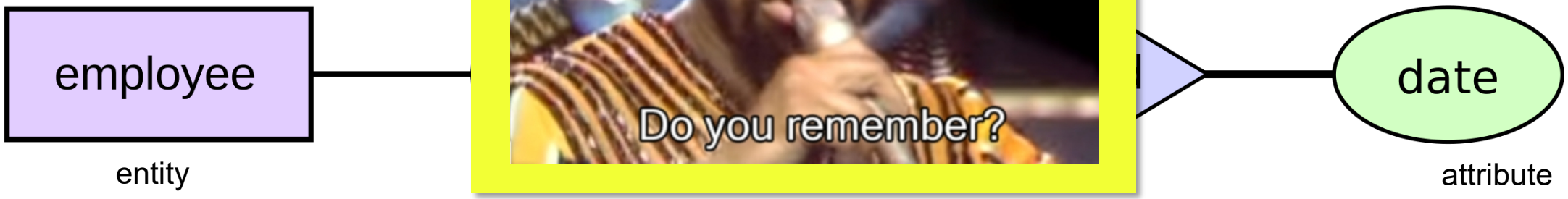
Two related entities:




Entities and relations with attribu





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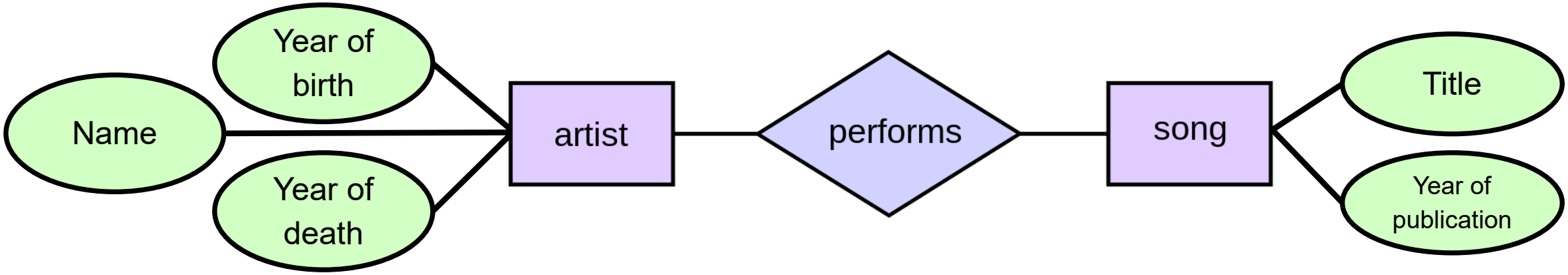
# From ER to Relational Models

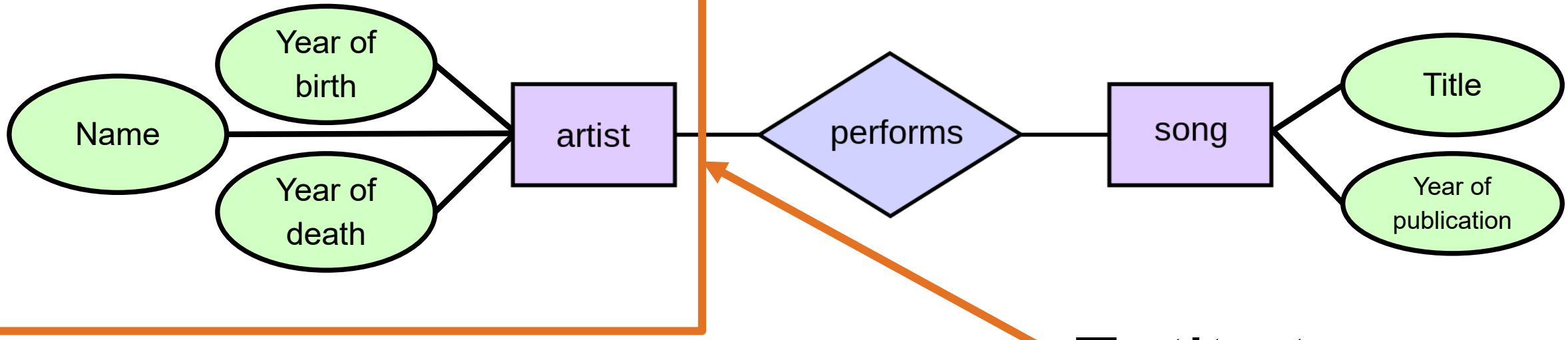



## artist

| Name | Year of Birth | Year of Death |
|---|---|---|
| Jimi Hendrix | 1942 | 1970 |
| Kurt Cobain | 1967 | 1994 |
| Amy Winehouse | 1983 | 2011 |

Codd, E. F. (1970). "A Relational Model of Data for Large Shared Data Banks". Communications of the ACM. 13 (6): 377–387.

# From ER to Relational Models




Entity type

artist

| Name | Year of Birth | Year of Death |
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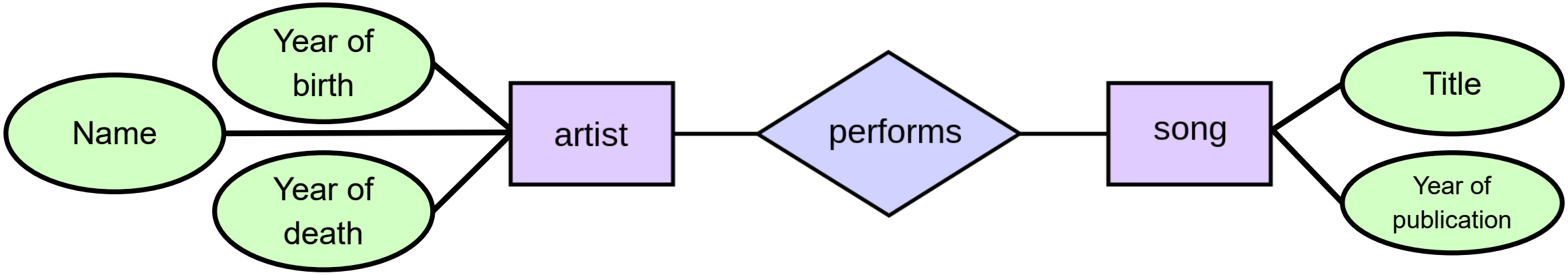
# From ER to Relational Models




artist

| Name | Year of Birth | Year of Death |
|---|---|---|
| Jimi Hendrix | 1942 | 1970 |
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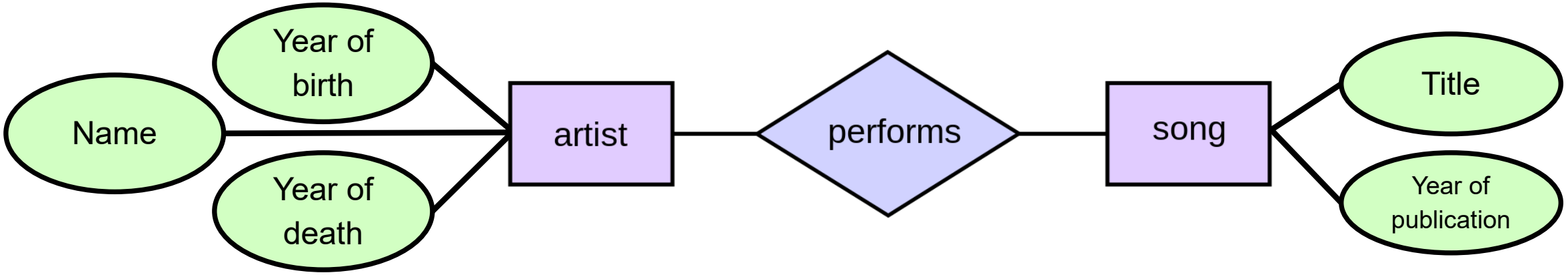
Entity occurrence / instance

# From ER to Relational Models




## artist

| Name | Year of Birth | Year of Death |
|---|---|---|
| Jimi Hendrix | 1942 | 1970 |
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## song

| Title | Year of publication |
|---|---|
| All Along the Watchtower | 1968 |
| Rehab | 2006 |
| Back to Black | 2006 |
| Come as you are | 1991 |

# From ER to Relational Models

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ER models are readily used to represent relational database structures

ER models are used to develop a database schema

Entities and relations in ER terminology are both (!) relations in the database world

Relational algebra helps structuring and optimizing databases and tables

# Relational Model

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A relational algebra defines operations that can be applied to a set of relations.

For example, relations can be filtered, linked or aggregated.

The results of all operations are also relations.

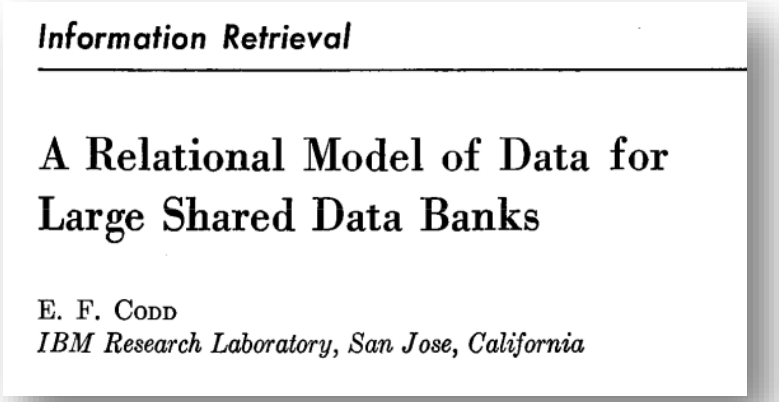
Relations are basically tables with unique entries.

An entry of a relation (i.e. a row of a table) is called a tuple.

It helps thinking of the rows of a table as being elements of a set.

Adding the same tuple twice is pointless, because the tuples cannot be logically distinguished from each other.

Implicit consequence: introduction of identifiers of elements of the set



*Information Retrieval*

A Relational Model of Data for Large Shared Data Banks

E. F. Codd
*IBM Research Laboratory, San Jose, California*

1970: Edgar Codd proposes the relational model

# The one and only Peter Müller

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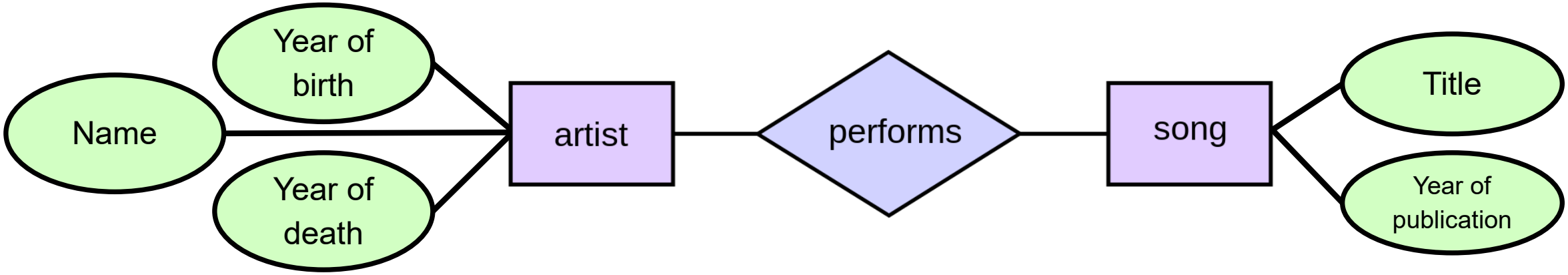
**Peter Muller**, **Peter Müller** or **Peter Mueller** may refer to:

- Peter Müller (ice hockey) (1896–?), Swiss ice hockey player
- Peter Muller (architect) (born 1927), architect with works in Bali, Sydney, South Australia and Melbourne
- Peter Müller (boxer) (born 1928), Swiss boxer
- Peter Müller (footballer, born 1946), East German footballer
- Peter Müller (footballer, born 1948), West German footballer
- Peter Mueller (Canadian football) (born 1951), former tight end for the Toronto Argonauts
- Peter Mueller (speed skater) (born 1954), former US speed skater and speed skating coach
- Peter Müller (politician) (born 1955), German politician and judge
- Peter Müller (skier) (born 1957), Swiss alpine skier competing in the 1980s
- Peter Müller (co-driver) (born 1962), Austrian rally co-driver
- Peter Müller (footballer, born 1969), German footballer
- Pete Muller (photographer) (born 1982), news photographer
- Peter Mueller (ice hockey) (born 1988), American ice hockey player, playing in the NLA
- Peter Muller (actor), played Dr. Logan King in the television series *Shortland Street*
- Pete Muller (businessman and singer-songwriter), musician and founder and CEO of PDT Partners

# From ER to Relational Models




## artist

| AID | Name | Year of Birth | Year of Death |
|---|---|---|---|
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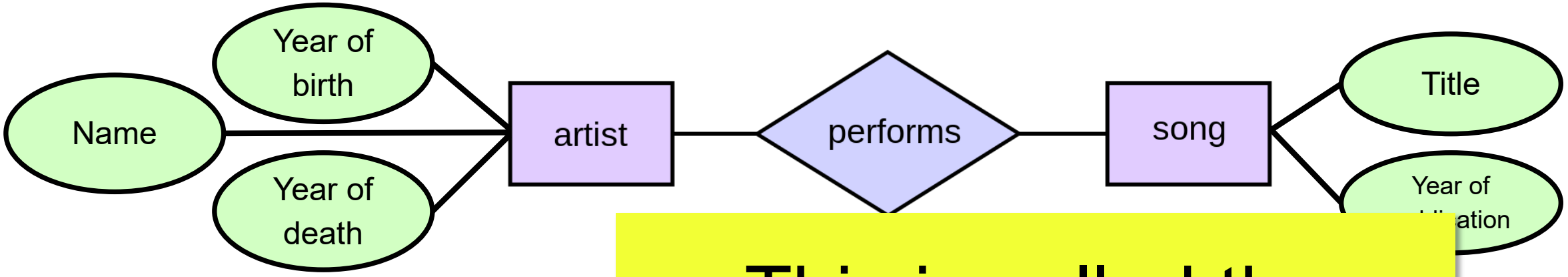
# From ER to Relational Models




This is called the **primary key**

artist

| AID | Name | Year of Birth | Death |
|---|---|---|---|
| 1 | Jimi Hendrix | 1942 | 1970 |
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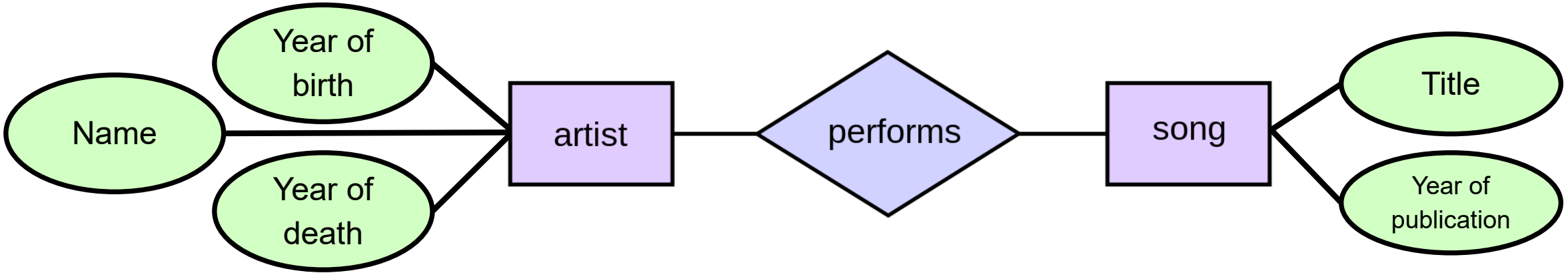
| 3 | Amy Winehouse | 1983 | 2011 |

Keys have to be unique in terms of the semantic of the real world!

# From ER to Relational Models

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## song

| SID | Title | Year of publication |
|---|---|---|
| 1 | All Along the Watchtower | 1968 |
| 2 | Rehab | 2006 |
| 3 | Back to Black | 2006 |
| 4 | Come as you are | 1991 |

# Minimizing redundancies

Key strength of the relational algebra: normalization

Normalization means to split columns into relations following certain rules such that redundancies are remove from the database.

Normal forms are classes of quality criteria for databases

Here, we focus on 1. NF, 2. NF, and 3. NF.
Informally, a database is “normalized” if it meets 3. NF

# Why normalization?

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Updates, insertions, and deletions should have no side-effects that impact database integrity, and these operations should affect as little parts of the database as possible.

**Employees' Skills**

| Employee ID | Employee Address | Skill |
|---|---|---|
| 426 | 87 Sycamore Grove | Typing |
| 426 | 87 Sycamore Grove | Shorthand |
| 519 | 94 Chestnut Street | Public Speaking |
| 519 | 96 Walnut Avenue | Carpentry |

An **update anomaly**. Employee 519 is shown as having different addresses on different records.

**Faculty and Their Courses**

| Faculty ID | Faculty Name | Faculty Hire Date | Course Code |
|---|---|---|---|
| 389 | Dr. Giddens | 10-Feb-1985 | ENG-206 |
| 407 | Dr. Saperstein | 19-Apr-1999 | CMP-101 |
| 407 | Dr. Saperstein | 19-Apr-1999 | CMP-201 |
| 424 | Dr. Newsome | 29-Mar-2007 | ? |

An **insertion anomaly**. Until the new faculty member, Dr. Newsome, is assigned to teach at least one course, their details cannot be recorded.

**Faculty and Their Courses**

| Faculty ID | Faculty Name | Faculty Hire Date | Course Code |
|---|---|---|---|
| 389 | Dr. Giddens | 10-Feb-1985 | ENG-206 |
| 407 | Dr. Saperstein | 19-Apr-1999 | CMP-101 |
| 407 | Dr. Saperstein | 19-Apr-1999 | CMP-201 |

DELETE

A **deletion anomaly**. All information about Dr. Giddens is lost if they temporarily ceases to be assigned to any courses.

# 1. Normal Form

Relations have atomic attributes, i.e. no table-valued attributes and no repeating groups

| AID | Name | Year of Birth | Year of Death |
|---|---|---|---|
| 1 | Jimi Hendrix | 1942 | 1970 |
| 2 | Kurt Cobain | 1967 | 1994 |
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| AID | Name | Given name | Year of Birth | Year of Death |
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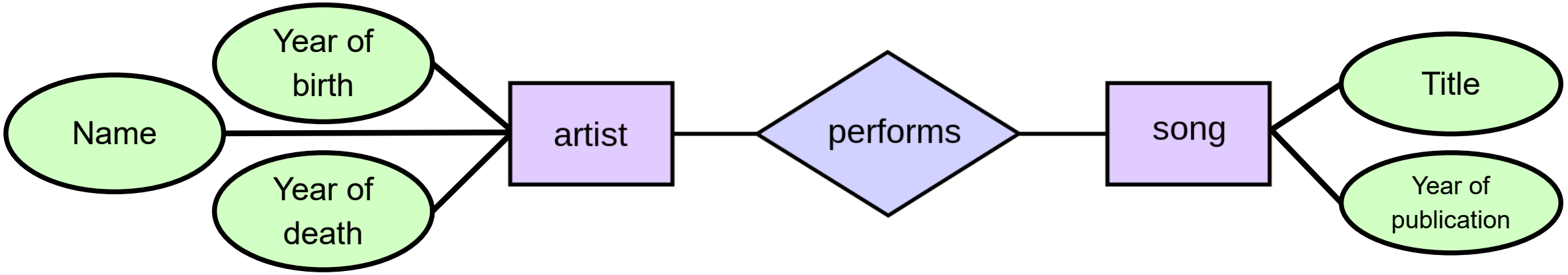
# 1. Normal Form




## artist

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|---|---|---|---|---|
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| 3 | Winehouse | Amy | 1983 | 2011 |

## song

| SID | Title | Year of publication |
|---|---|---|
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| 2 | Rehab | 2006 |
| 3 | Back to Black | 2006 |
| 4 | Come as you are | 1991 |

# 2. Normal Form

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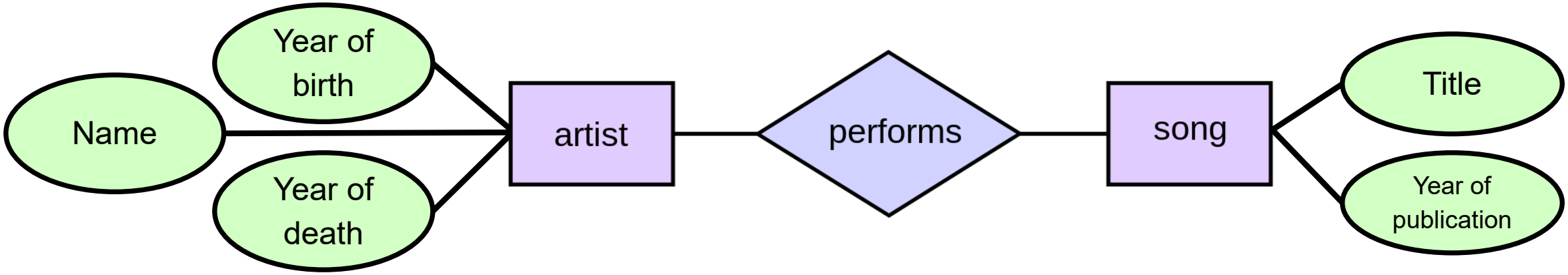
A table is in 1. normal form

All non-prime attributes of the relation are dependent on the whole of every candidate key

| Name | Given name | Year of Birth | Year of Death | Title | Album |
|---|---|---|---|---|---|
| Hendrix | Jimi | 1942 | 1970 | All Along the Watchtower | Electric Ladyland |
| Winehouse | Amy | 1983 | 2011 | Rehab | Back to Black |
| Winehouse | Amy | 1983 | 2011 | Back to Black | Back to Black |
| Cobain | Kurt | 1967 | 1994 | Come as you are | Nevermind |

A violation of the 2. NF because non-prime attributes containing artist information depend on album only but not on the title of the track!

# 2. Normal Form

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## song

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| 1 | All Along the Watchtower | 1968 |
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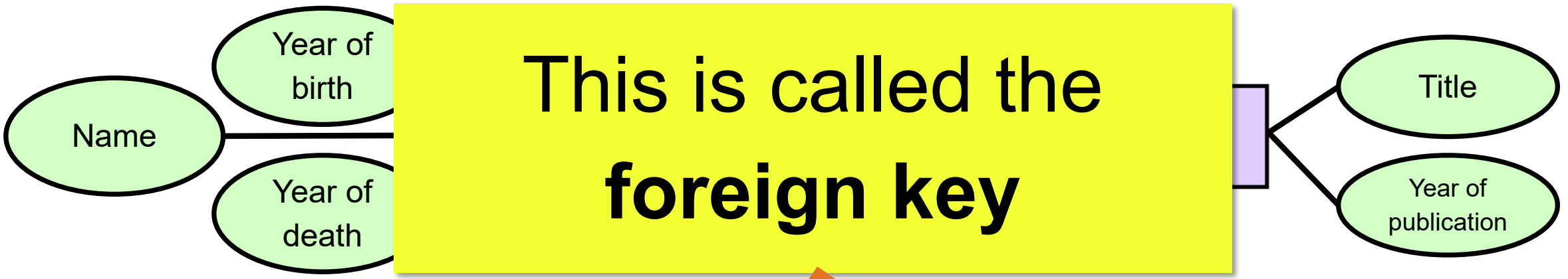
# 2. NF a) Foreign Keys




This is called the **foreign key**

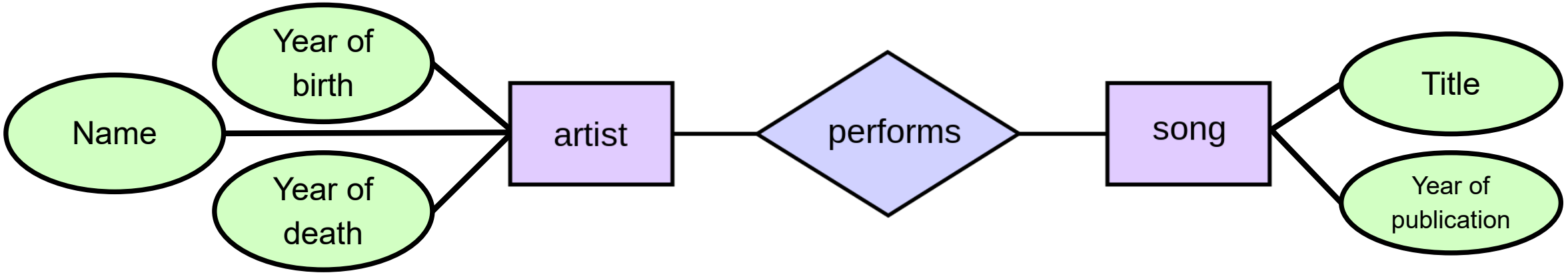
artist

| AID | Name | Given name | Year of Birth | Year of Death |
|---|---|---|---|---|
| 1 | Hendrix | Jimi | 1942 | 1970 |
| 2 | Cobain | Kurt | 1967 | 1994 |
| 3 | Winehouse | Amy | 1983 | 2011 |

song

| SID | AID | Title | Year of publication |
|---|---|---|---|
| 1 | 1 | All Along the Watchtower | 1968 |
| 2 | 3 | Rehab | 2006 |
| 3 | 3 | Back to Black | 2006 |
| 4 | 2 | Come as you are | 1991 |

# 2. NF b) Association table




## artist

| AID | Name | Given name | Year of Birth | Year of Death |
|---|---|---|---|---|
| 1 | Hendrix | Jimi | 1942 | 1970 |
| 2 | Cobain | Kurt | 1967 | 1994 |
| 3 | Winehouse | Amy | 1983 | 2011 |

## performs

| AID | SID |
|---|---|
| 1 | 1 |
| 2 | 4 |
| 3 | 2 |
| 3 | 3 |

## song

| SID | Title | Year of publication |
|---|---|---|
| 1 | All Along the Watchtower | 1968 |
| 2 | Rehab | 2006 |
| 3 | Back to Black | 2006 |
| 4 | Come as you are | 1991 |

As you can see: both ER entities and relations can be relations in the relational model!

# 3. Normal Form

A table is in 2. NF

All attributes are functionally dependent solely on the primary key

| CD_ID | Album title | Interpret | Year of foundation | Year of publication |
|---|---|---|---|---|
| 1 | Electric Ladyland | Jimi Hendrix | 1963 | 1968 |
| 3 | Back to Black | Amy Winehouse | 2002 | 2006 |
| 4 | Nevermind | Nirvana | 1987 | 1991 |
| 5 | Lioness: Hidden Treasures | Amy Winehouse | 2002 | 2011 |

Album title and interpret depend on CD_ID but year of foundation has a transitive dependency on interpret.
Violation of 3.NF creates redundancy in the database.

# Relational Databases

Database systems based on the relational model

Most relational databases use SQL as their query language

Still the de-facto industry standard

ACID transactions intend to guarantee data validity

- Atomicity: indivisible and irreducible series of operations
- Consistency: data is only changed in allowed ways. Ambiguous meaning in different systems
- Isolation: defining how and when database operations become visible to other users
- Durability: transactions that have been committed will survive permanently

# NoSQL!

Non-relational databases provide a mechanism for storage and retrieval of data that is modeled in means other than the tabular relations used in relational databases.

Provide 3 operations:

- Insert(k,v)
- Lookup(k)
- Delete(k)

Extremely simple and efficient from a provider-perspective

These databases scale!

Relaxed database consistency model.

Most Join/Selection/… operations are offloaded to the application

# Semantic Web: RDF

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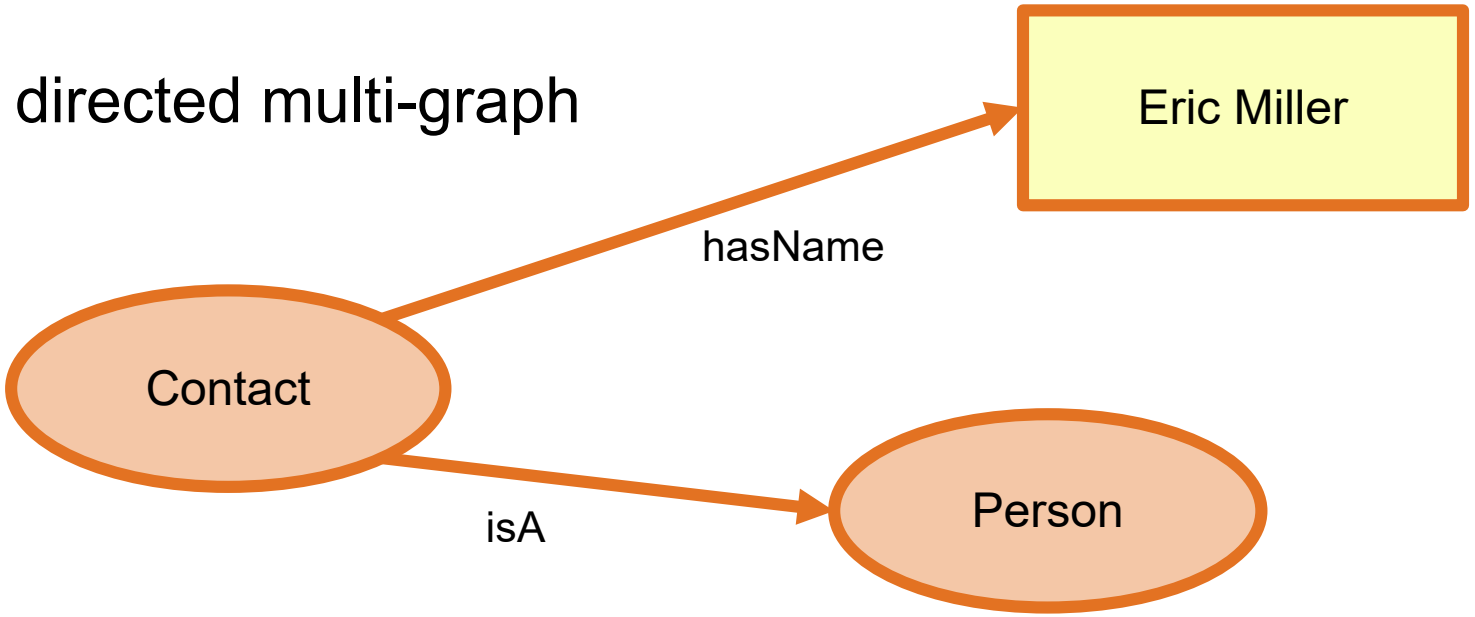
Classical modeling approach based on the idead of making statements about resources

Data model consisting of SPO-triples: Subject-Predicate-Object

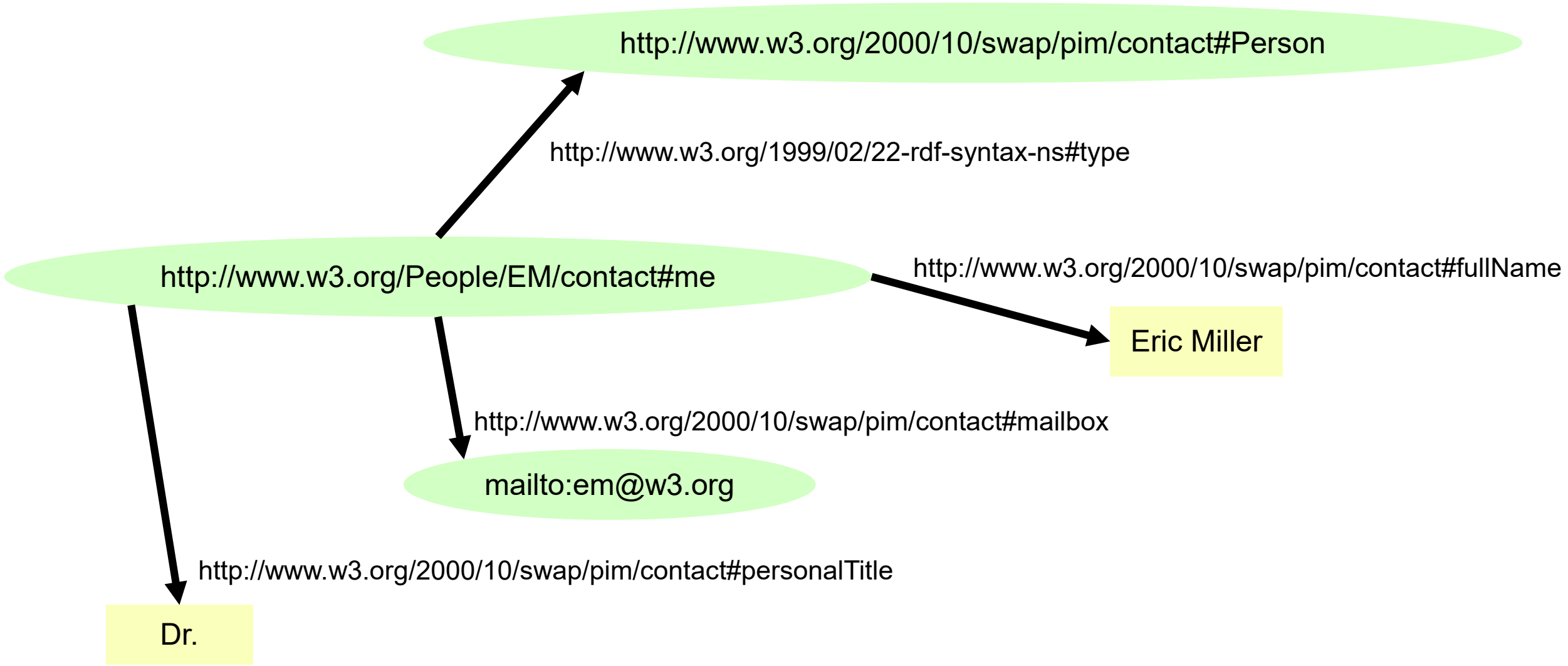
Subject represents the resource, the predicate denotes aspects of the resource and expresses relation between subject and object

Allows modeling disparate, abstract concepts very efficiently

Often visualized as a labeled, directed multi-graph



# RDF Predicates are globally unique

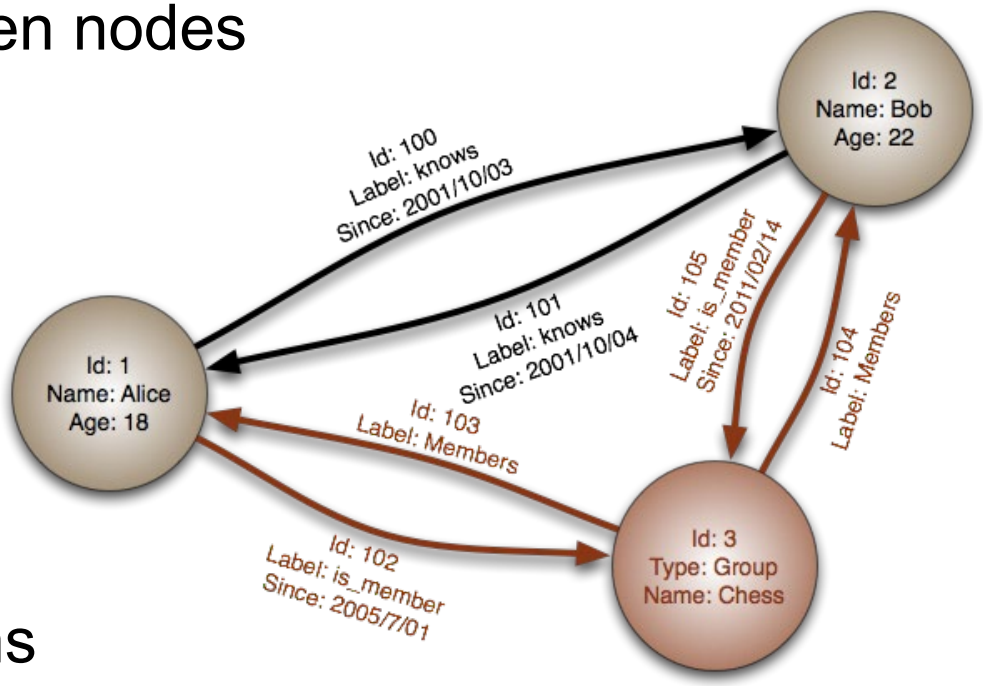



https://www.w3.org/TR/rdf-primer/

# Graph databases

Graph databases explicitly model relations between nodes

Examples:
Social Graph, Consumption Graph,
Mobile Graph, Interest Graph, …




Graph databases store pointers to records
of adjacent nodes eliminating costly join operations

True power of graph databases shows for queries that are more than one level deep,
i.e. querying friends of friends of friends…

# Wrap-up
# Data Modeling

# Abstraction is Key

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General meaning: identify basic rules and features from specific examples

In Computer Science:

- Avoid repetition!
  Generalize program code so that it can be run in different contexts
- Separate concepts and implementation!
  Separate abstract view on data from actual implementation of databases, for example

With all forms: there is no natural abstraction!

User requirements, world view, prejudices, and blind spots influence the process of abstraction

# Steps of Data Modeling

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1. Conceptual data modeling:
   identification and description of that part of the world a modeler is modeling
   notation of the findings
2. Logical data modeling:
   defining tables of a database – translating the conceptual model
3. Physical data modeling:
   optimizing the database design
   actual implementation
   usually not done by a data modeler

Best case:

Conceptual and Logical model are *independent* of an actual implementation

# Distinction Between Steps

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| Conceptual Model | Logical Model |
| --- | --- |
| Organizes information | Provides structure to the data that defines a set of suitable algorithms |
| Makes logical model easy to derive | Achieves computability (often through mathematical models) |
| Captures semantics of information | Powerful formal abstraction |

Thanks.

mirco.schoenfeld@uni-bayreuth.de