Database Architecture and Data Model

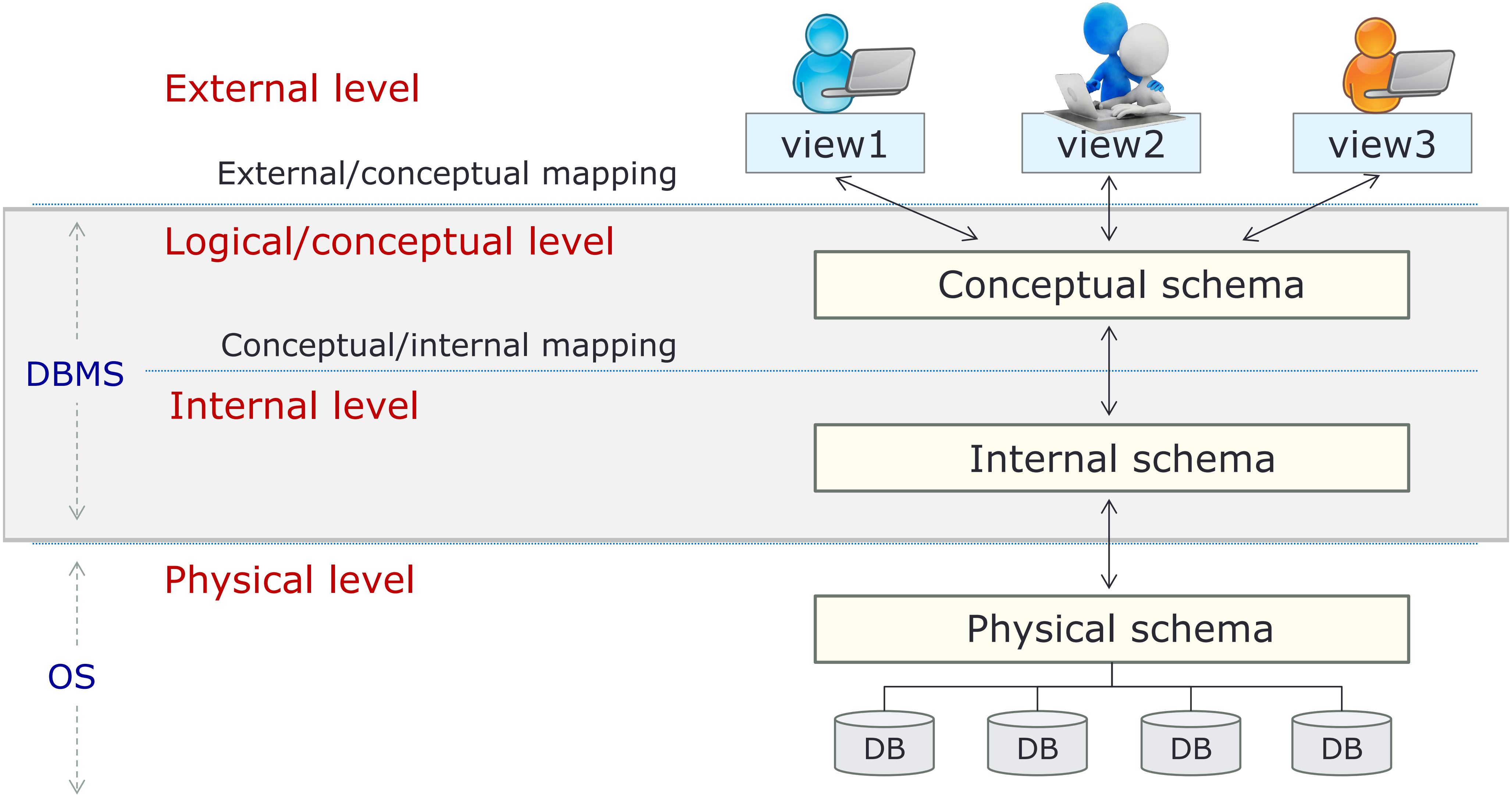
CS 4750
Database Systems

[A. Silberschatz, H. F. Korth, S. Sudarshan, Database System Concepts, Ch.2]

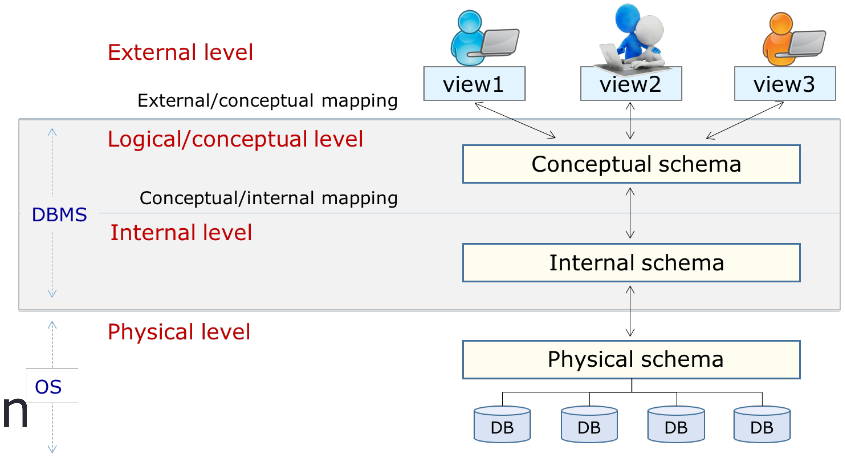
[C.M. Ricardo and S.D. Urban, Database Illuminated, Ch. 2.6-2.7]

Levels of Database Architecture

Databases are stored as files of records stored on disks



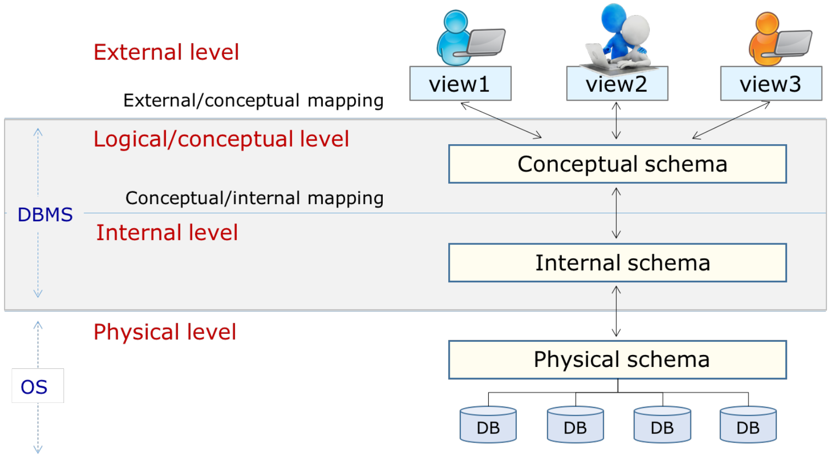
External Level



- Different users see different views
- Different views may consists of
  - Different contents, or
  - Same contents, different representation
- Some views may include virtual data (or calculated data)
  - Calculated age on demand
- External view – a collection of external records
- External record – a record as seen by a particular user
- External schema – describes an external view
- DBMS uses the external schema to create a user interface

Logical Level

- Include description of all the data that is available to be shared



- Logical schema – a complete description of the information content of the database

- DBMS uses the logical schema to create logical record interface

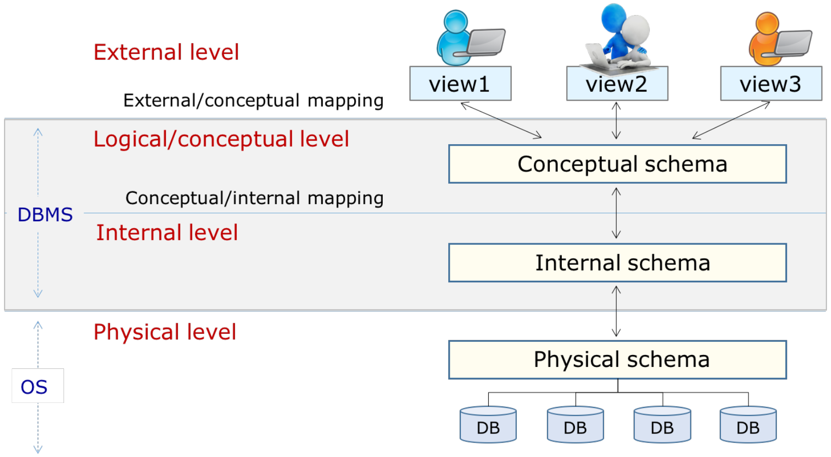
- Logical record interface – conceptual level and internal level (defines what are visible / invisible to external level and physical level)

- Logical model – a collection of logical records (“comprehensive view of the user’s mini-world”)

Internal and Physical Levels

- Internal level deals with physical implementation of the database, responsible by DBMS

- Physical level is managed by operating system



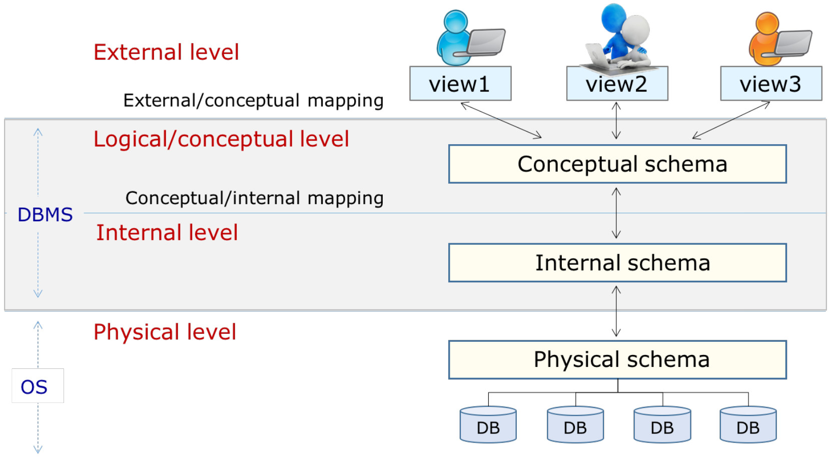
- Internal schema – a complete description of the internal model
  - Describe how data are represented, how records are sequenced, what indexes exist, …

- Stored record interface – a boundary between the physical level and the internal level

- Physical record interface – a boundary where storage details (such as what portion of what track contains what data) are hidden

Data Independence

Data independence – upper levels are unaffected by changes to lower levels



Logical data independence – changes to logical model do not impact external models

Physical data independence – changes to internal model or physical do not impact logical model

Recap: Data Independence

What is physical data independence?

- Working with a model of the data
- Don’t care how the data in the database is stored, abstracting away details we don’t want / have to deal with

Data Model

Data model = a collection of concepts or notations for describing the data in a database

- Allow us to deal with data conceptually without having to think about implementation

Three parts of a data model

- Structure – the definition of relations and contents
- Integrity – constraints on the database's contents
- Manipulation – actions that can be done on the database's contents

Data Model

- Relational ← Most DBMSs
- Key/value
- Graph
- Document
- Column-family
- Array / matrix
- Hierarchical
- Network

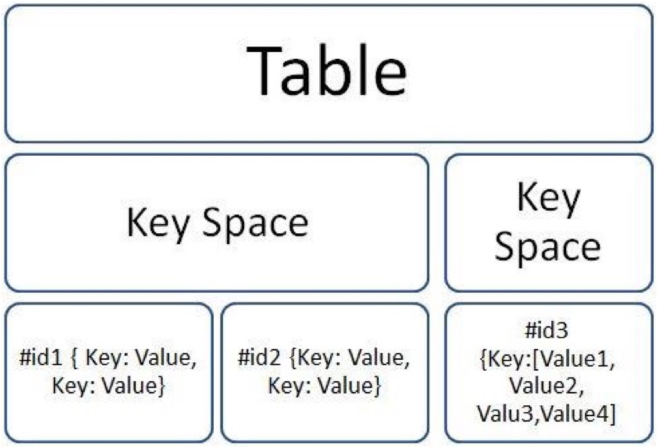
Title	Year	Length	Genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne’s World	1992	95	comedy

Data Model

- Relational

NoSQL

- Key/value
- Graph
- Document
- Column-family



Table

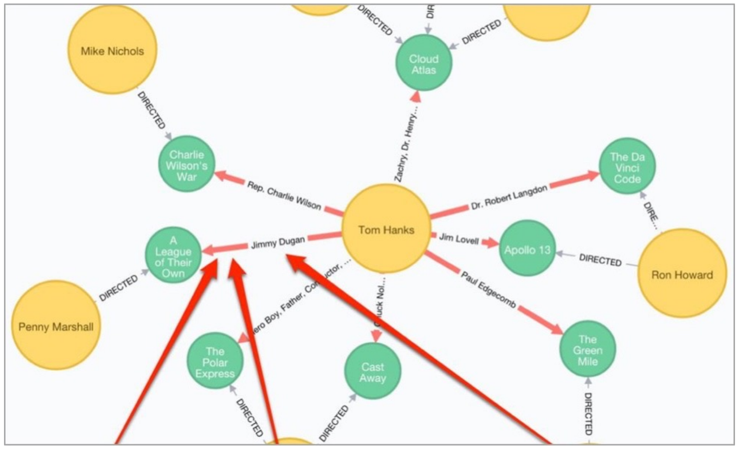
Key Space

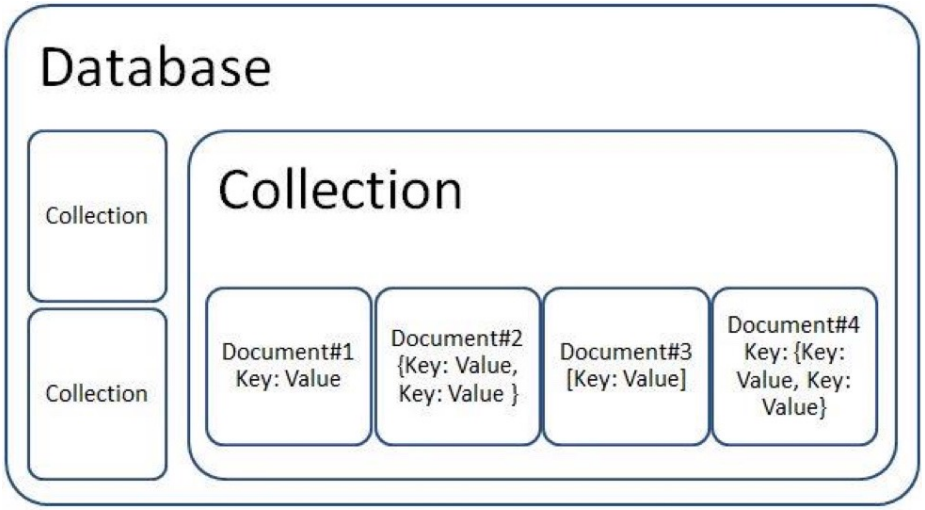
Key Space

#id1 { Key: Value, Key: Value}

#id2 {Key: Value, Key: Value}

#id3 {Key:[Value1, Value2, Valu3,Value4]}




Database

Collection

Collection

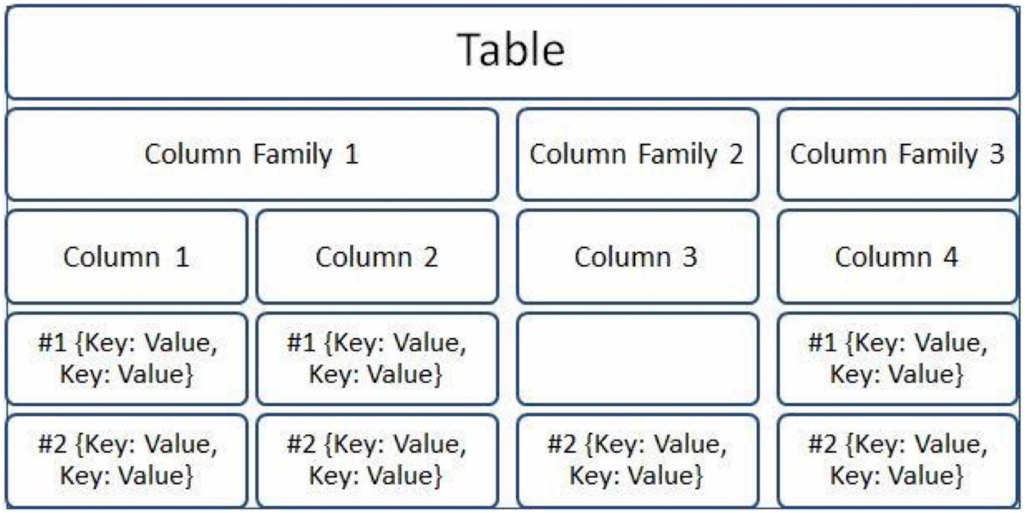
Collection

Document#1 Key: Value

Document#2 {Key: Value, Key: Value }

Document#3 [Key: Value]

Document#4 Key: {Key: Value, Key: Value}



Table

Column Family 1		Column Family 2	Column Family 3
Column 1	Column 2	Column 3	Column 4
#1 {Key: Value, Key: Value}	#1 {Key: Value, Key: Value}		#1 {Key: Value, Key: Value}
#2 {Key: Value, Key: Value}	#2 {Key: Value, Key: Value}	#2 {Key: Value, Key: Value}	#2 {Key: Value, Key: Value}

Data Model

- Relational
- Key/value
- Graph
- Document
- Column-family
- Array / matrix ← Machine learning
- Hierarchical
- Network

$$\begin{array}{cccc} & Joe & Ann & Bob \\ Joe & 0 & 1 & 0 \\ Ann & 1 & 0 & 1 \\ Bob & 0 & 1 & 0 \end{array}$$

Data Model

- Relational
- Key/value
- Graph
- Document
- Column-family
- Array / matrix
- Hierarchical
- Network

← Obsolete / rare

Data Model

- Relational

← This course

- Key/value
- Graph
- Document
- Column-family
- Array / matrix
- Hierarchical
- Network

title	year	length	genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne’s World	1992	95	comedy

Relational Model

Three parts:

- Structure (schema) – the definition of relations and contents
- Integrity – ensure the database’s contents satisfy constraints
- Manipulation – how to access and modify a database’s contents

Relational model gives us a single way to represent data as a two-dimensional table called a “relation”

Relational Model

Relational model

Relational Algebra

attribute ↓

relation name ↗ movies

title	year	length	genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne’s world	1992	95	comedy

← *tuple*

Relation = set of tuples (thus no duplicate), has no order

Actual DB / SQL

SQL

column ↓

table name ↗ movies

title	year	length	genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne’s world	1992	95	comedy

← *row / record*

Table = list of rows (thus can have duplicates), has order

Relational Model

attribute ↓

relation name ↗ movies

title	year	length	genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne’s world	1992	95	comedy

← *tuple*

Relation = unordered set of tuples that contain the relationship of attributes

n-ary relation = table with n columns

Tuple = set of attribute values (“domain”) in the relation

- Values are (normally) atomic
- The special value NULL is a member of every domain

Schema

Schema – logical design of the database (describe the tables), not generally change (note order of attributes)

movies

title	year	length	genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne's world	1992	95	comedy

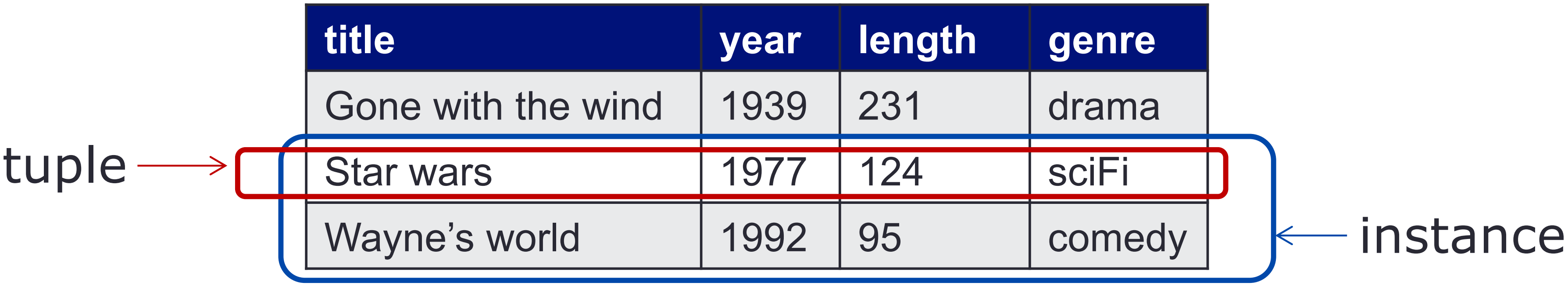
Write a schema statement for the above relation

schema movies(title, year, length, genre)
movies(title:string, year:integer, length:integer, genre:string)

Instance

Instance – data stored in the database at a given time (set of tuples), change from time to time

movies



title	year	length	genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne’s world	1992	95	comedy

Write the selected tuple

tuple (Star wars, 1977, 124, sciFi)

Write the selected instance

instance {(Star wars, 1977, 124, sciFi),(Wayne’s world, 1992, 95, comedy) }

Recap: Schema and Instance

Describe the difference between schema and instance

- Schema – describe the relation (the attributes), doesn’t change
- Instance – actual values of data in the relation at that moment, change constantly

Keys of Relations

To specify which tuple, use the attribute values of a tuple to distinguish (uniquely identify the tuple)

movies

title	year	length	genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne’s world	1992	95	comedy

Make use of the real-world fact

Assumption:

- A movie may be remade in different years
- For each year, many movies may be made

Write a schema statement for the above relation, indicate the key of the relation

movies(title, year, length, genre)

Super Key – Candidate Key - Primary Key

Super key – any attribute(s) that can uniquely identify a tuple

Candidate key – minimal super key

Primary key – a candidate key that is the most important key

Students_info

computingID	SSN	name
mi1y	111-11-1111	Mickey
mi2e	222-22-2222	Minnie
do3d	333-33-3333	Donald
da4y	444-44-4444	Daisy
do5d	555-55-5555	Donald

Identify super key

computingID
SSN
computingID+SSN
computingID+name
SSN+name
computingID+SSN+name

Start with assumptions

Super Key – Candidate Key - Primary Key

Super key – any attribute(s) that can uniquely identify a tuple

Candidate key – minimal super key

Primary key – a candidate key that is the most important key

Students_info

computingID	SSN	name
mi1y	111-11-1111	Mickey
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do3d	333-33-3333	Donald
da4y	444-44-4444	Daisy
do5d	555-55-5555	Donald

Candidate key

Identify candidate key

computingID
SSN

Super Key – Candidate Key - Primary Key

Super key – any attribute(s) that can uniquely identify a tuple

Candidate key – minimal super key

Primary key – a candidate key that is the most important key

Students_info

computingID	SSN	name
mi1y	111-11-1111	Mickey
mi2e	222-22-2222	Minnie
do3d	333-33-3333	Donald
da4y	444-44-4444	Daisy
do5d	555-55-5555	Donald

Primary key

Identify primary key

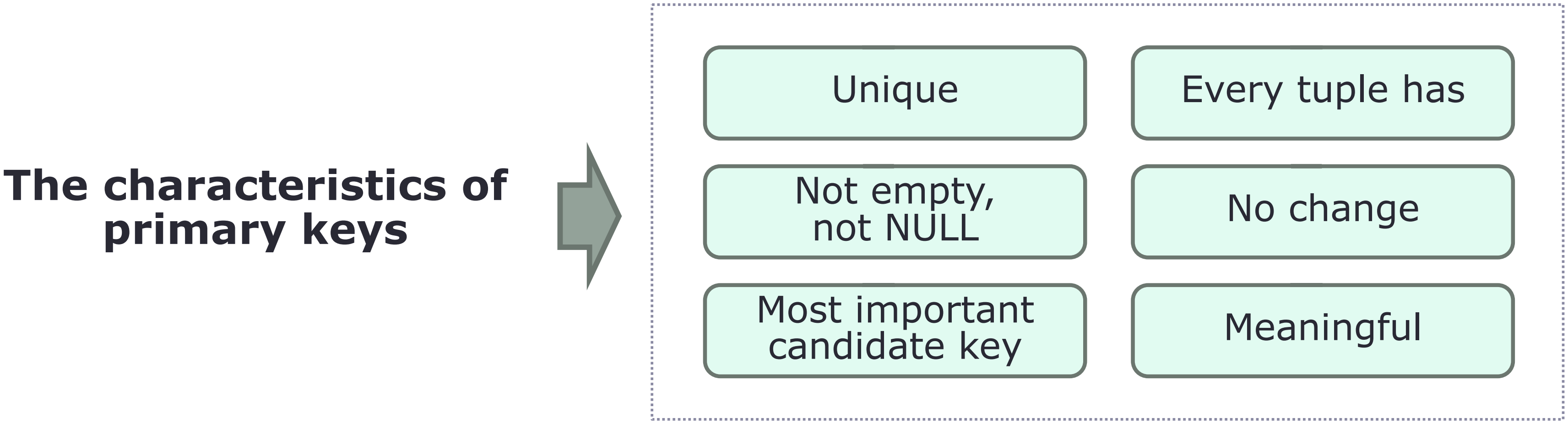
computingID

Primary Keys

A relation's primary key uniquely identifies a single tuple

movies

title	year	length	genre
Gone with the wind	1939	231	drama
Star wars	1977	124	sciFi
Wayne's world	1992	95	comedy



The characteristics of primary keys

Unique

Every tuple has

Not empty, not NULL

No change

Most important candidate key

Meaningful

Primary Keys

Some DBMSs automatically create an internal primary key if none is defined for the relation

Auto-generation of unique integer primary keys:

- SEQUENCE (SQL: 2003)

movies

id	title	year	length	genre
123	Gone with the wind	1939	231	drama
456	Star wars	1977	124	sciFi
789	Wayne’s world	1992	95	comedy

- AUTO_INCREMENT (MySQL)

Foreign Keys

A foreign key specifies that an attribute from one relation has to map to a tuple in another relation

Attribute(s) that uniquely identify a row in another table

Artist(id, name, year, country)

id	name	year	country
123	Mickey	1992	USA
456	Minnie	1992	USA
789	Donald	1994	USA

Primary key

Album(id, name, artists, year)

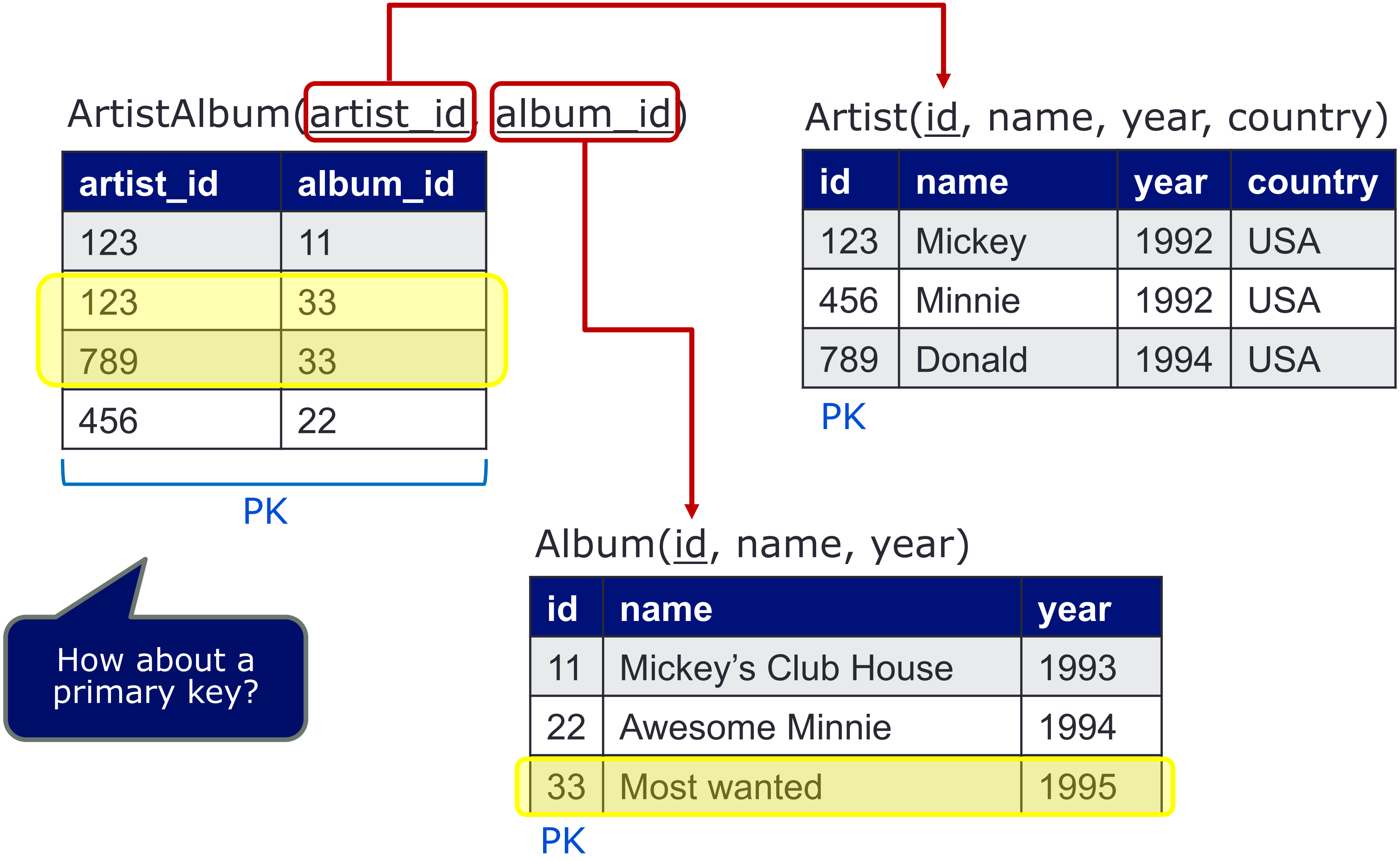
id	name	artists	year
11	Mickey's Club House	123	1993
22	Awesome Minnie	456	1994
33	Most wanted	789	1995

Foreign key

How about 2 artists (123 and 789)?

33	Most wanted	123	1995
33	Most wanted	789	1995

Foreign Keys



ArtistAlbum(artist_id, album_id)

artist_id	album_id
123	11
123	33
789	33
456	22

PK

Artist(id, name, year, country)

id	name	year	country
123	Mickey	1992	USA
456	Minnie	1992	USA
789	Donald	1994	USA

PK

Album(id, name, year)

id	name	year
11	Mickey's Club House	1993
22	Awesome Minnie	1994
33	Most wanted	1995

PK

How about a primary key?

Recap: Keys

List properties of primary keys

- (has to be a candidate key)
- Unique
- Not NULL
- “Everyone” has one
- Doesn’t change
- Meaningful, given the domain (recommendation)
- Typically small in size (recommendation)

Characteristics of Relational Model

- Originally defined with Set semantics (no duplicate tuples)
- Attributes are typed and static (INTEGER, FLOAT, …)
- Tables are flat
- Attribute values are atomic
- Order of tuples doesn't matter

id	name	year	country
123	Mickey	1992	USA
456	Minnie	1992	USA
789	Donald	1994	USA

=

id	name	year	country
456	Minnie	1992	USA
789	Donald	1994	USA
123	Mickey	1992	USA

Recap: Relational Model

Does the following table satisfy the characteristics of relational model?

id	name	year	country
123	Mickey	1992	USA
456	Minnie	1992	USA
789	Donald	1994	USA
567	Humpty	2016	USA
567	Humpty	2016	USA

No. Violates set semantics

Recap: Relational Model (2)

Does the following table satisfy the characteristics of relational model?

id	name	year	country
123	Mickey	1992	USA
456	Minney	1992	USA
789	Donald	1994	USA
567	Humpty	banana	USA

No. Violates attribute type, assuming INT

Recap: Relational Model (3)

Does the following table satisfy the characteristics of relational model?

<table>
<tr><th>id</th><th>name</th><th>year</th><th>country</th></tr>
<tr><td>123</td><td>Mickey</td><td>1992</td><td><table><tr><th>country</th><th>note</th></tr><tr><td>USA</td><td>Some info</td></tr><tr><td>USA</td><td>Another info</td></tr></table></td></tr>
<tr><td>456</td><td>Minnie</td><td>1992</td><td>USA</td></tr>
<tr><td>789</td><td>Donald</td><td>1994</td><td>USA</td></tr>
<tr><td>567</td><td>Humpty</td><td>2016</td><td>USA</td></tr>
</table>

No. No sub-tables allowed;
must be flat and atomic

Recap: Relational Model (4)

How are these data actually stored?

id	name	year	country
123	Mickey	1992	USA
456	Minnie	1992	USA
789	Donald	1994	USA
567	Humpty	2016	USA

Don’t know. Don’t care.

“Physical Data Independence”

Wrap-Up

- Database architecture – separation of concerns
- Data independence – physical and logical
- Data model – schema, integrity, manipulation
- Relational model
- Key constraints – super key, candidate key, primary key, foreign key

What’s next?

- DB design – using E-R model
- Mapping E-R model to schemas

Practice Activity

This is an open-ended activity, consisting of 3 relations. For each relation, think about the data to be stored. You should also consider the type of data. Write a schema for each relation. Feel free to make any reasonable assumption.

Consider the following description. Write schemas that represent the data models for the given description.

Practice Activity (2)

Relation: **Movies**

Each movie has a *title* and *year*; *title* and *year* together uniquely identify the movie. *Length* and *genre* are maintained for each movie. Each movie is associated with a *studioName* which tells us the studio that owns the movie, and *producerC#* which is an integer that represents the producer of the movie.

Relation: **MovieStar**

This relation tells us something about stars. It maintains the *name* of the movie star, address, gender, and birthdate. The gender can be a single character (*M* or *F*). Birthday is of type “date,” which might be a character string of a special form.

Relation: **StarsIn**

This relation connects movies to the stars of that movie, and likewise connects a stars to the movies in which they appeared. A star might appear in multiple movies in one year.