Why use Data Model?

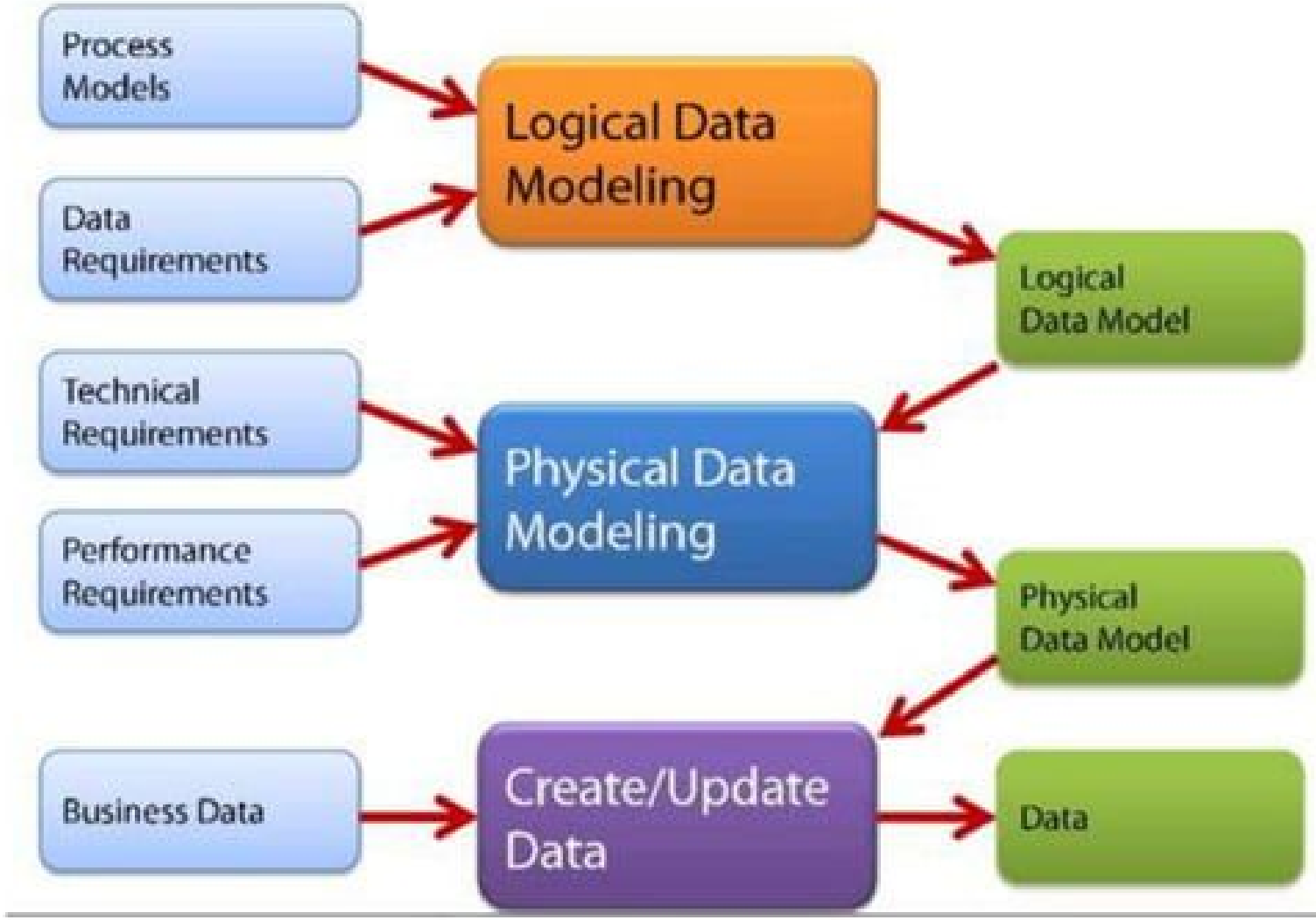
- The primary goal of using data model are:

1. Ensures that all data objects required by the database are accurately represented. Omission of data will lead to creation of faulty reports and produce incorrect results.
2. A data model helps design the database at the conceptual, physical and logical levels.
3. Data Model structure helps to define the relational tables, primary and foreign keys and stored procedures.
4. It provides a clear picture of the base data and can be used by database developers to create a physical database.
5. It is also helpful to identify missing and redundant data.
6. Though the initial creation of data model is labor and time consuming, in the long run, it makes your IT infrastructure upgrade and maintenance cheaper and faster.

Types of Data Models [1/2]

- **Conceptual:** This Data Model defines **WHAT** the system contains. This model is typically created by Business stakeholders and Data Architects. The purpose is to organize, scope and define business concepts and rules.
- **Logical:** Defines **HOW** the system should be implemented regardless of the DBMS. This model is typically created by Data Architects and Business Analysts. The purpose is to developed technical map of rules and data structures.
- **Physical**: This Data Model describes **HOW** the system will be implemented using a specific DBMS system. This model is typically created by DBA and developers. The purpose is actual implementation of the database.

Types of Data Models [2/2]



Advantages of Data model

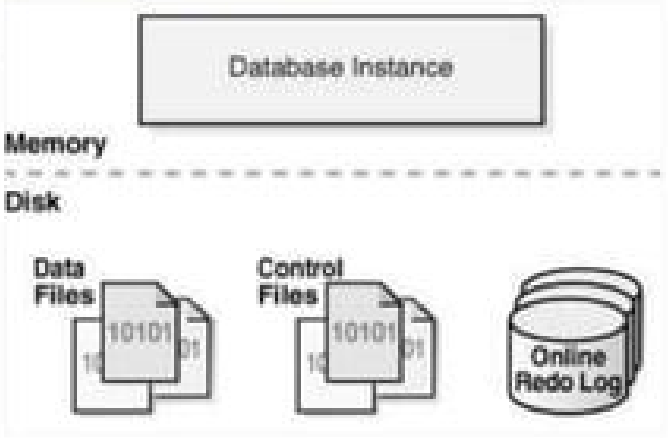
- The main goal of a designing data model is to make certain that data objects offered by the functional team are represented accurately.
- The data model should be detailed enough to be used for building the physical database.
- The information in the data model can be used for defining the relationship between tables, primary and foreign keys, and stored procedures.
- Data Model helps business to communicate the within and across organizations.
- Data model helps to documents data mappings in ETL process
- Help to recognize correct sources of data to populate the model

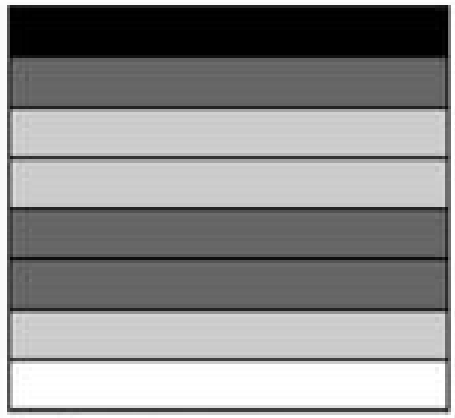
Importance of Data Models

- Are a communication tool
- Give an overall view of the database
- Organize data for various users
- Are an abstraction for the creation of good database

Disadvantages of Data model

- To develop Data model one should know physical data stored characteristics.
- This is a navigational system produces complex application development, management. Thus, it requires a knowledge of the biographical truth.
- Even smaller change made in structure require modification in the entire application.
- There is no set data manipulation language in DBMS.

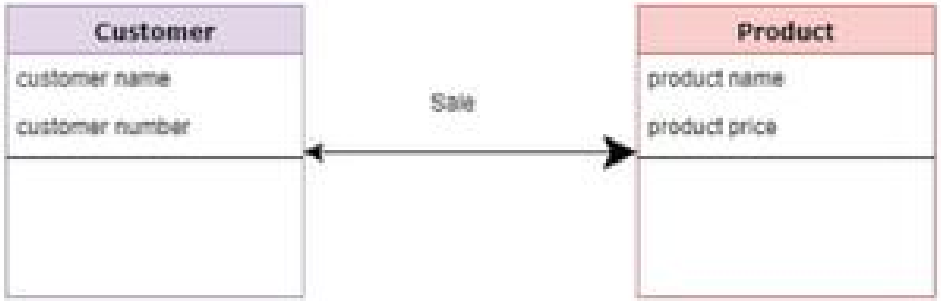




Space in a Data File

Data Model Basic Building Blocks

- **Entity**: Unique and distinct object used to collect and store data
  - **Attribute**: Characteristic of an entity
- **Relationship**: Describes an association among entities
  - **One-to-many (1:M)**
  - **Many-to-many (M:N or M:M)**
  - **One-to-one (1:1)**



- **Constraint**: Set of rules to ensure data integrity

Business Rules

- Brief, precise, and unambiguous description of a policy, procedure, or principle
- Enable defining the basic building blocks
- Describe main and distinguishing characteristics of the data

Implementing a constraint imposed by a database oriented business rule

Logical Elements

Key Type:	☒ Non	☐ Primary	**Edit Rule:**	
	☐ Foreign	☐ Alternate	☒ Enter Now, Edits Allowed	
Key Structure:	☐ Simple	☐ Composite	☐ Enter Now, Edits Not Allowed	
Uniqueness:	☒ Non-unique	☐ Unique	☐ Enter Later, Edits Allowed	
Null Support:	☐ Nulls Allowed	☒ No Nulls	☐ Enter Later, Edits Not Allowed	
Values Entered By:	☒ User	☐ System	☐ Not Determined At This Time	
Required Value:	☐ No	☒ Yes		
Default Value:	None			
Range of Values:	ID, MT, OR, WA			

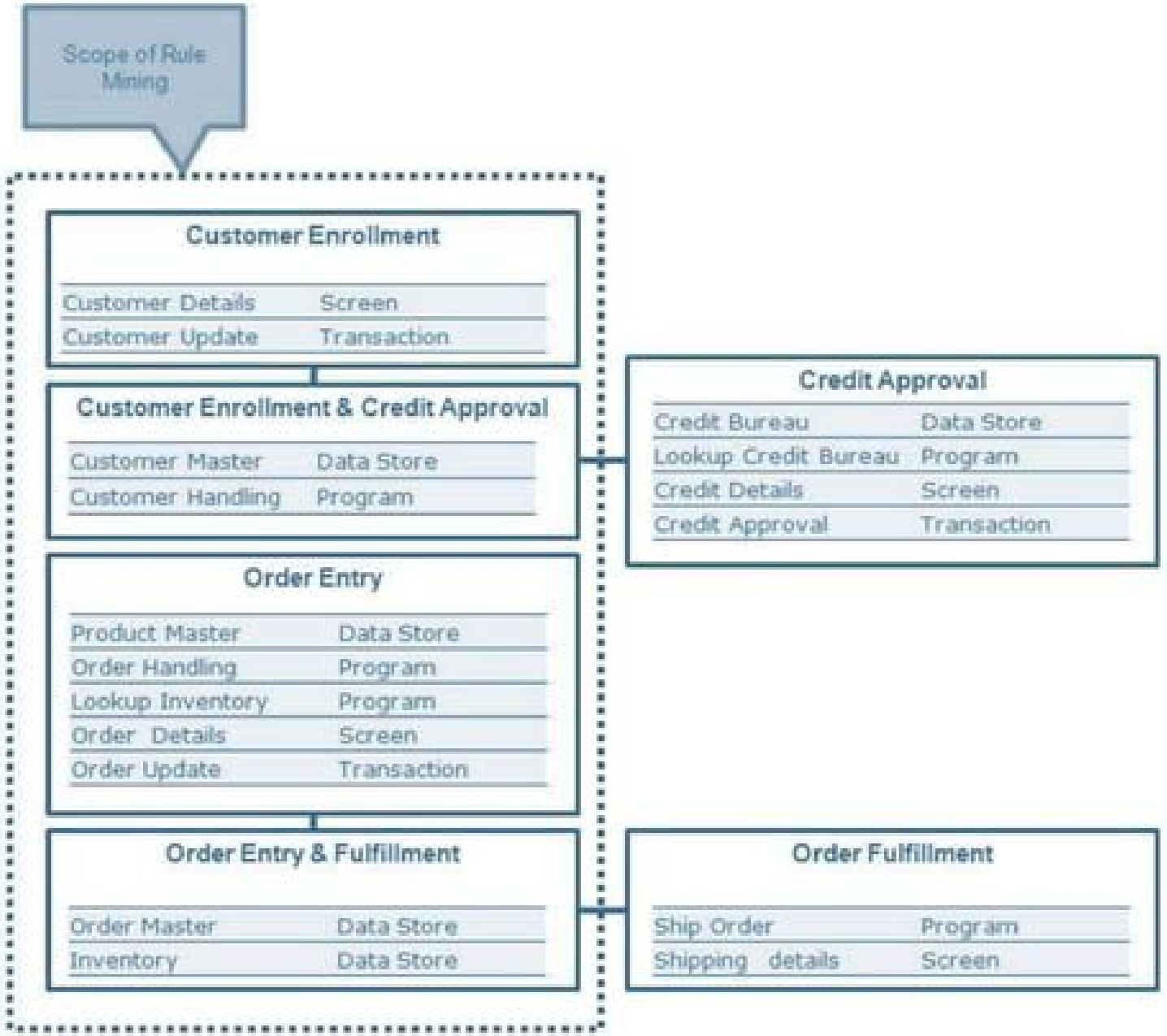
Comparisons Allowed:

☒ Same Field	☐ All	☒ =	☐ >	☐ >=	☐ ≠	☐ <	☐ <=
☐ Other Fields	☐ All	☐ =	☐ >	☐ >=	☐ ≠	☐ <	☐ <=
☐ Value Expression	☐ All	☐ =	☐ >	☐ >=	☐ ≠	☐ <	☐ <=

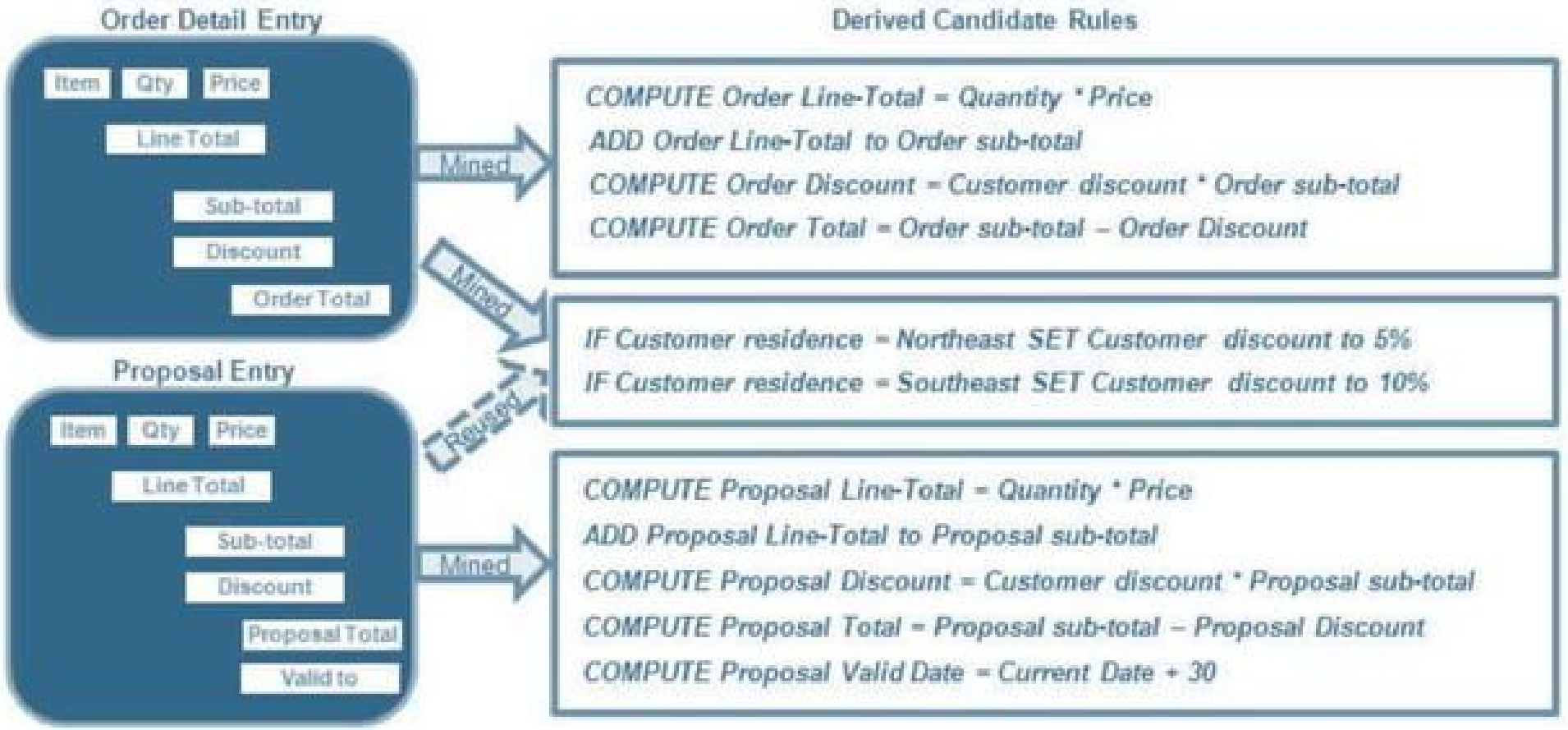
Operations Allowed:

☐ Same Field	☐ All	☐ +	☐ -	☐ x	☐ ÷	☐ Concatenation
☐ Other Fields	☐ All	☐ +	☐ -	☐ x	☐ ÷	☐ Concatenation
☐ Value Expression	☐ All	☐ +	☐ -	☐ x	☐ ÷	☐ Concatenation

Business Process Mapping to Application Objects



Business Rule Transformation

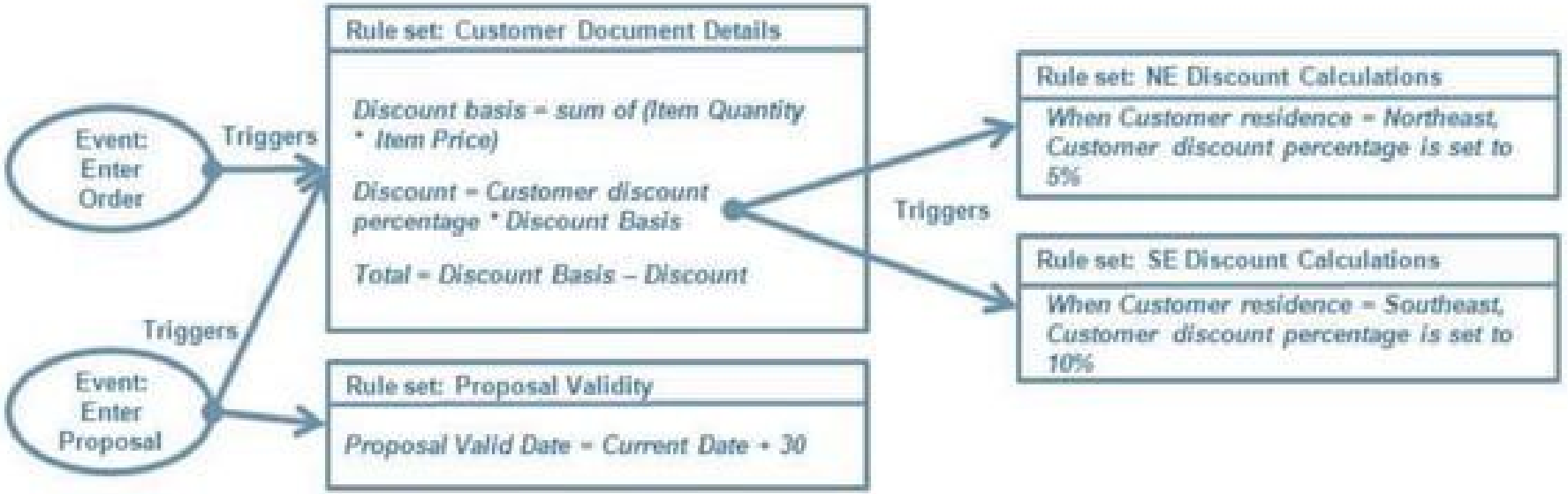


Ask yourself the following questions, before any modification

1. Will this rule be violated if I enter a new record into this table?
2. Will this rule be violated if I do not enter a new record into this table?
3. Will this rule be violated if I delete a record from this table?
4. Will this rule be violated if I enter a value into this field?
5. Will this rule be violated if I do not enter a value into this field?
6. Will this rule be violated if I update the value of this field?
7. Will this rule be violated if I delete the value of this field?

Business Rules are normalized to represent the desired business level semantics

As-is Business Rule Model (Event-driven)



Sources of Business Rules

- Company managers
- Policy makers
- Department managers
- Written documentation
- Direct interviews with end users

Reasons for Identifying and Documenting Business Rules

- Help standardize company's view of data
- Communications tool between users and designers
- Allow designer to:
  - Understand the nature, role, scope of data, and business processes
  - Develop appropriate relationship participation rules and constraints
  - Create an accurate data model

Translating Business Rules into 'Data Model Components'

- Nouns translate into entities
- Verbs translate into relationships among entities
- Relationships are bidirectional
- Questions to identify the relationship type
  - How many instances of 'B' are related to one instance of 'A'?
  - How many instances of 'A' are related to one instance of 'B'?

Naming Conventions

- Entity names - Required to:
  - Be descriptive of the objects in the business environment
  - Use terminology that is familiar to the users
- Attribute name - Required to be descriptive of the data represented by the attribute
- Proper naming:
  - Facilitates communication between parties
  - Promotes self-documentation

Database Naming Conventions Best Practices

1. Consistency is always the best policy.
2. Every table should have its own row identifier
3. Plural or singular names don't really matter
4. Never allow the database to put in the constraint names automatically
5. Avoid being redundant so you can avoid being redundant

Hierarchical and Network Models

Hierarchical Models

- Manage large amounts of data for complex manufacturing projects
- Represented by an upside-down tree which contains segments
  - **Segments**: Equivalent of a file system's record type
- Depicts a set of one-to-many (1:M) relationships

Network Models

- Represent complex data relationships
- Improve database performance and impose a database standard
- Depicts both one-to-many (1:M) and many-to-many (M:N) relationships

Hierarchical Model

Advantages	Disadvantages
▪ Promotes data sharing ▪ Parent/child relationship promotes conceptual simplicity and data integrity ▪ Database security is provided and enforced by DBMS ▪ Efficient with 1:M relationships	▪ Requires knowledge of physical data storage characteristics ▪ Navigational system requires knowledge of hierarchical path ▪ Changes in structure require changes in all application programs ▪ Implementation limitations ▪ No data definition ▪ Lack of standards

Network Model

Advantages	Disadvantages
▪ Conceptual simplicity ▪ Handles more relationship types ▪ Data access is flexible ▪ Data owner/member relationship promotes data integrity ▪ Conformance to standards ▪ Includes data definition language (DDL) and data manipulation language (DML)	▪ System complexity limits efficiency ▪ Navigational system yields complex implementation, application development, and management ▪ Structural changes require changes in all application programs

Standard Database Concepts

- Schema
  - Conceptual organization of the entire database as viewed by the database administrator
    - To add a new entity attribute in the relational model, you need to modify the table definition. To add a new attribute in the key-value store, you add a row to the key-value store, which is why it is said to be "schema-less."
    - Schema is of three types: Physical schema, logical schema and view schema.
      - The design of a database at physical level is called physical schema. It describes how the data stored on the disk or the physical storage.
      - Design of database at logical level is called logical schema, programmers and database administrator work at this level. At this level data can be described as certain types of data records gets stored in data structures.
      - Design of database at view level is called view schema. This generally describes end user interaction with database systems.

Standard Database Concepts

- Subschema
  - Portion of the database seen by the application programs that produce the desired information from the data within the database
    - A subschema provides a view of the database as seen by an application program.
      - This view is often a subset of the complete schema definition.
    - A subschema is used at run time to provide the DBMS with a description of those portions of the database that are accessible to the application program.
      - The subschema allows the user to view only that part of the database that is of interest to him.
    - The subschema defines the portion of the database as seen by the application programs and the application programs can have different view of data stored in the database.

Standard Database Concepts

- Data manipulation language (DML)
  - Environment in which data can be managed and is used to work with the data in the database
  - SQL includes commands to insert, update, delete, and retrieve data within the database tables.
  - PL/SQL blocks can contain only standard SQL data manipulation language (DML) commands such as SELECT, INSERT, UPDATE, and DELETE. The use of data definition language (DDL) commands is not directly supported in a PL/SQL block.

SQL DATA DEFINITION COMMANDS	
COMMAND OR OPTION	DESCRIPTION
CREATE SCHEMA AUTHORIZATION	Creates a database schema
CREATE TABLE	Creates a new table in the user's database schema
NOT NULL	Ensures that a column will not have null values
UNIQUE	Ensures that a column will not have duplicate values
PRIMARY KEY	Defines a primary key for a table
FOREIGN KEY	Defines a foreign key for a table
DEFAULT	Defines a default value for a column (when no value is given)
CHECK	Validates data in an attribute
CREATE INDEX	Creates an index for a table
CREATE VIEW	Creates a dynamic subset of rows and columns from one or more tables (see Chapter 8, Advanced SQL)
ALTER TABLE	Modifies a table's definition (adds, modifies, or deletes attributes or constraints)
CREATE TABLE AS	Creates a new table based on a query in the user's database schema
DROP TABLE	Permanently deletes a table (and its data)
DROP INDEX	Permanently deletes an index
DROP VIEW	Permanently deletes a view

Standard Database Concepts

- Schema data definition language (DDL)
  - Enables the database administrator to define the schema components
    - DDL allows a database administrator to define the database structure, schema, and subschema.
- Sub-Schema DDL, allows application programs to define the database components that will be used.

Standard Database Concepts

- Schema data definition language
  - Data Definition allows the specification of not only a set of relations but also information about each relation, including:
    - The schema for each relation.
    - The domain of values associated with each attribute.
    - Integrity constraints
    - The set of indices to be maintained for each relations.
    - Security and authorization information for each relation.
    - The physical storage structure of each relation on disk.

Standard Database Concepts

- Schema data definition language (DDL) Commands
  - CREATE

create table r (A_1 D_1, A_2 D_2, ..., A_n D_n,
(integrity-constraint$_1$),
...,
(integrity-constraint$_k$))

- r is the name of the relation
- each A_i is an attribute name in the schema of relation r
- D_i is the data type of values in the domain of attribute A_i

```
create table branch
    (branch_name char(15),
    branch_city char(30) not null,
    assets integer,
    primary key (branch_name))
```

  - ALTER
    - The Oracle ALTER TABLE statement is used to add, modify, or drop/delete columns in a table. The Oracle ALTER TABLE statement is also used to rename a table.
  - DROP
    - To remove a relation from an SQL database, we use the drop table command. The drop table command deletes all information about the dropped relation from the database. The command
      drop table r

```
SQL> drop table student;
```

The Relational Model

- Produced an automatic transmission database that replaced standard transmission databases
- Based on a relation
  - **Relation** or **table**: Matrix composed of intersecting tuple and attribute
    - **Tuple**: Rows
    - **Attribute**: Columns
- Describes a precise set of data manipulation constructs

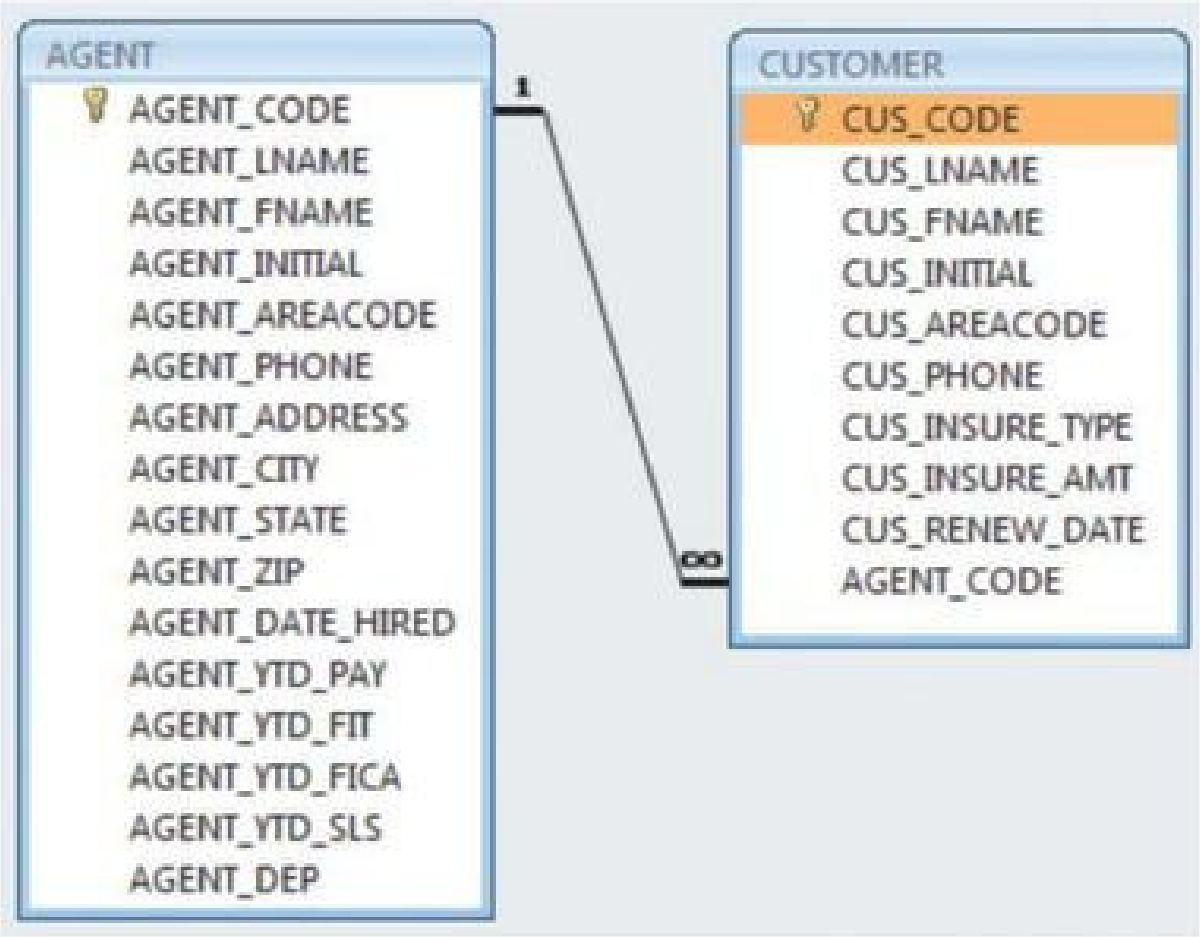
Relational Model

Advantages	Disadvantages
▪ Structural independence is promoted using independent tables ▪ Tabular view improves conceptual simplicity ▪ Ad hoc query capability is based on SQL ▪ Isolates the end user from physical-level details ▪ Improves implementation and management simplicity	▪ Requires substantial hardware and system software overhead ▪ Conceptual simplicity gives untrained people the tools to use a good system poorly ▪ May promote information problems

Relational Database Management System(RDBMS)

- Performs basic functions provided by the hierarchical and network DBMS systems
- Makes the relational data model easier to understand and implement
- Hides the complexities of the relational model from the user

Figure 2.2 - A Relational Diagram



SQL-Based Relational Database Application

- **End-user interface**
  - Allows end user to interact with the data
- **Collection of tables stored in the database**
  - Each table is independent from another
  - Rows in different tables are related based on common values in common attributes
- **SQL engine**
  - Executes all queries

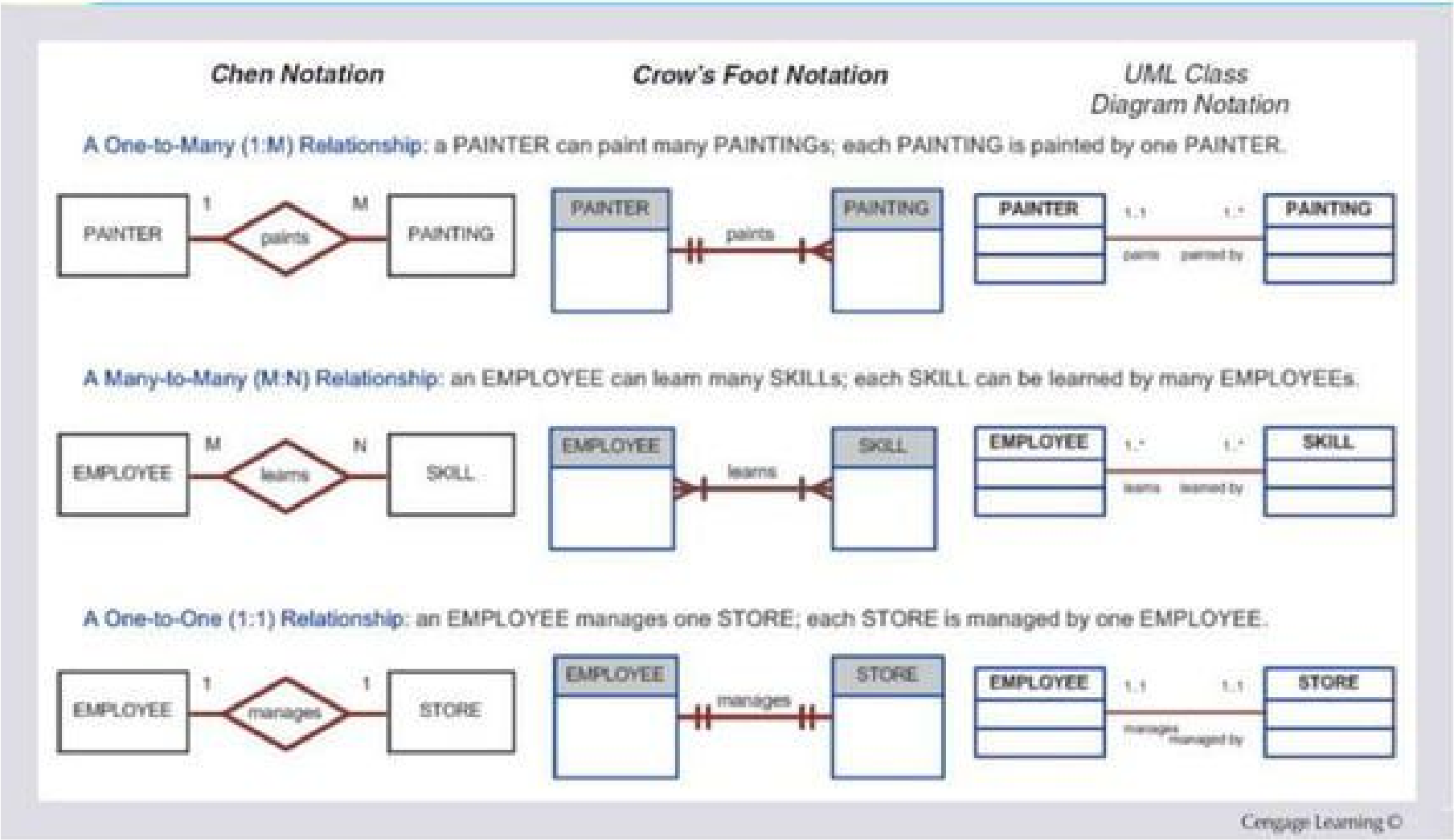
The Entity Relationship Model

- Graphical representation of entities and their relationships in a database structure
- **Entity relationship diagram (ERD)**
  - Uses graphic representations to model database components
- **Entity instance or entity occurrence**
  - Rows in the relational table
- **Connectivity**: Term used to label the relationship types

Entity Relationship Model

Advantages	Disadvantages
▪ Visual modeling yields conceptual simplicity ▪ Visual representation makes it an effective communication tool ▪ Is integrated with the dominant relational model	▪ Limited constraint representation ▪ Limited relationship representation ▪ No data manipulation language ▪ Loss of information content occurs when attributes are removed from entities to avoid crowded displays

Figure 2.3 - The ER Model Notations



The Object-Oriented Data Model (OODM) or Semantic Data Model

- **Object-oriented database management system (OODBMS)**
  - Based on OODM
- **Object**: Contains data and their relationships with operations that are performed on it
  - Basic building block for autonomous structures
  - Abstraction of real-world entity
- Attributes - Describe the properties of an object

The Object-Oriented Data Model (OODM)

- **Class**: Collection of similar objects with shared structure and behavior organized in a class hierarchy
  - **Class hierarchy**: Resembles an upside-down tree in which each class has only one parent
- **Inheritance**: Object inherits methods and attributes of parent class
- **Unified Modeling Language (UML)**
  - Describes sets of diagrams and symbols to graphically model a system

Object-Oriented Model

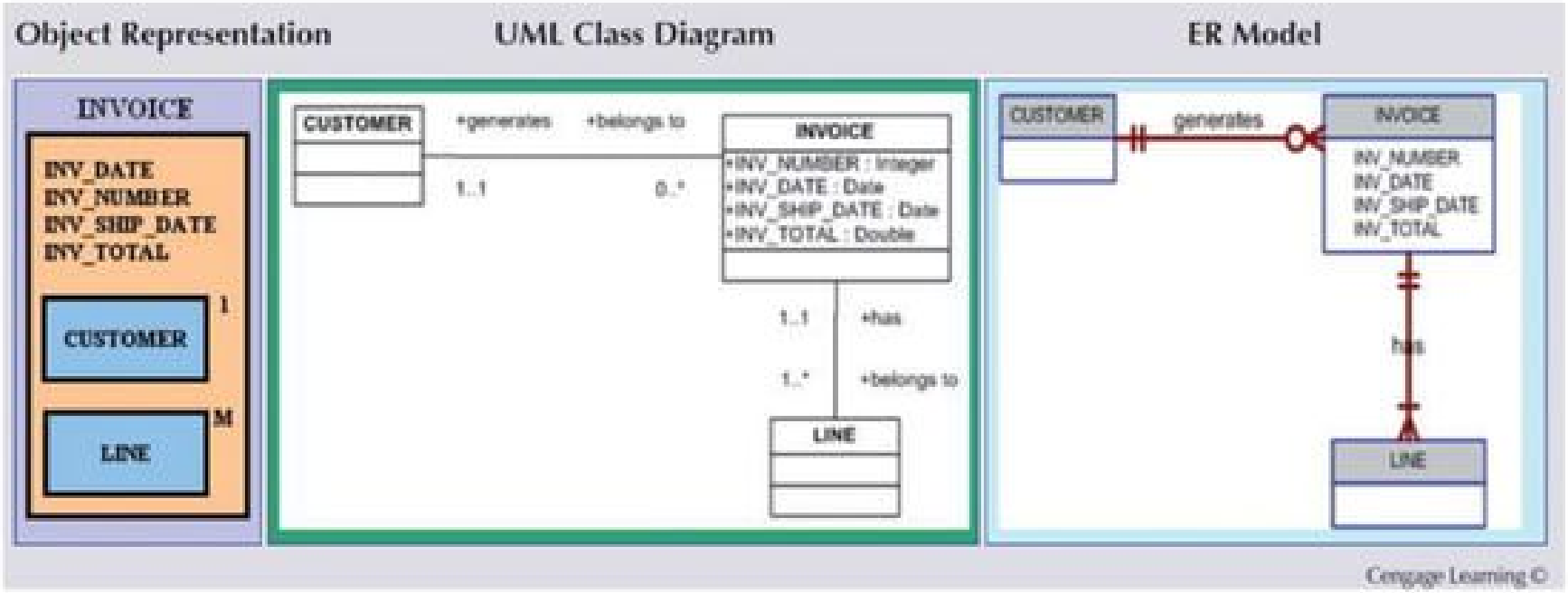
Advantages

- Semantic content is added
- Visual representation includes semantic content
- Inheritance promotes data integrity

Disadvantages

- Slow development of standards caused vendors to supply their own enhancements
  - Compromised widely accepted standard
- Complex navigational system
- Learning curve is steep
- High system overhead slows transactions

Figure 2.4 - A Comparison of OO, UML, and ER Models



Object/Relational and XML

- **Extended relational data model (ERDM)**
  - Supports OO features and complex data representation
  - **Object/Relational Database Management System (O/R DBMS)**
    - Based on ERDM, focuses on better data management
- **Extensible Markup Language (XML)**
  - Manages unstructured data for efficient and effective exchange of all data types

Big Data

- Aims to:
  - Find new and better ways to manage large amounts of web and sensor-generated data
  - Provide high performance and scalability at a reasonable cost
- Characteristics
  - Volume
  - Velocity
  - Variety

Different formats of 'big data'

- The three different formats of big data are:
- ***Structured:*** Organized data format with a fixed schema. Ex: RDBMS
- ***Semi-Structured:*** Partially organized data which does not have a fixed format. Ex: XML, JSON
- ***Unstructured:*** Unorganized data with an unknown schema. Ex: Audio, video files etc.

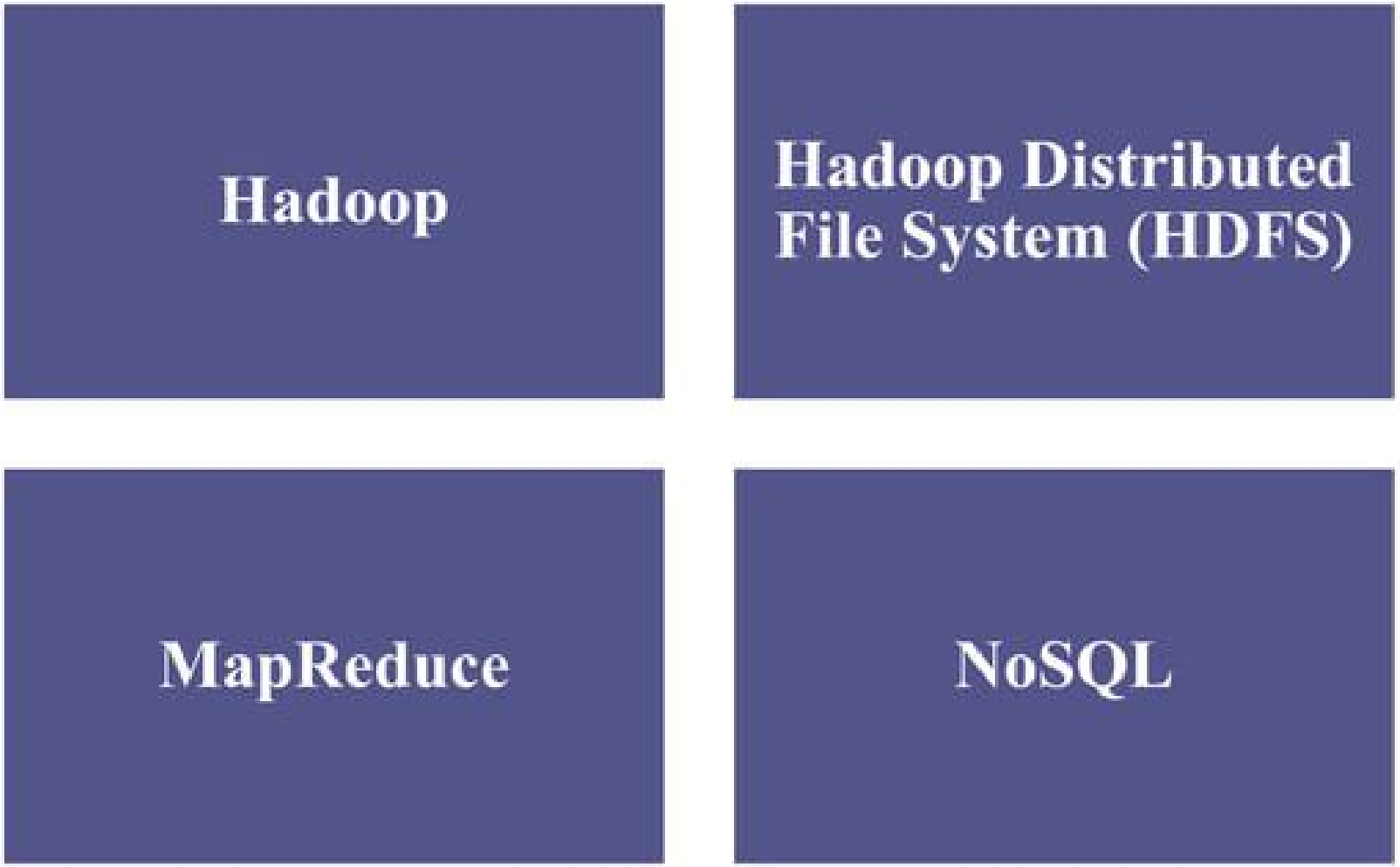
Characteristics of Big Data

- Validity: correctness of data
- Variability: dynamic behavior
- Volatility: tendency to change in time
- Vulnerability: vulnerable to breach or attacks
- Visualization: visualizing meaningful usage of data

Big Data Challenges

- Volume does not allow the usage of conventional structures
- Expensive
- OLAP tools proved inconsistent dealing with unstructured data

Big Data New Technologies



Big Data Tools

Big Data Applications

- **Entertainment:** Netflix and Amazon use Big Data to make shows and movie recommendations to their users.
- **Insurance:** Uses Big data to predict illness, accidents and price their products accordingly.
- **Driver-less Cars:** Google's driver-less cars collect about one gigabyte of data per second. These experiments require more and more data for their successful execution.
- **Education:** Opting for big data powered technology as a learning tool instead of traditional lecture methods, which enhanced the learning of students as well aided the teacher to track their performance better.
- **Automobile:** Rolls Royce has embraced Big Data by fitting hundreds of sensors into its engines and propulsion systems, which record every tiny detail about their operation. The changes in data in real-time are reported to engineers who will decide the best course of action such as scheduling maintenance or dispatching engineering teams should the problem require it.
- **Government:** A very interesting use of Big Data is in the field of politics to analyze patterns and influence election results. Cambridge Analytica Ltd. is one such organization which completely drives on data to change audience behavior and plays a major role in the electoral process.

Big Data Use Cases | https://www.oracle.com/big-data/guide/what-is-big-data.html

NoSQL Databases

- Not based on the relational model
- Support distributed database architectures
- Provide high scalability, high availability, and fault tolerance
- Support large amounts of sparse data
- Geared toward performance rather than transaction consistency
- Store data in key-value stores

Top 4 NoSQL Databases

	MongoDB	Cassandra	Elasticsearch	Couchbase
Description	One of the most popular document stores	Wide-column store based on ideas of BigTable and DynamoDB	A modern search and analytics engine based on Apache Lucene	JSON-based document store derived from CouchDB with a Memcached-compatible interface
Database model	Document store	Wide Column store	Search engine	Document store
Developer	MongoDB, Inc.	Apache Software Foundation	Elastic	Couchbase, Inc.
Release	2009	2008	2010	2011
Language	C++	Java	Java	C, C++ and Erlang
Server-side scripts	JavaScript	No	Yes	View functions in JavaScript
Replication methods	Master-slave replication	Selectable replication factor	Yes	Master-master replication, Master-slave replication
Best use	If you need dynamic queries. If you prefer to define indexes, not map and reduced functions. If you need good performance on a big DB and when your data changes too much	When data you need to store doesn't fit on server, but requires friendly familiar interface to it	When you have objects with flexible fields, and you need "advanced search" functionality	Any application that requires low-latency data access, high concurrency support and high availability

NoSQL

Advantages	Disadvantages
▪ High scalability, availability, and fault tolerance are provided ▪ Uses low-cost commodity hardware ▪ Supports Big Data ▪ 4. Key-value model improves storage efficiency ▪ In terms of data consistency, it provides an eventually consistent model	▪ Complex programming is required ▪ There is no relationship support ▪ There is no transaction integrity support

NoSQL and Relational Databases Comparison

Feature	NoSQL Databases	Relational Databases
Performance	High	Low
Reliability	Poor	Good
Availability	Good	Good
Consistency	Poor	Good
Data Storage	Optimized for huge data	Medium sized to large
Scalability	High	High (but more expensive)

NoSQL databases	https://dev.to/lmolivera/everything-you-need-to-know-about-nosql-databases-3o3h

Figure 2.5 - A Simple Key-value Representation

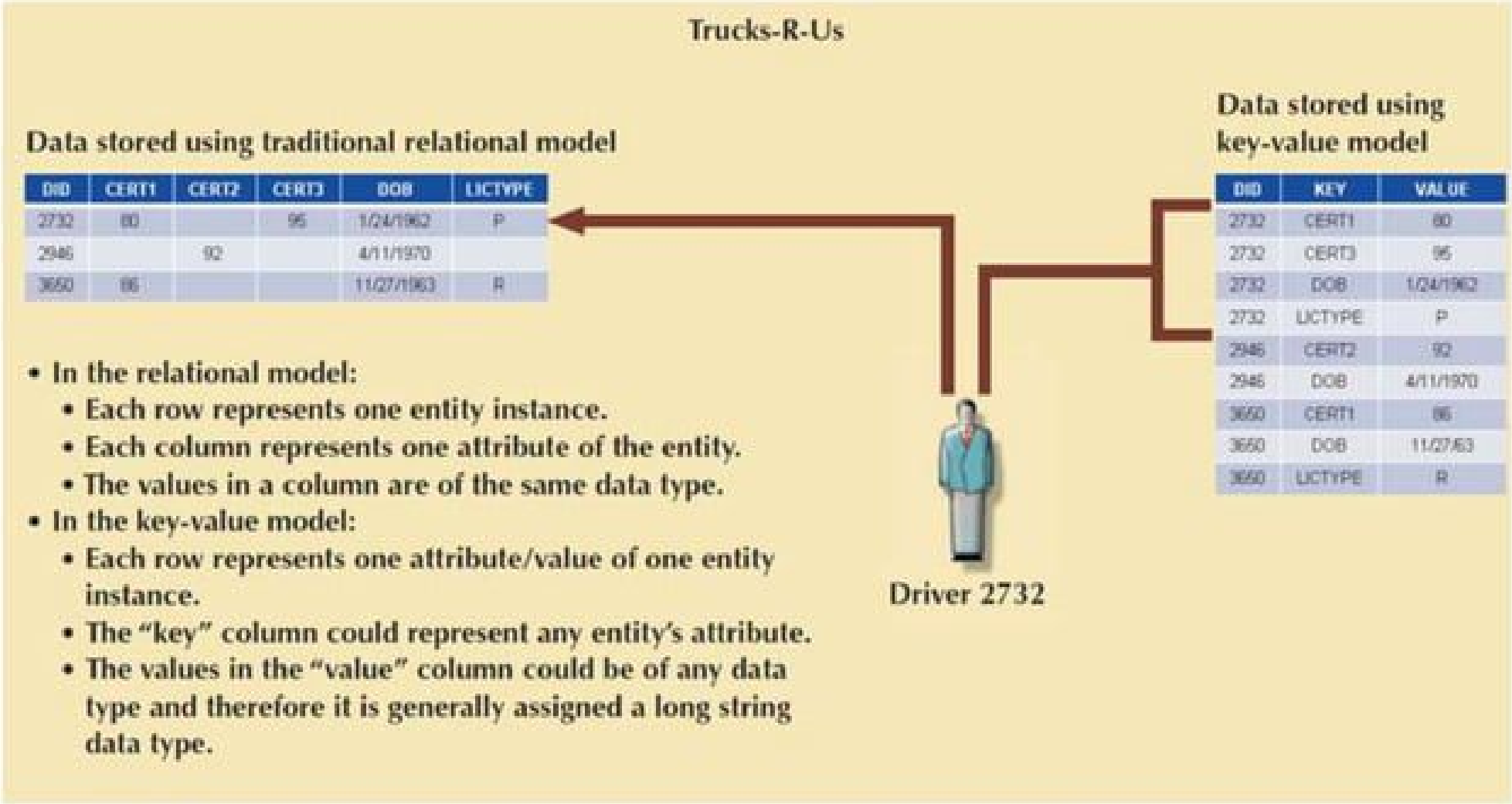


Figure 2.6 - The Evolution of Data Models

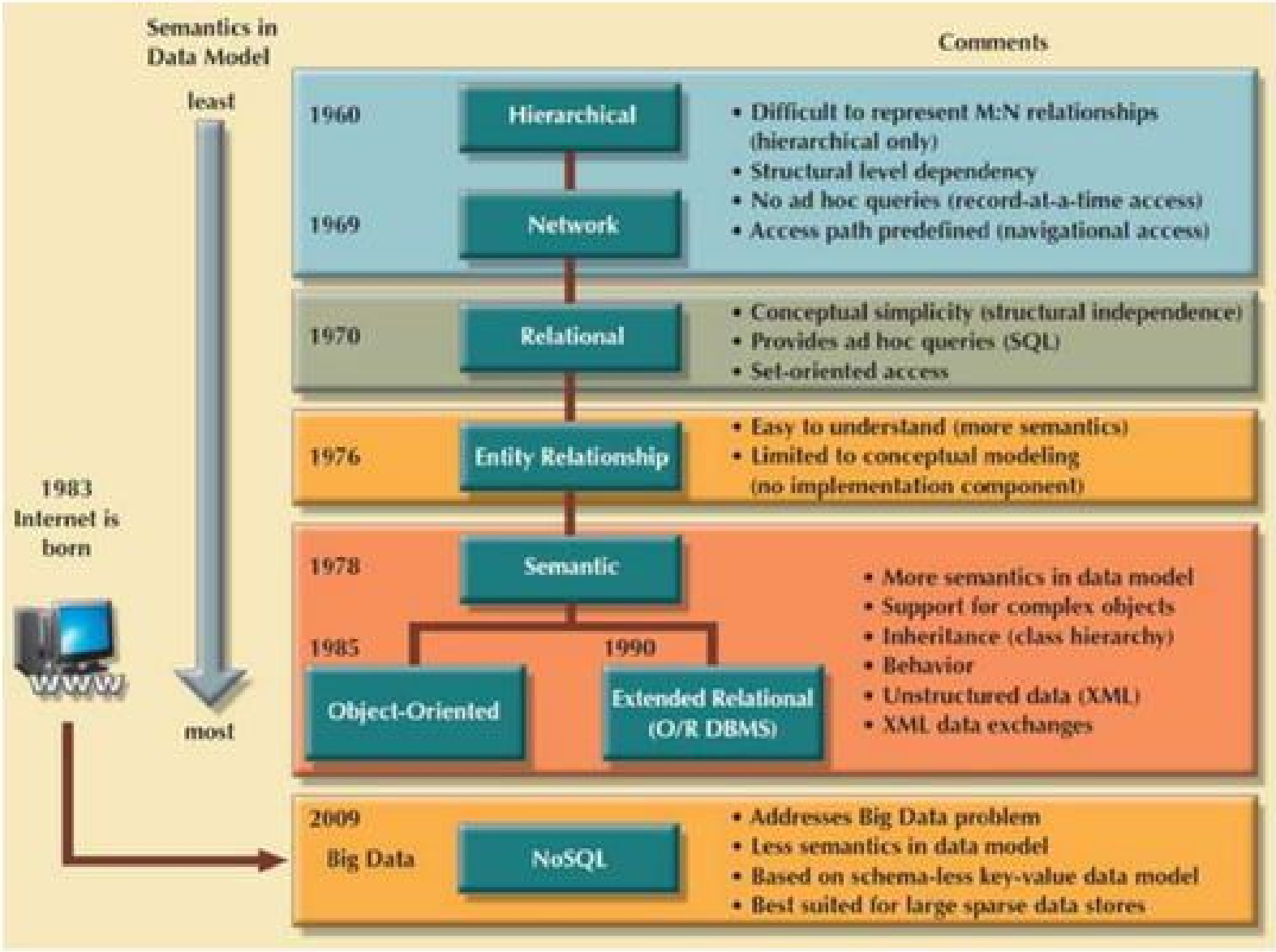
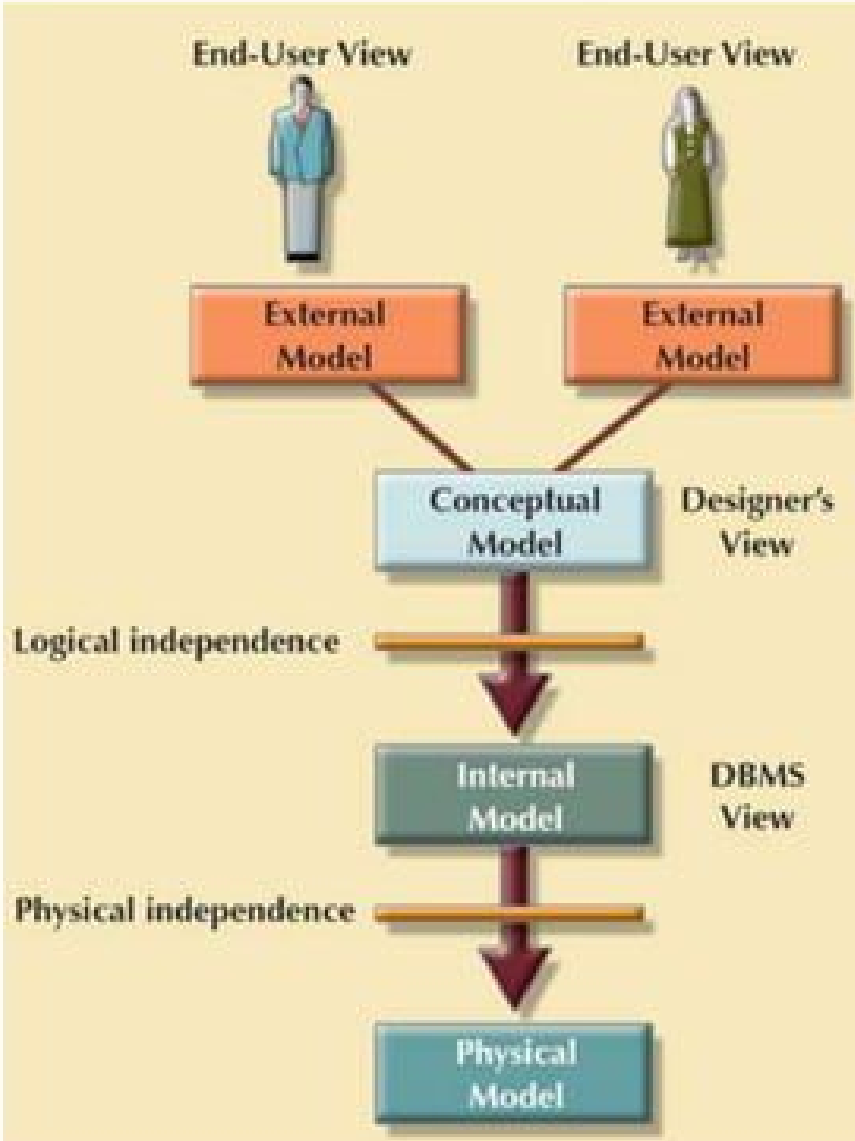


Table 2.3 - Data Model Basic Terminology Comparison

REAL WORLD	EXAMPLE	FILE PROCESSING	HIERARCHICAL MODEL	NETWORK MODEL	RELATIONAL MODEL	ER MODEL	OO MODEL
A group of vendors	Vendor file cabinet	File	Segment type	Record type	Table	Entity set	Class
A single vendor	Global supplies	Record	Segment occurrence	Current record	Row (tuple)	Entity occurrence	Object instance
The contact name	Johnny Ventura	Field	Segment field	Record field	Table attribute	Entity attribute	Object attribute
The vendor identifier	G12987	Index	Sequence field	Record key	Key	Entity identifier	Object identifier
Note: For additional information about the terms used in this table, consult the corresponding chapters and online appendixes that accompany this book. For example, if you want to know more about the OO model, refer to Appendix G, Object-Oriented Databases.							

Figure 2.7 - Data Abstraction Levels

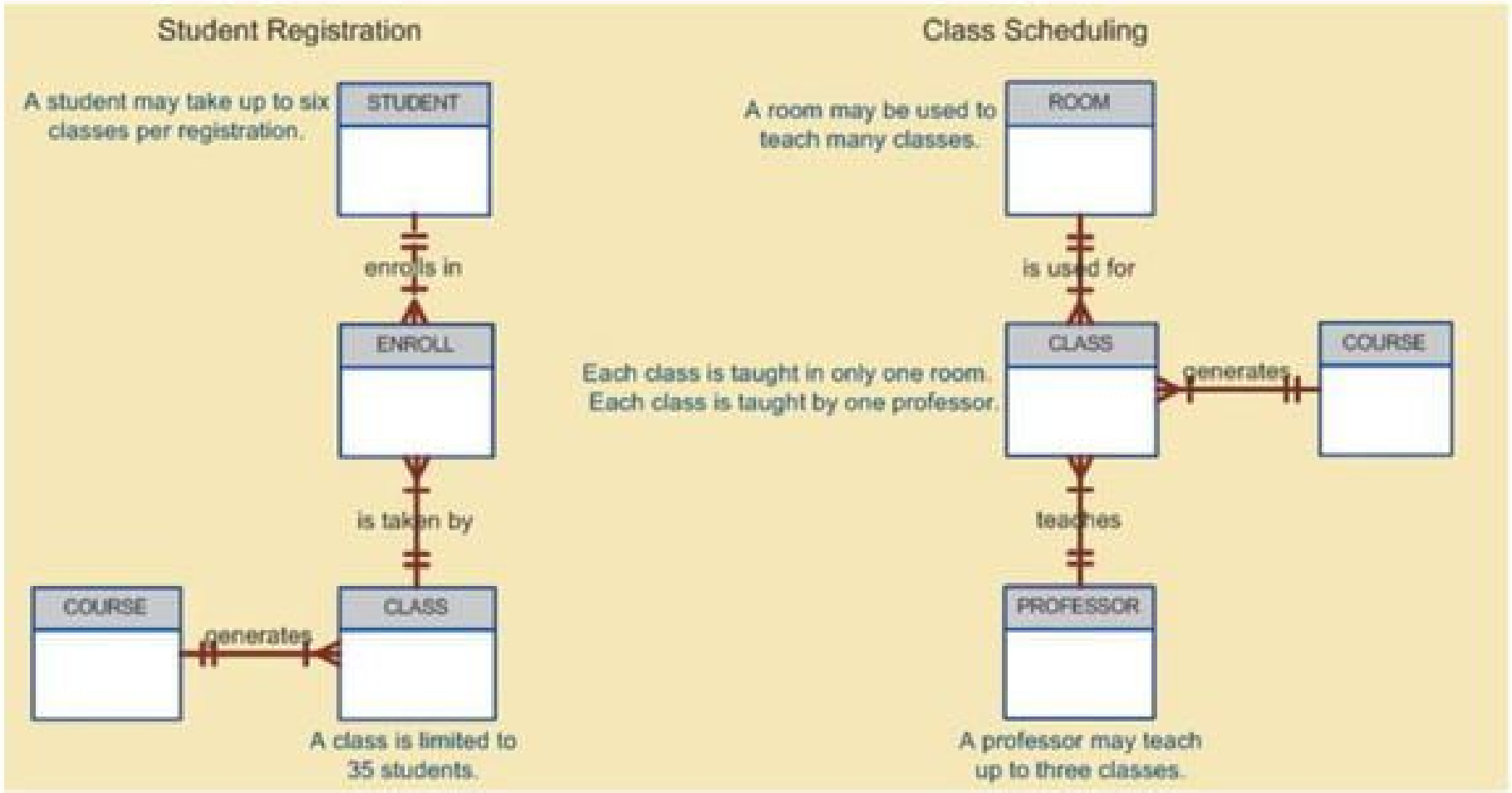


Degree of Abstraction		Characteristics
High	ER Object-Oriented	Hardware-independent Software-independent
Medium	Relational	Hardware-independent Software-dependent
Low	Network Hierarchical	Hardware-dependent Software-dependent

The External Model

- End users' view of the data environment
- ER diagrams are used to represent the external views
- **External schema**: Specific representation of an external view

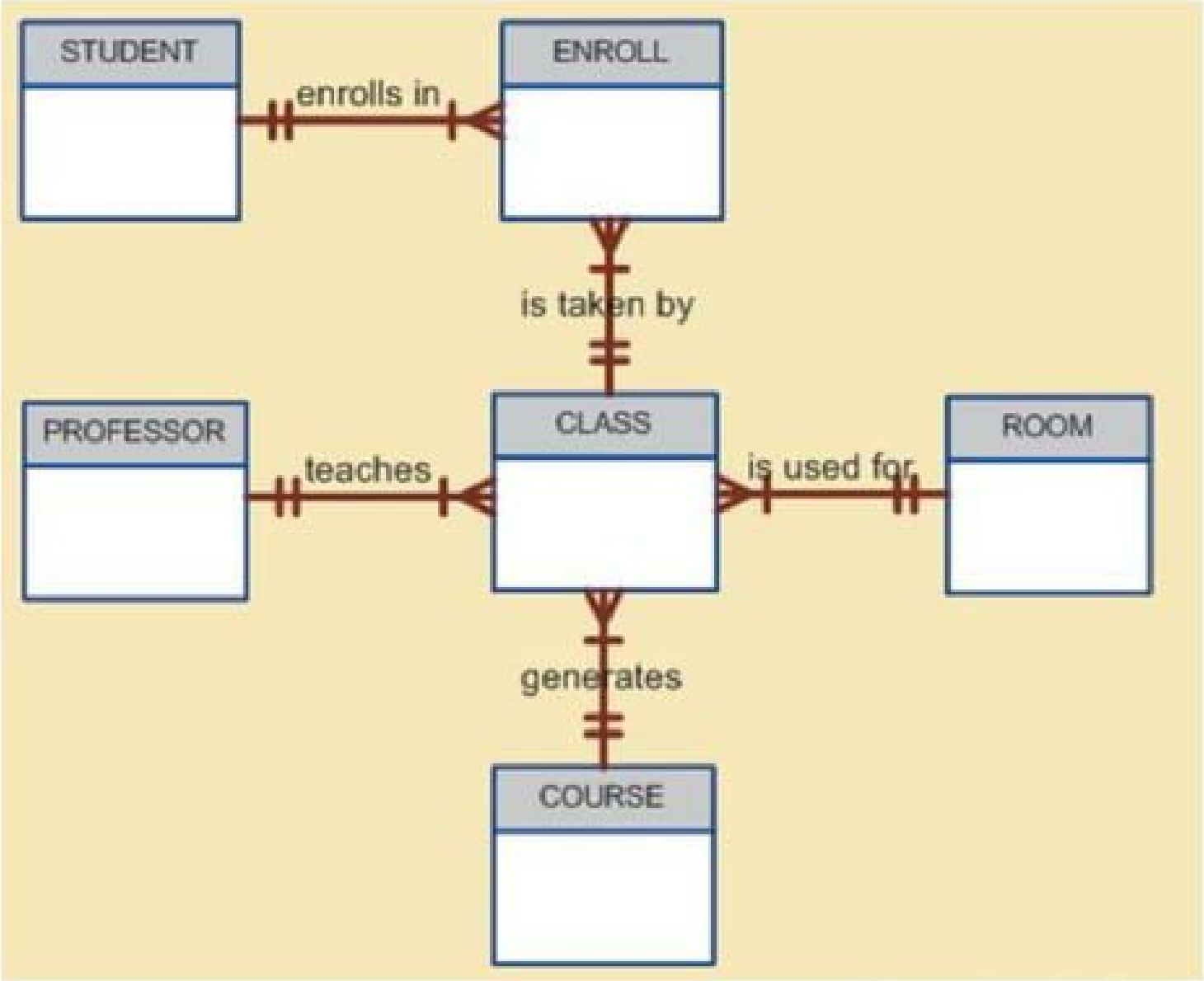
Figure 2.8 - External Models for Tiny College



The Conceptual Model

- Represents a global view of the entire database by the entire organization
- **Conceptual schema**: Basis for the identification and high-level description of the main data objects
- Has a macro-level view of data environment
- Is software and hardware independent
- **Logical design**: Task of creating a conceptual data model

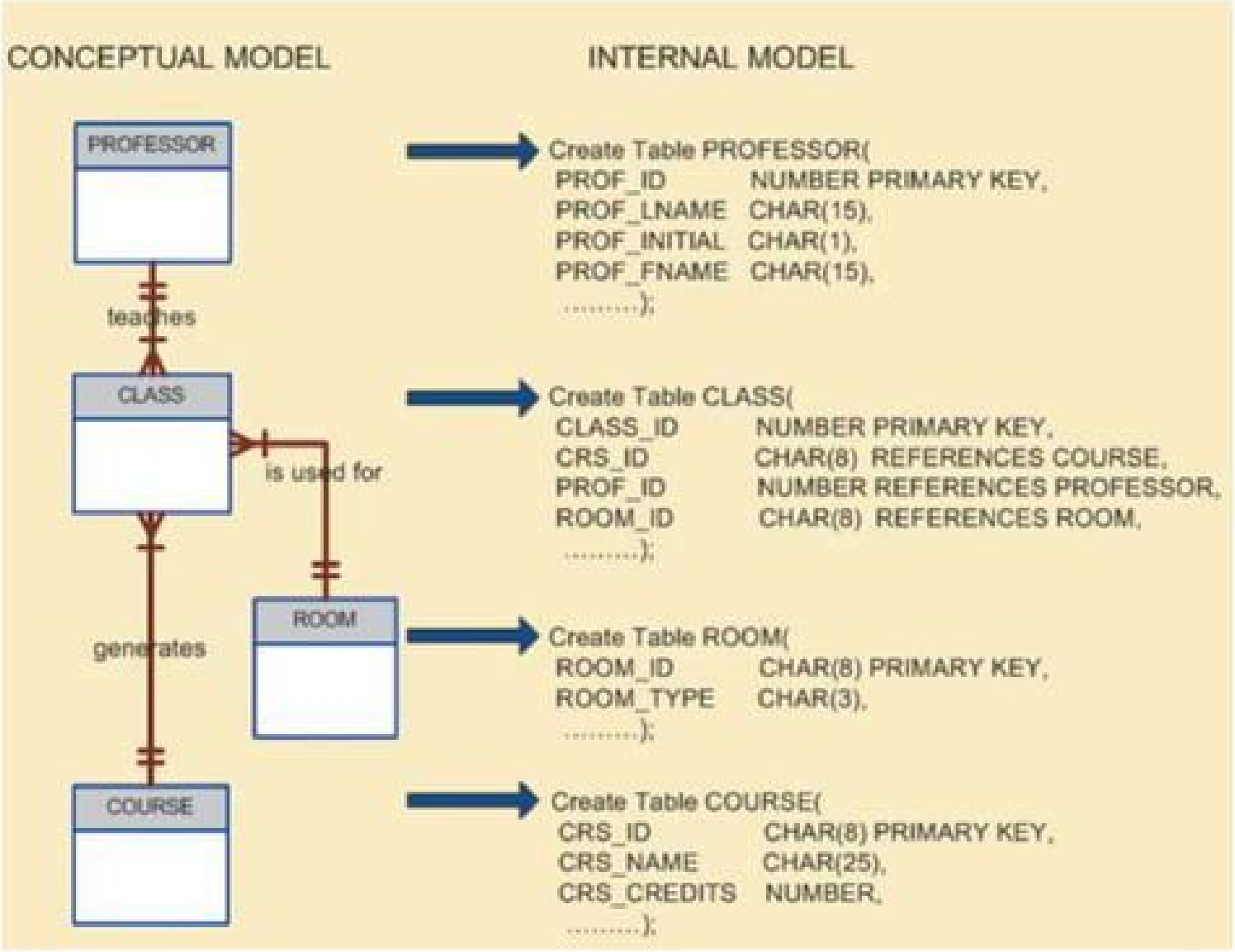
Figure 2.9 - Conceptual Model for Tiny College



The Internal Model

- Representing database as seen by the DBMS mapping conceptual model to the DBMS
- **Internal schema**: Specific representation of an internal model
  - Uses the database constructs supported by the chosen database
- Is software dependent and hardware independent
- **Logical independence**: Changing internal model without affecting the conceptual model

Figure 2.10 - Internal Model for Tiny College



The Physical Model

- Operates at lowest level of abstraction
- Describes the way data are saved on storage media such as disks or tapes
- Requires the definition of physical storage and data access methods
- Relational model aimed at logical level
  - Does not require physical-level details
- **Physical independence**: Changes in physical model do not affect internal model

Table 2.4 - Levels of Data Abstraction

MODEL	DEGREE OF ABSTRACTION	FOCUS	INDEPENDENT OF
External	High	End-user views	Hardware and software
Conceptual	↕	Global view of data (database model independent)	Hardware and software
Internal	↕	Specific database model	Hardware
Physical	Low	Storage and access methods	Neither hardware nor software