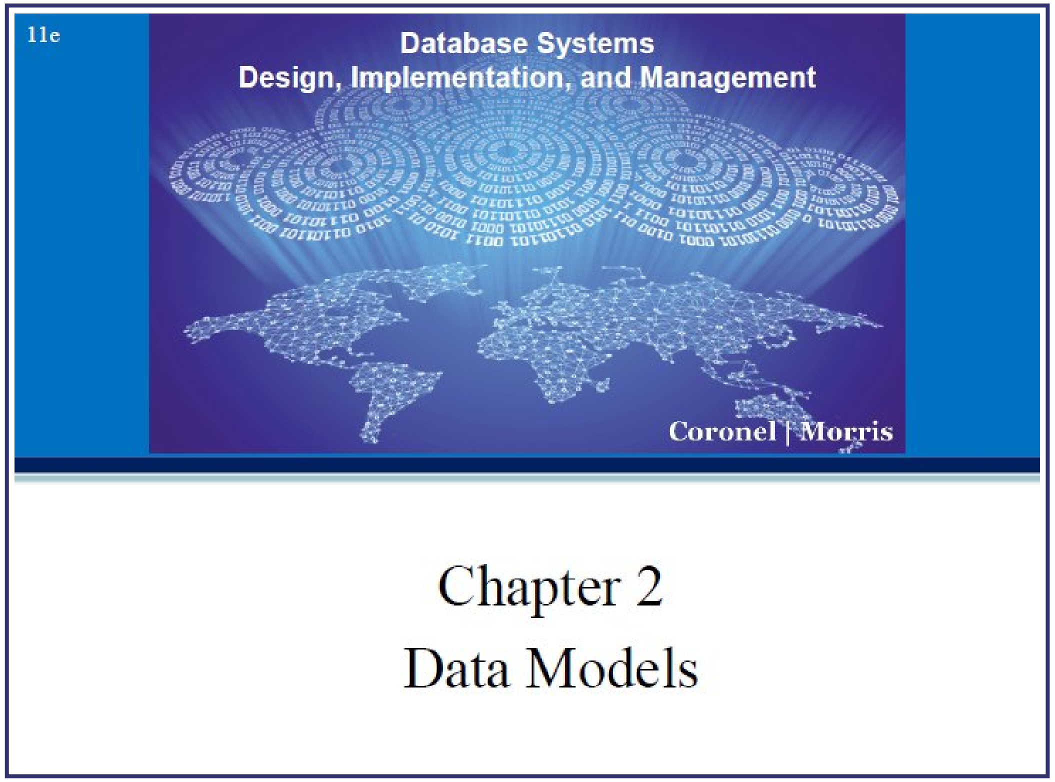
Data Modeling

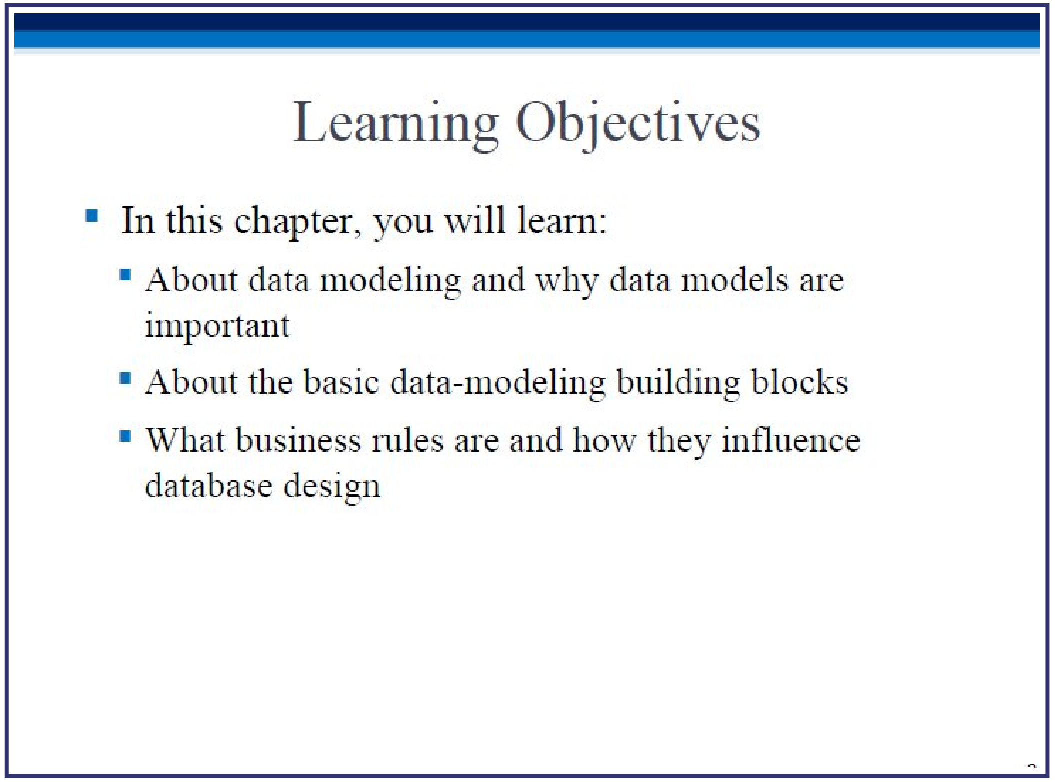


11e

Database Systems
Design, Implementation, and Management

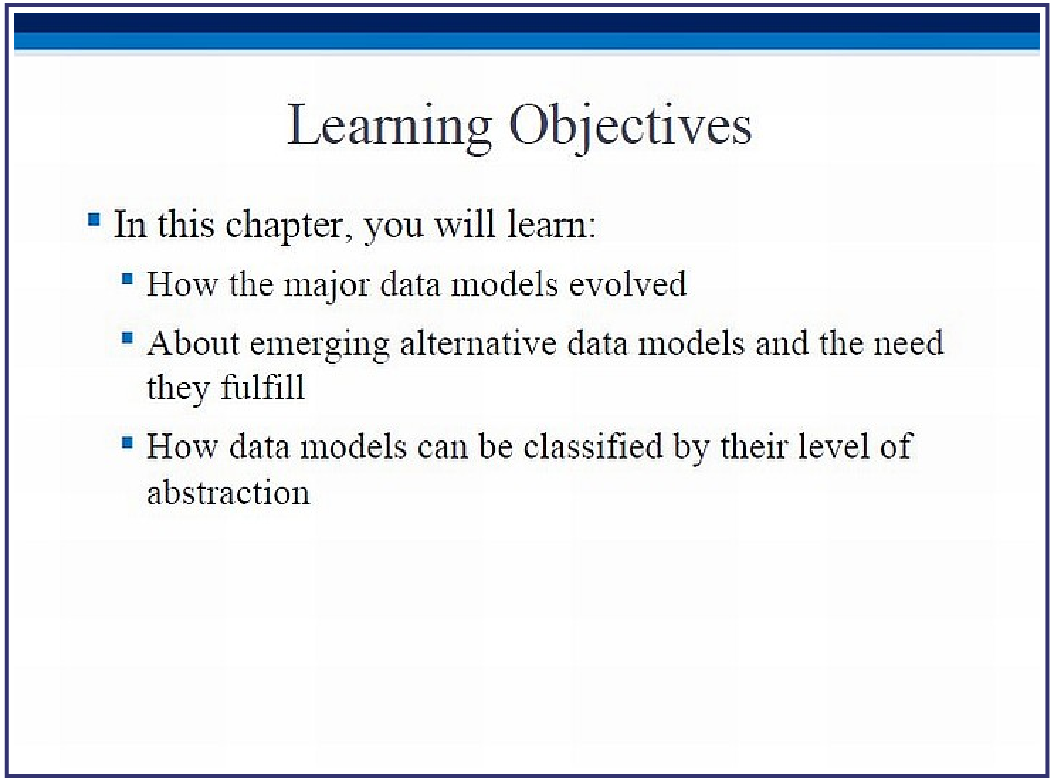
Coronel | Morris

Chapter 2
Data Models



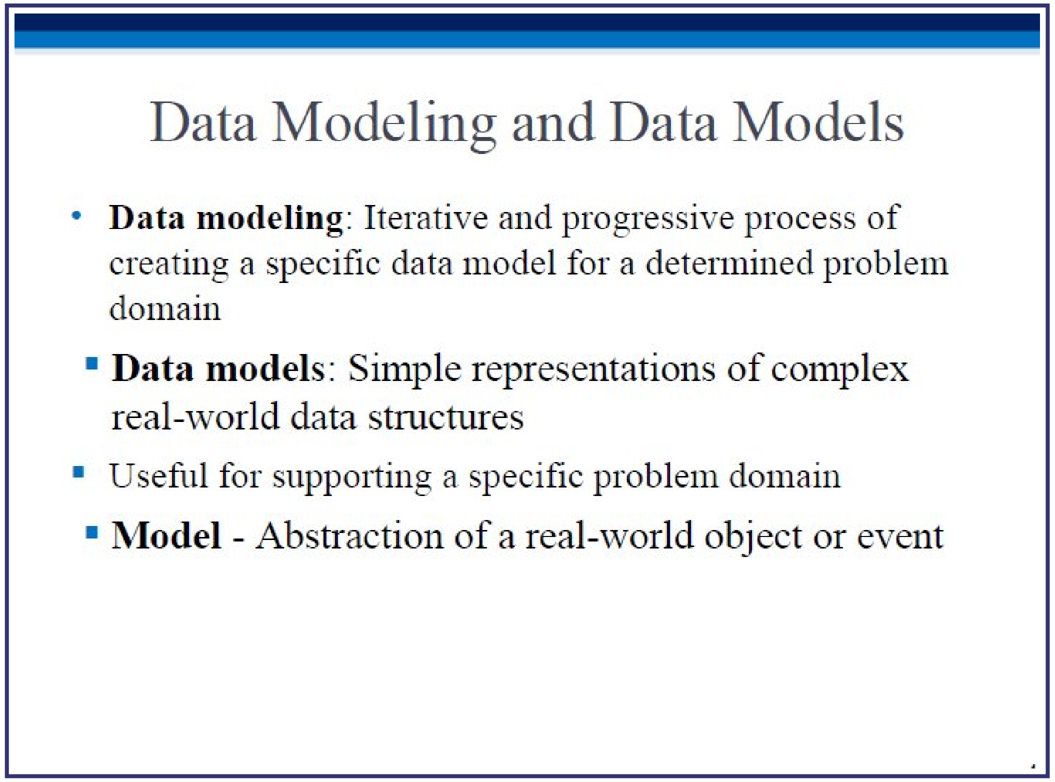
Learning Objectives

- In this chapter, you will learn:
  - About data modeling and why data models are important
  - About the basic data-modeling building blocks
  - What business rules are and how they influence database design



Learning Objectives

- In this chapter, you will learn:
  - How the major data models evolved
  - About emerging alternative data models and the need they fulfill
  - How data models can be classified by their level of abstraction



Data Modeling and Data Models

- **Data modeling**: Iterative and progressive process of creating a specific data model for a determined problem domain
- **Data models**: Simple representations of complex real-world data structures
- Useful for supporting a specific problem domain
- **Model** - Abstraction of a real-world object or event

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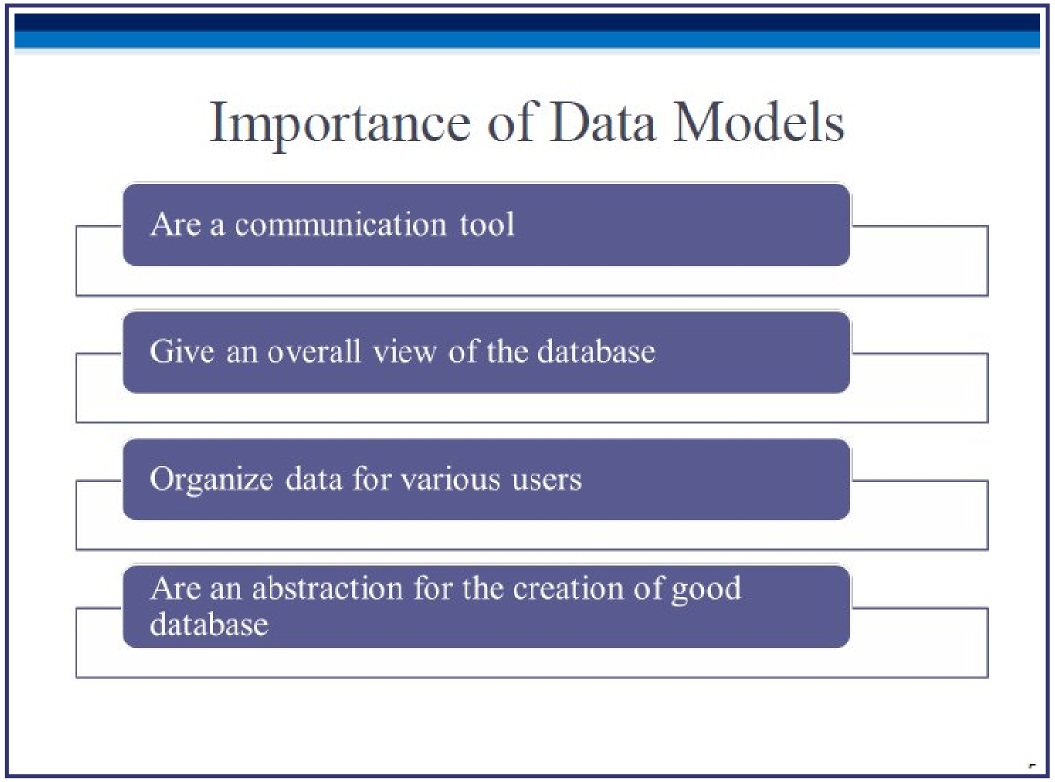

Importance of Data Models

- 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

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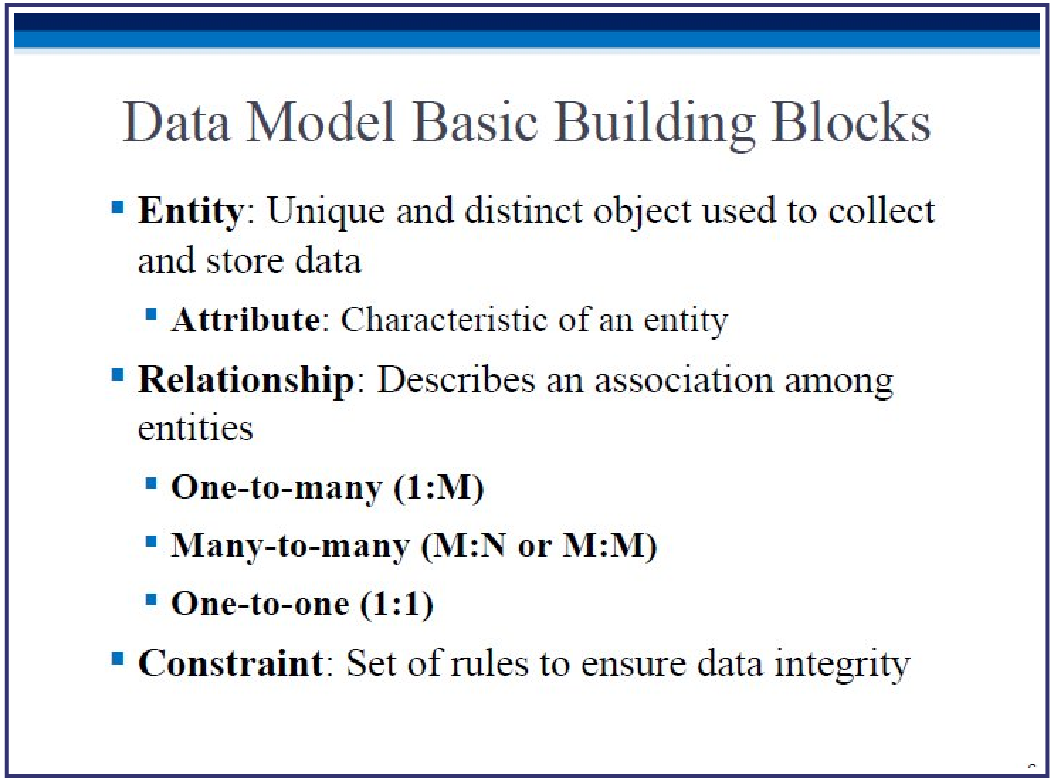
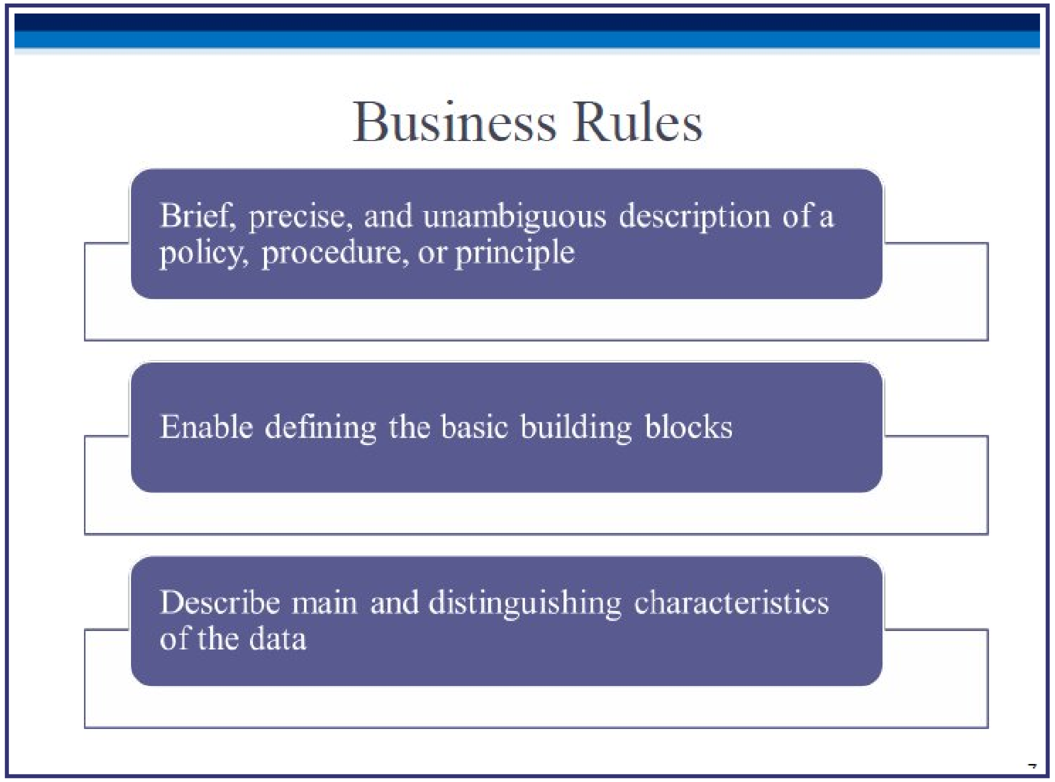


Data Model Basic Building Blocks

- **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

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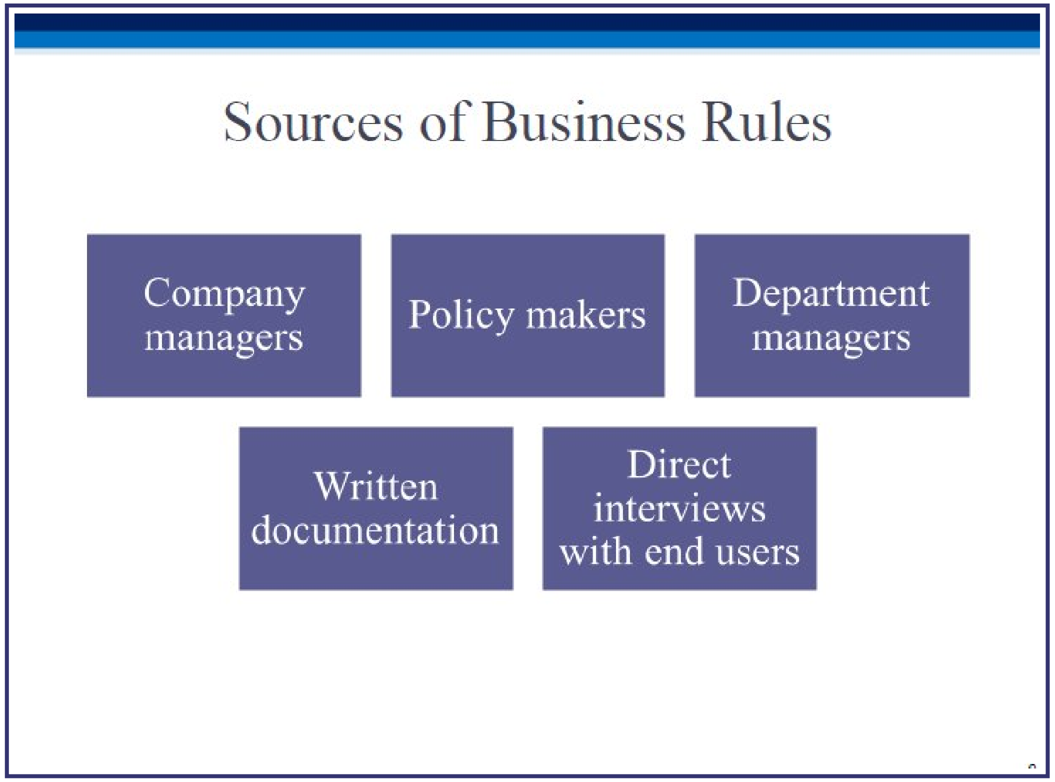
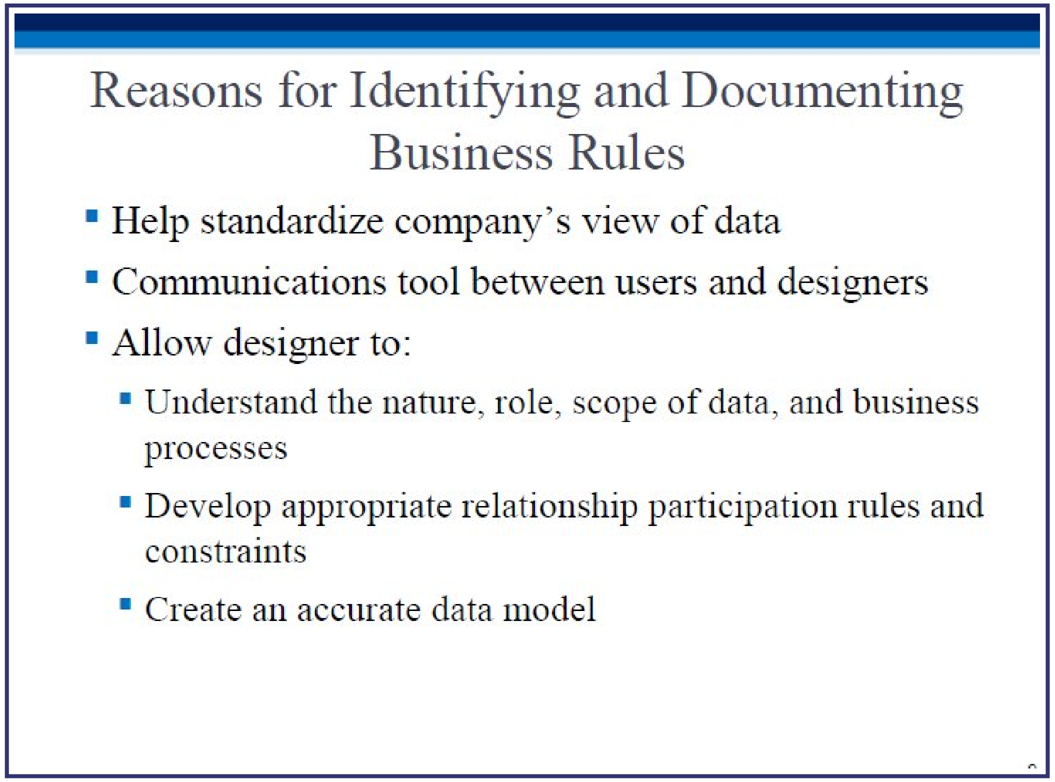


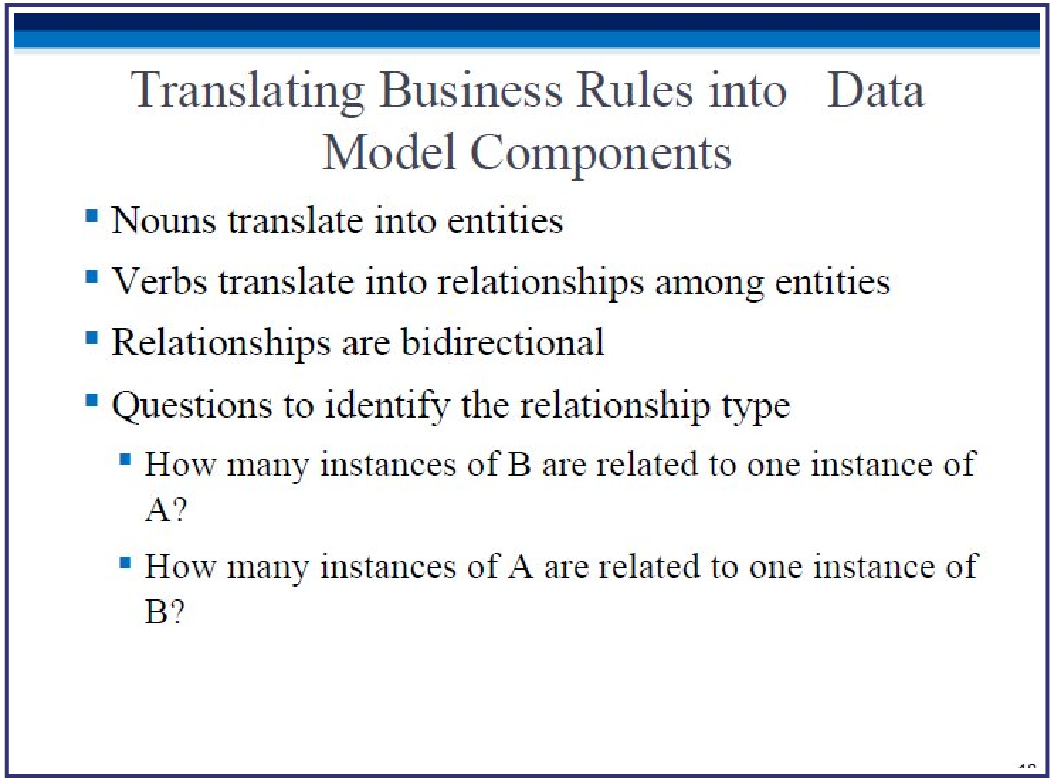
Sources of Business Rules

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



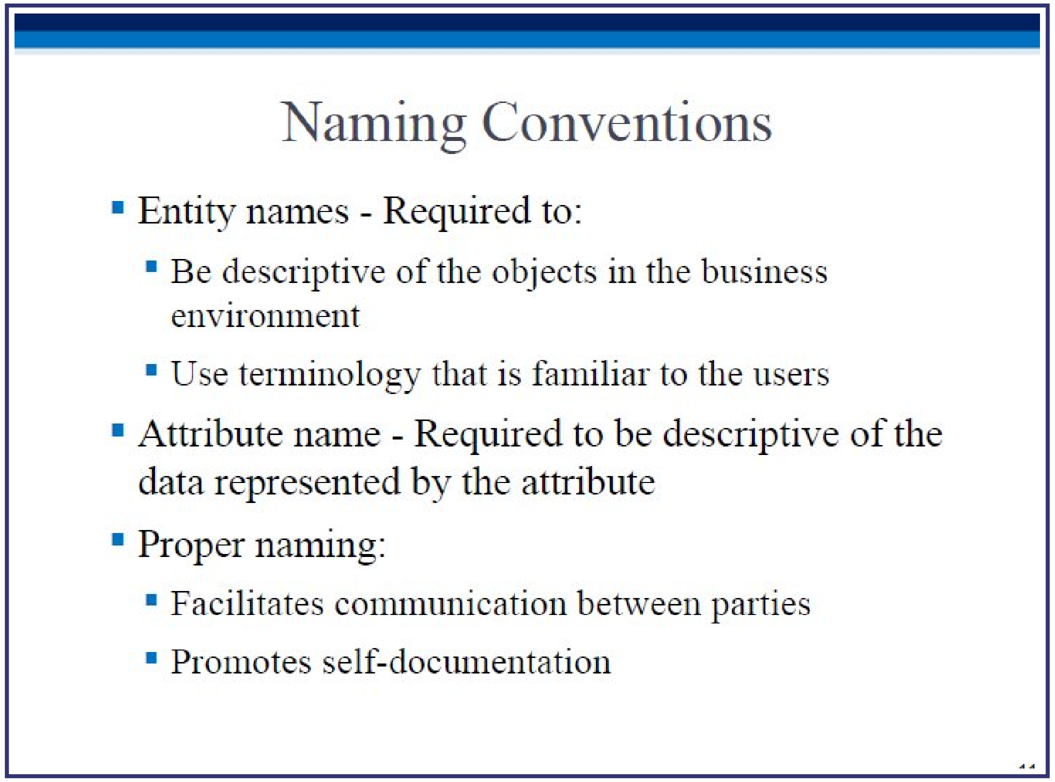
Reasons for Identifying and Documenting Business Rules

- 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

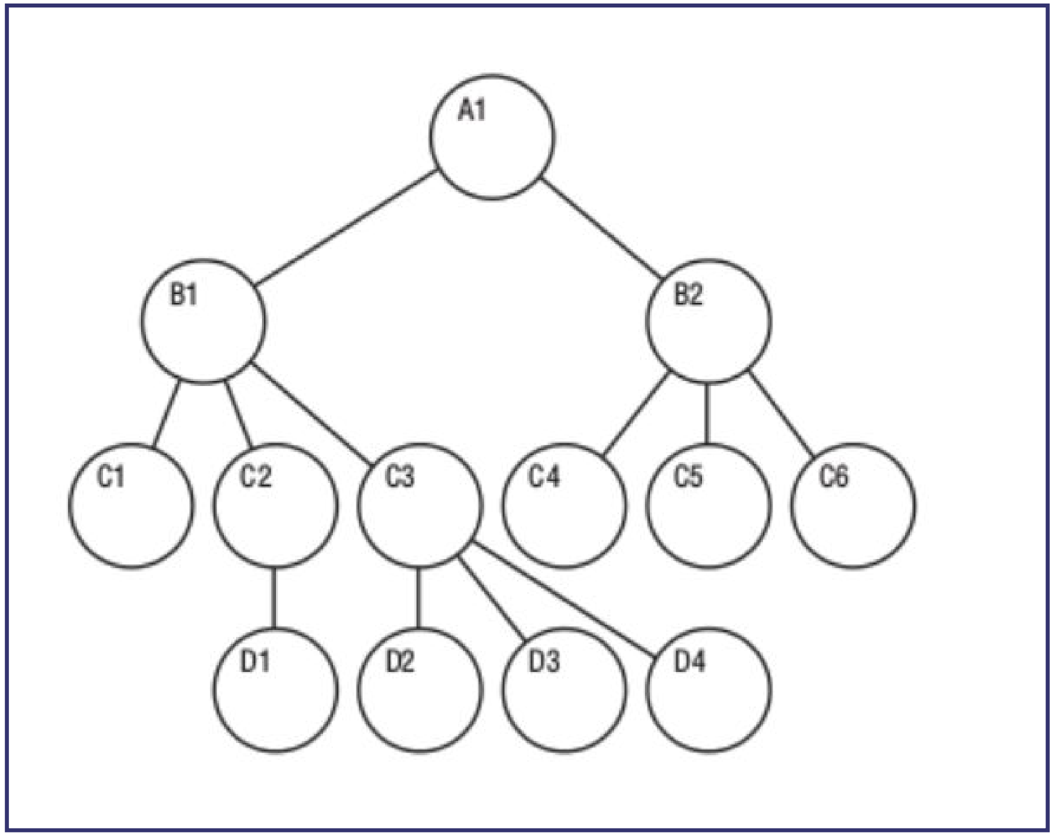
- Nouns translate into entities
- Verbs translate into relationships among entities
- Relationships are bidirectional
- Questions to identify the relationship type
  - How many instances of B are related to one instance of A?
  - How many instances of A are related to one instance of B?



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

Hierarchical modeling



At first, data was stored in individual files (transitioned from paper). The next improvement was a 'hierarchical DB model', where data was structured in the form of a tree [similar to a modern filesystem]. Data, in the form of nodes, are linked in a tree-like fashion. To traverse the tree, we need to know the underlying format ('class hierarchy, to make an analogy with classes and objects), and the actual path [eg. to relate A1 and D2, we need to traverse A1->B1->C3>D2].

Hierarchies are good for '1:M' [tree], but not 'M:N' [graph or multiple inheritance].

Network modeling

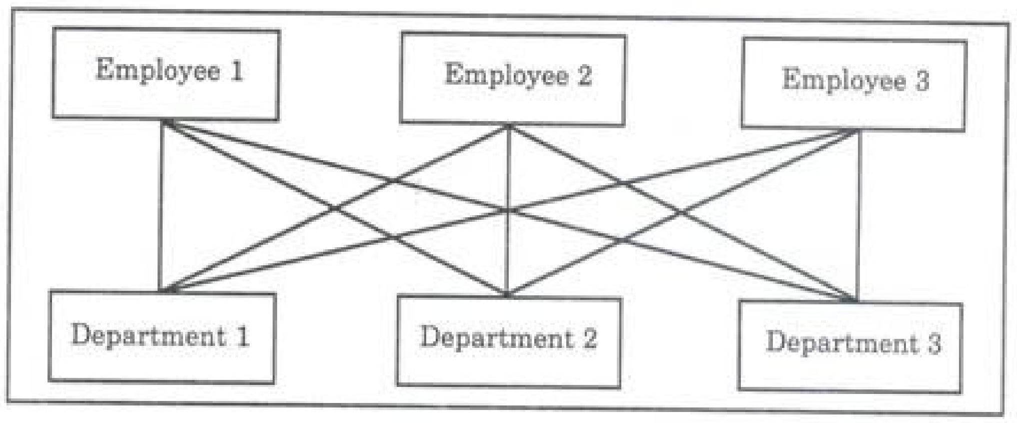
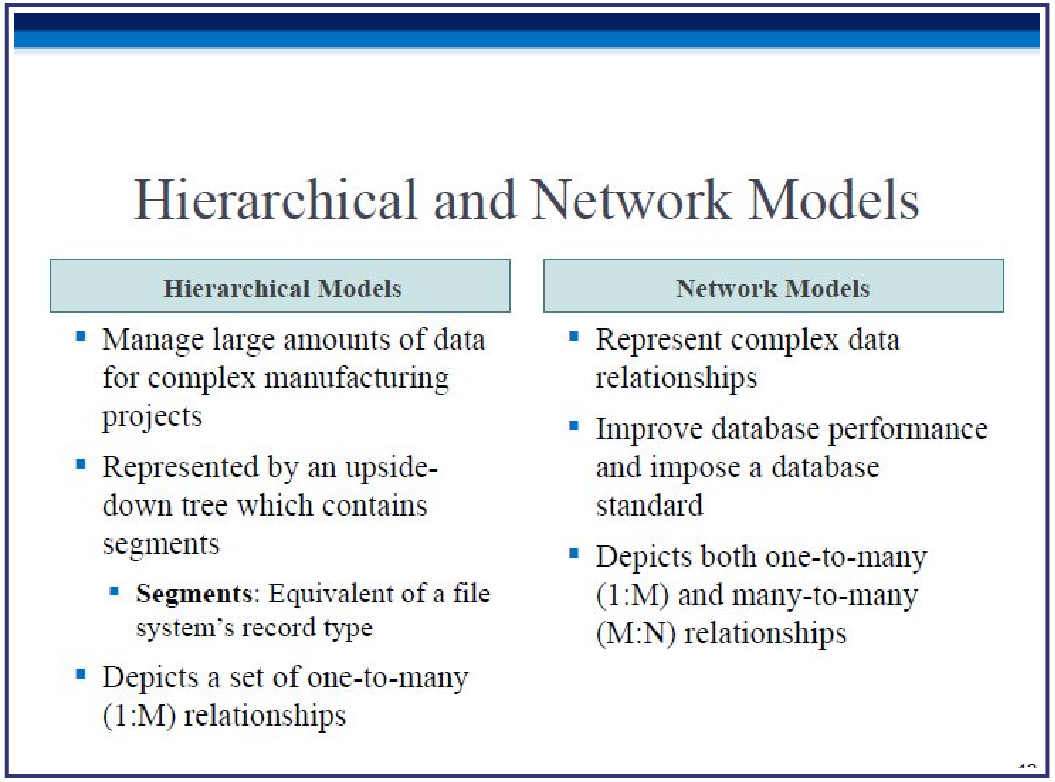


Fig. 9.5 Network model of employee information systems

A network model is better than a hierarchical one, because it can capture M:N [in addition to the above, another example is 'products and orders'].



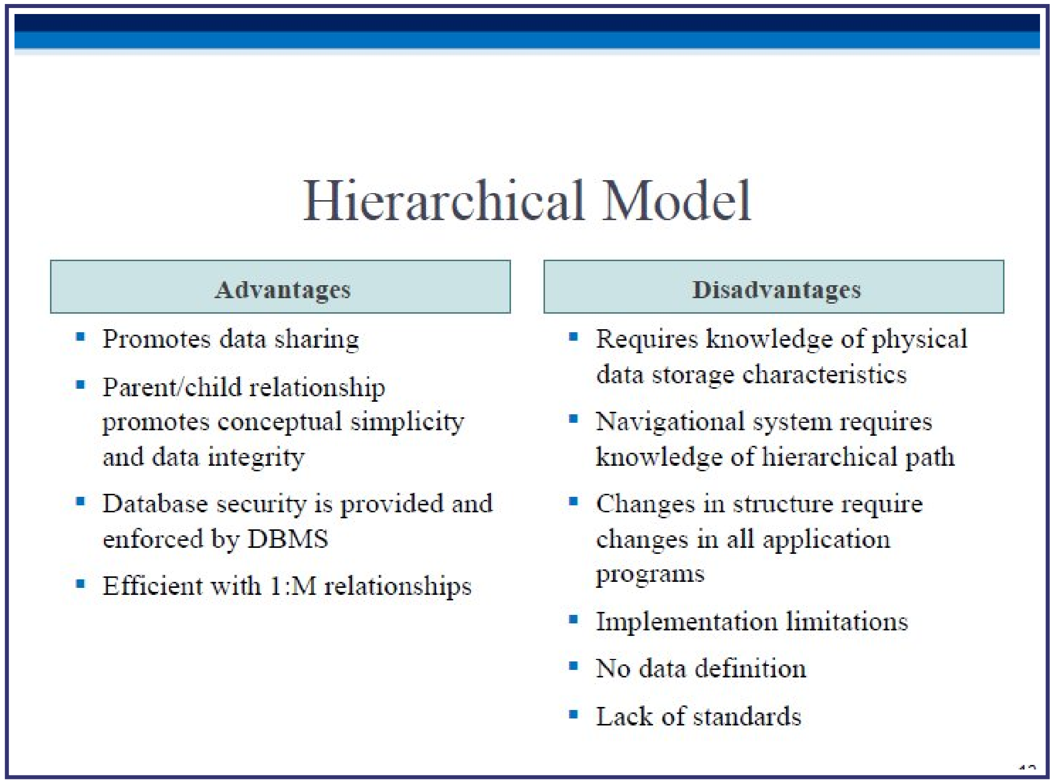
Hierarchical and Network Models

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



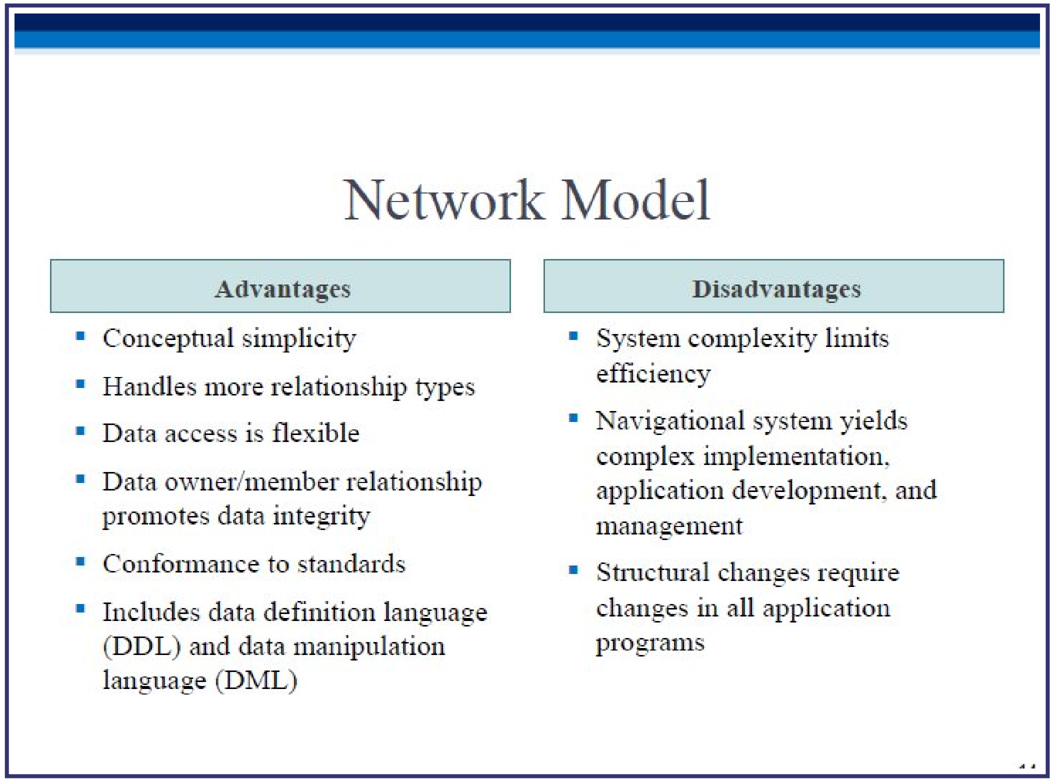
Hierarchical Model

Advantages

- 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

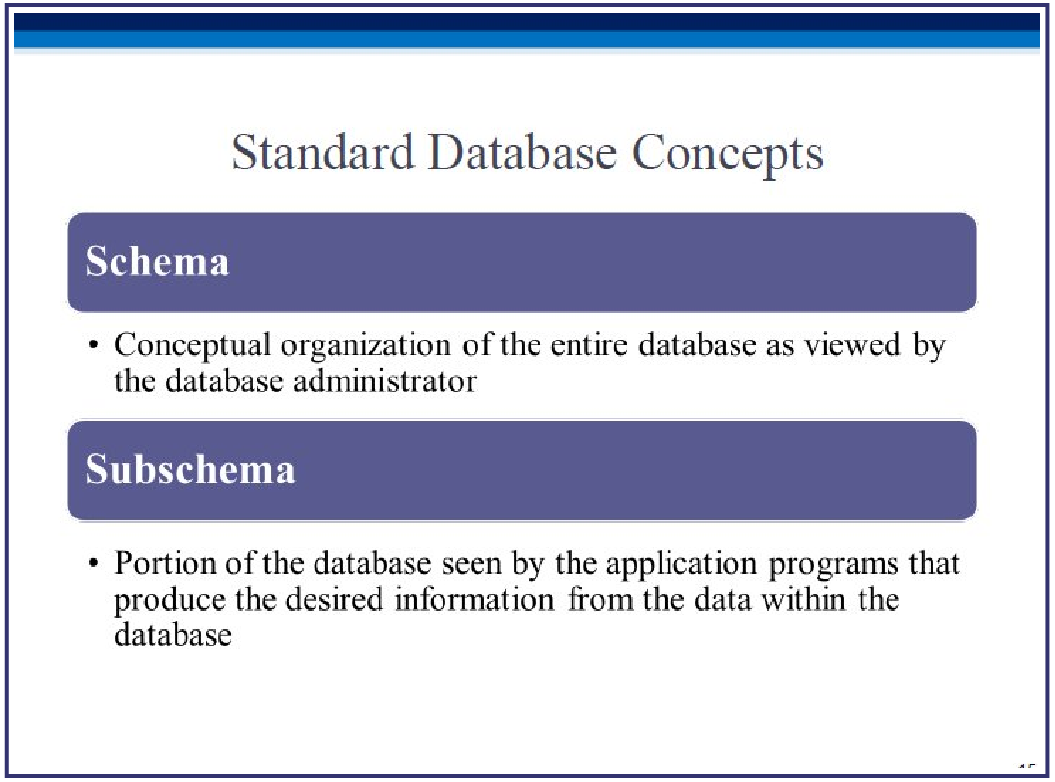
Disadvantages

- 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

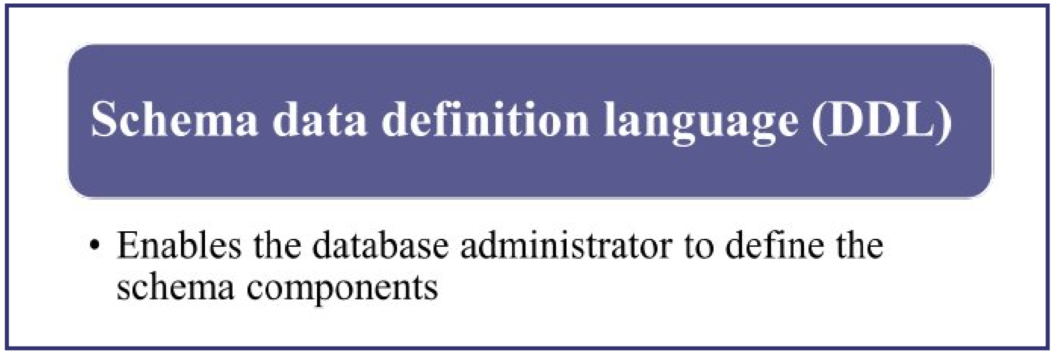
Schema

- Conceptual organization of the entire database as viewed by the database administrator

Subschema

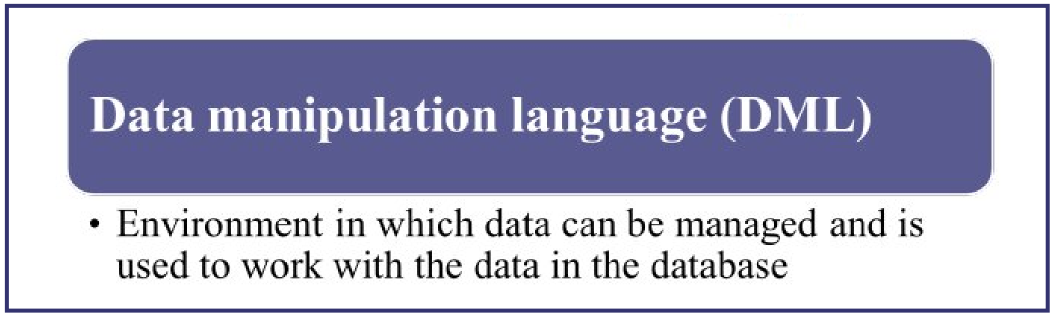
- Portion of the database seen by the application programs that produce the desired information from the data within the database

Data creation, querying



Schema data definition language (DDL)

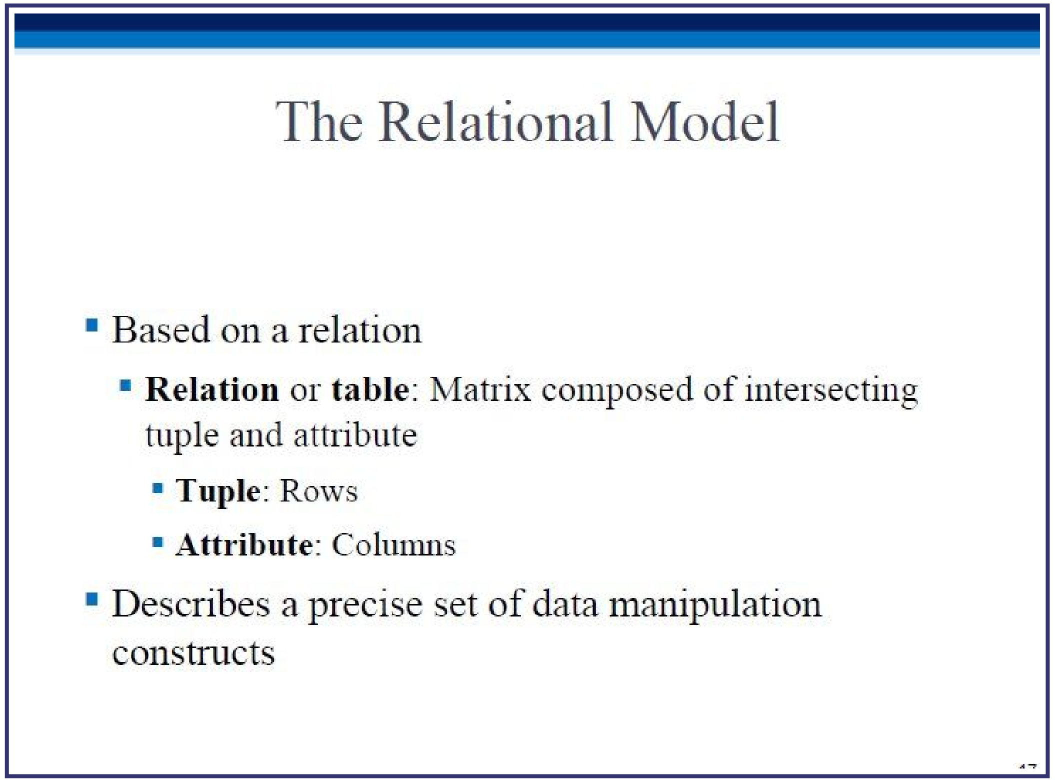
- Enables the database administrator to define the schema components



Data manipulation language (DML)

- Environment in which data can be managed and is used to work with the data in the database

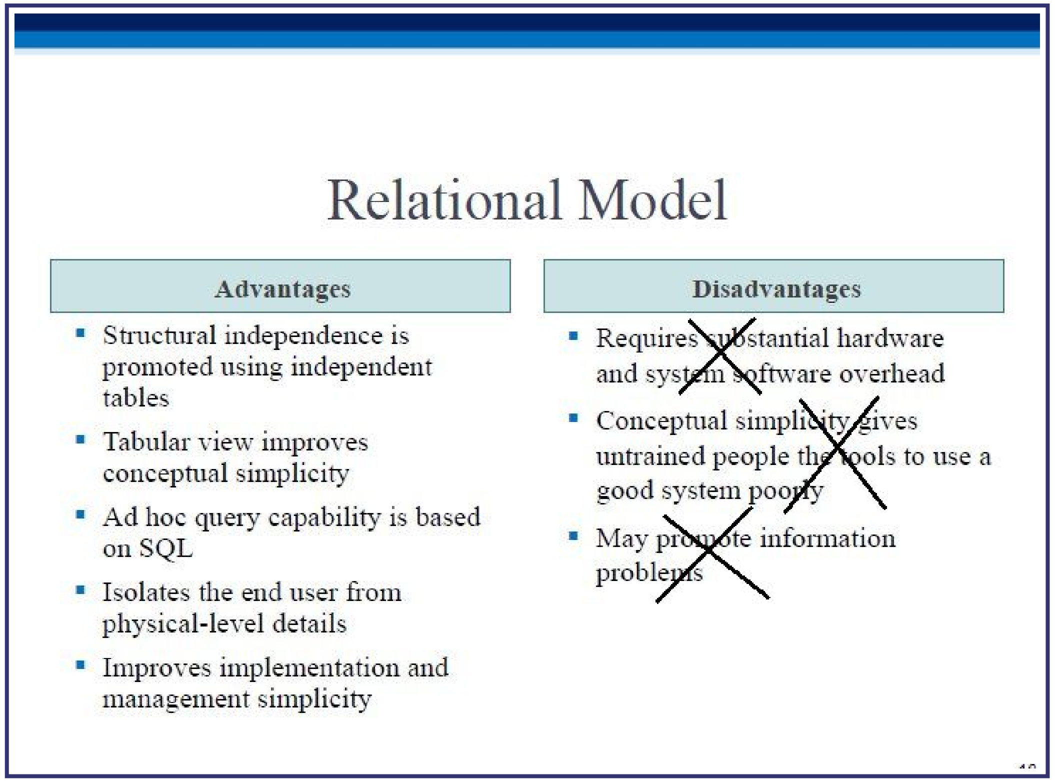
Relational model



The Relational Model

- 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



Relational Model

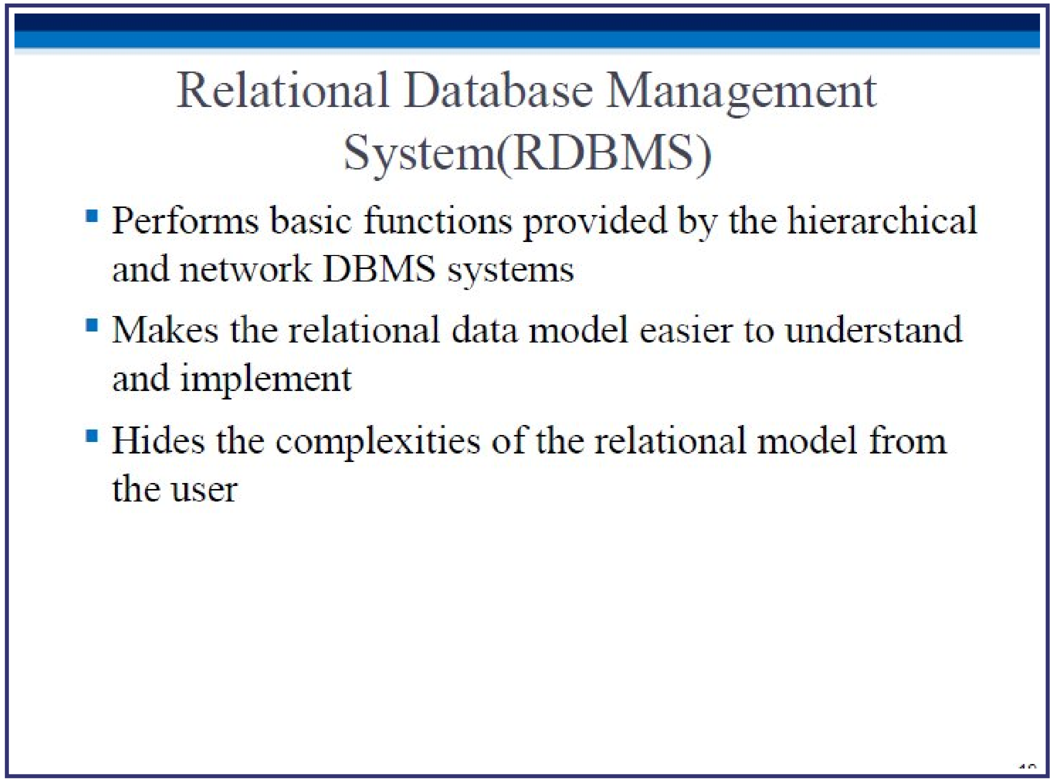
Advantages

- 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

Disadvantages

- ~~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 DBMS



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

Relation - BETWEEN entities

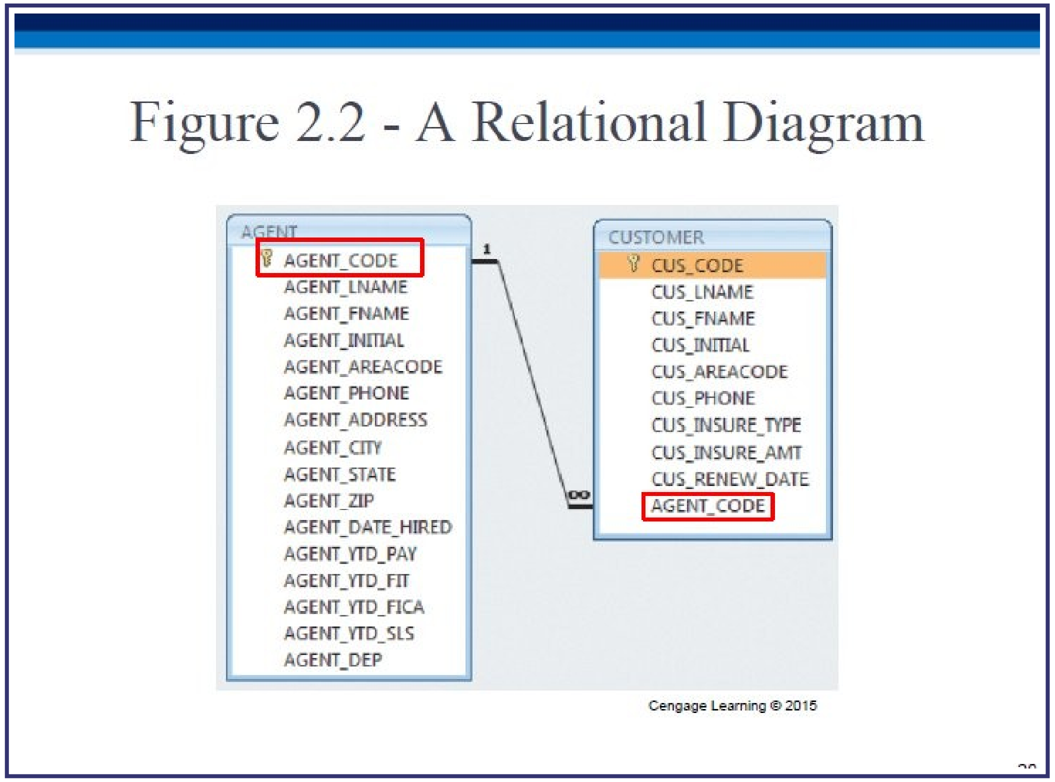
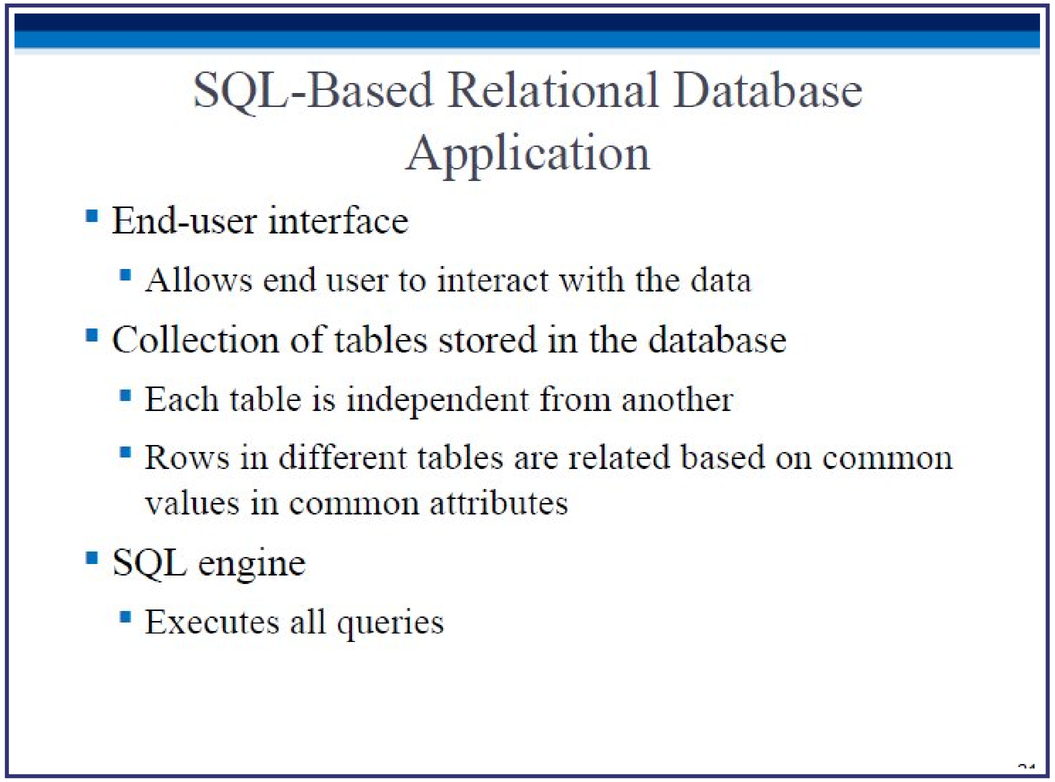


Figure 2.2 - A Relational Diagram

Note: this relation is NOT what relational modeling is about!! Here, we relate two entities, via a common attribute (AGENT_CODE, in our example).

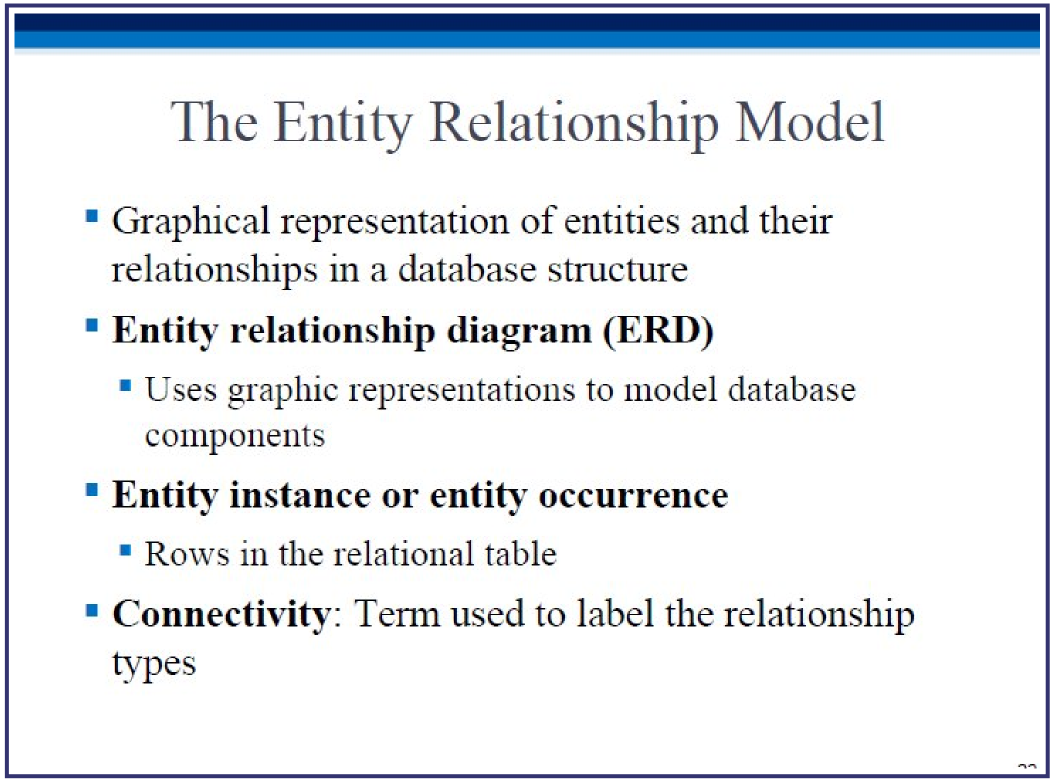
SQL + RDBMS



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

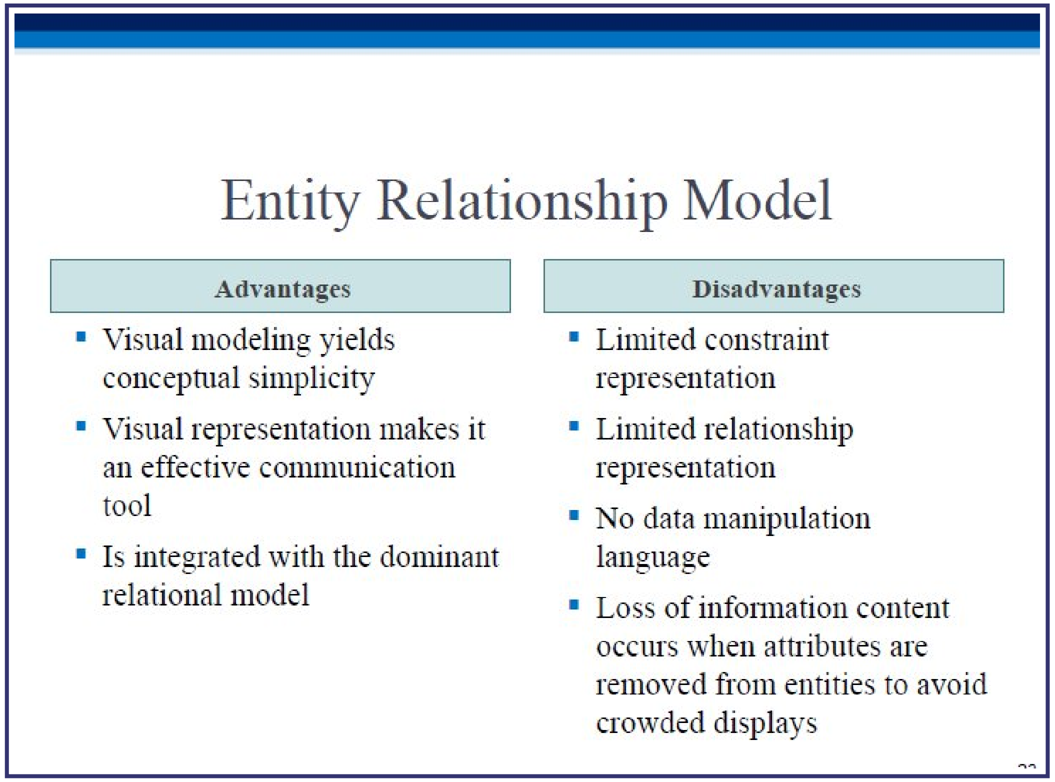
E-R



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

E-R

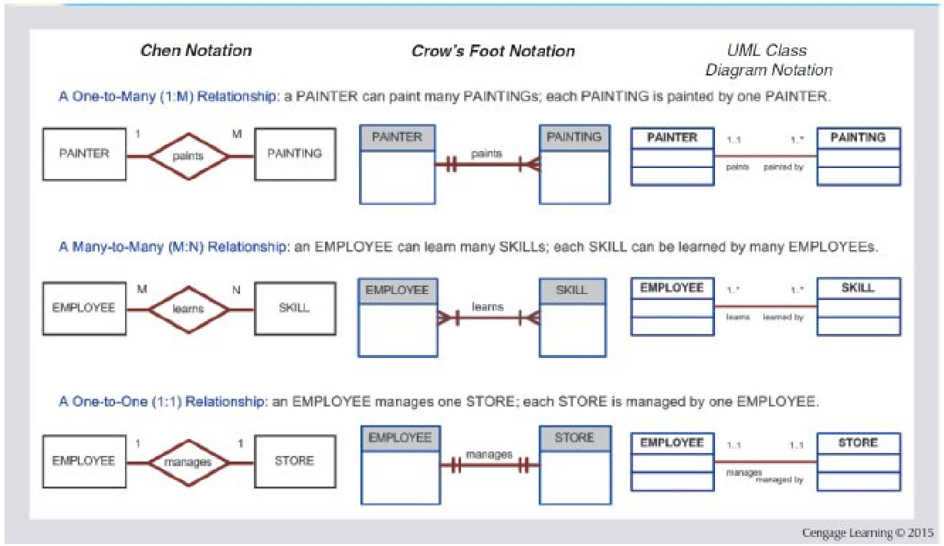


Entity Relationship Model

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

Notations

Figure 2.3 - The ER Model Notations



A One-to-Many (1:M) Relationship: a PAINTER can paint many PAINTINGs; each PAINTING is painted by one PAINTER.

A Many-to-Many (M:N) Relationship: an EMPLOYEE can learn many SKILLs; each SKILL can be learned by many EMPLOYEEs.

A One-to-One (1:1) Relationship: an EMPLOYEE manages one STORE; each STORE is managed by one EMPLOYEE.

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Notations - more..

Additional reading: here is information on, and comparison between, four ER notations: Chen, Crow, Rein85, IDEFIX.

O-O databases

Also called 'object stores', these dbs offer(ed) a way to store ("persist") objects on disk. The objects (entity instances) are instanced from classes (entities), like with standard OO programming practice.

Advantages:

- 'cleaner' design - objects mimic real-world counterparts
- inheritance and encapsulation possible
- richer datatypes (attributes) available
- good for CAD, multimedia..

Drawbacks:

- harder to query (compared to relational DBs) - no straightforward way to build and traverse relations between objects
- relations are simpler in certain situations

The RDBMS community collectively ignored this development..

O-R databases

These are a compromise between RDBs and OODBs - they feature an O-O front-end over a relational architecture. Interfacing applications do so in an O-O way, and queries/modifications are translated to/from relational form ("ORM").

Benefits:

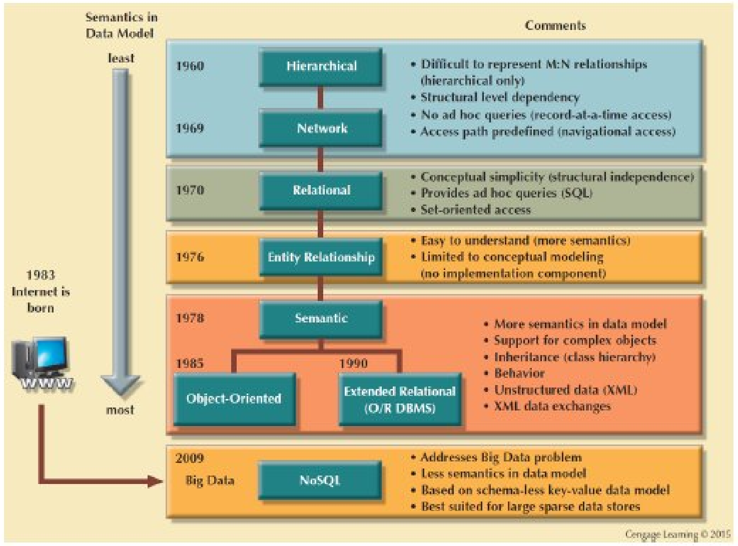
- easy to access the data from an O-O application
- queries can be simpler (can use objects' structure)

Drawback:

- performance can be poor on account of the two-way translation

Data models: hierarchical => => NoSQL

Figure 2.6 - The Evolution of Data Models


Semantics in Data Model
least
most
Comments
1960
Hierarchical
1969
Network
• Difficult to represent M:N relationships (hierarchical only)
• Structural level dependency
• No ad hoc queries (record-at-a-time access)
• Access path predefined (navigational access)
1970
Relational
• Conceptual simplicity (structural independence)
• Provides ad hoc queries (SQL)
• Set-oriented access
1976
Entity Relationship
• Easy to understand (more semantics)
• Limited to conceptual modeling (no implementation component)
1983 Internet is born
WWW
1978
Semantic
1985
1990
Object-Oriented
Extended Relational (O/R DBMS)
• More semantics in data model
• Support for complex objects
• Inheritance (class hierarchy)
• Behavior
• Unstructured data (XML)
• XML data exchanges
2009
Big Data
NoSQL
• Addresses Big Data problem
• Less semantics in data model
• Based on schema-less key-value data model
• Best suited for large sparse data stores
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Data models have evolved - from 'hierarchical' (very rigid) to 'NoSQL' (VERY flexible).

Layered data abstraction

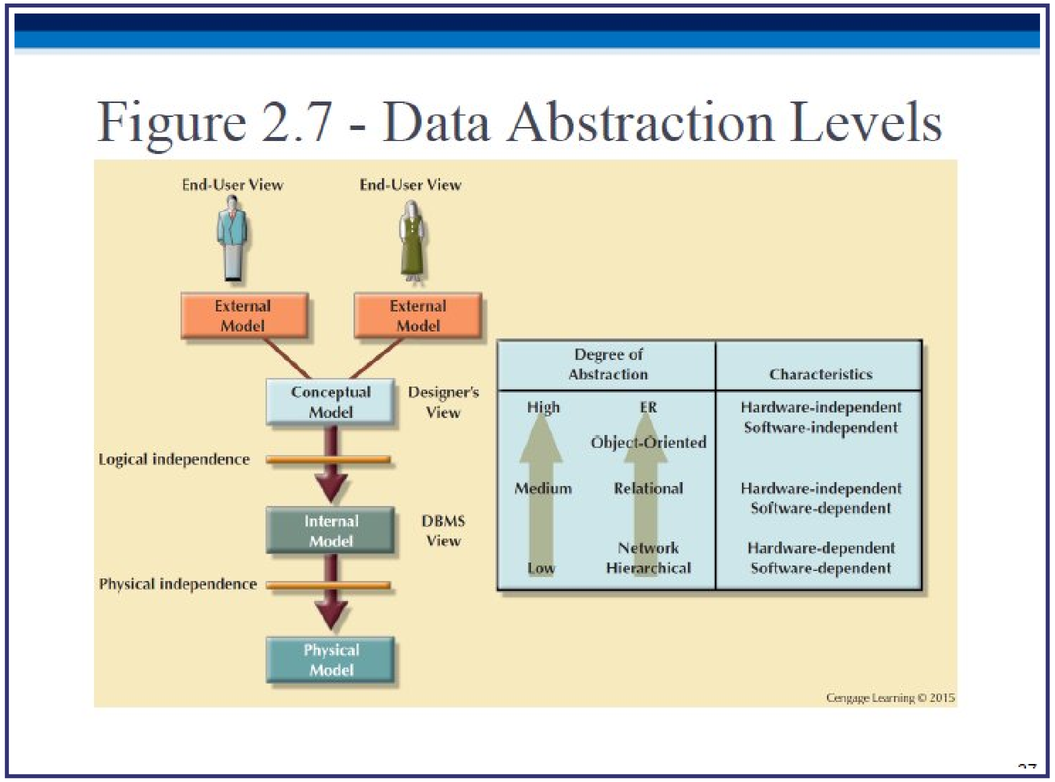
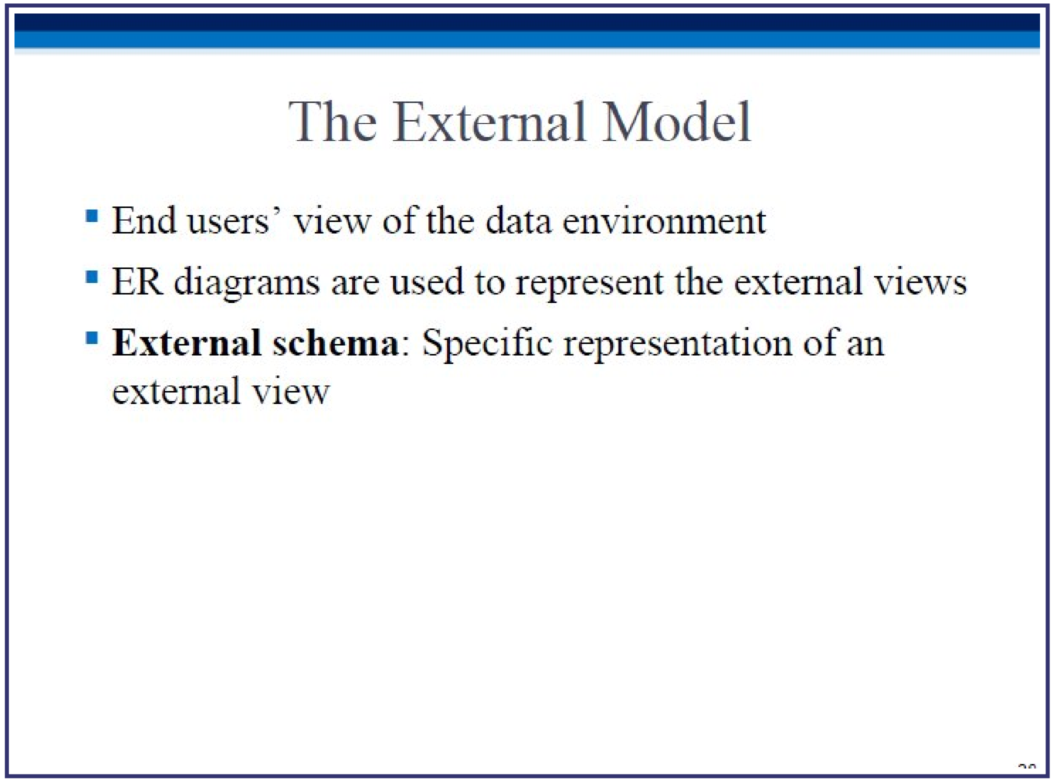


Figure 2.7 - Data Abstraction Levels

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

External model



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

An external model is a collection of 'fragmented', 'from the stakeholders' POV', modeling of a database.

External model

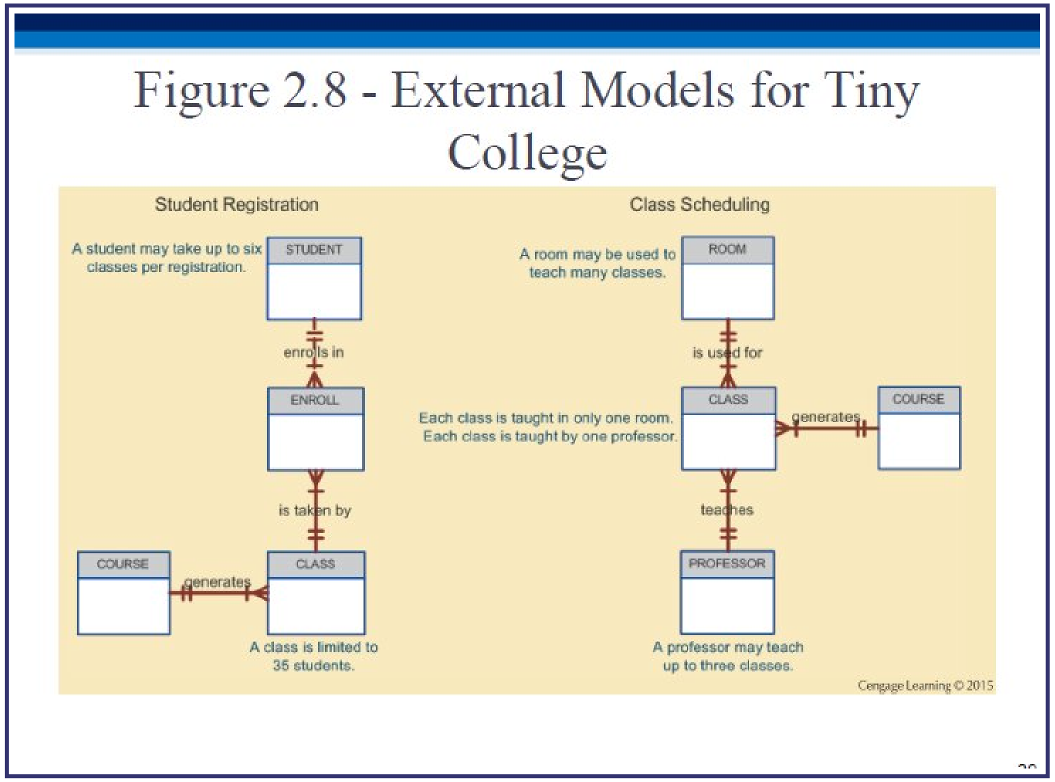


Figure 2.8 - External Models for Tiny College

Student Registration
Class Scheduling
A student may take up to six classes per registration.
STUDENT
enrolls in
ENROLL
is taken by
CLASS
COURSE
generates
A class is limited to 35 students.
A room may be used to teach many classes.
ROOM
is used for
CLASS
Each class is taught in only one room. Each class is taught by one professor.
generates
COURSE
teaches
PROFESSOR
A professor may teach up to three classes.
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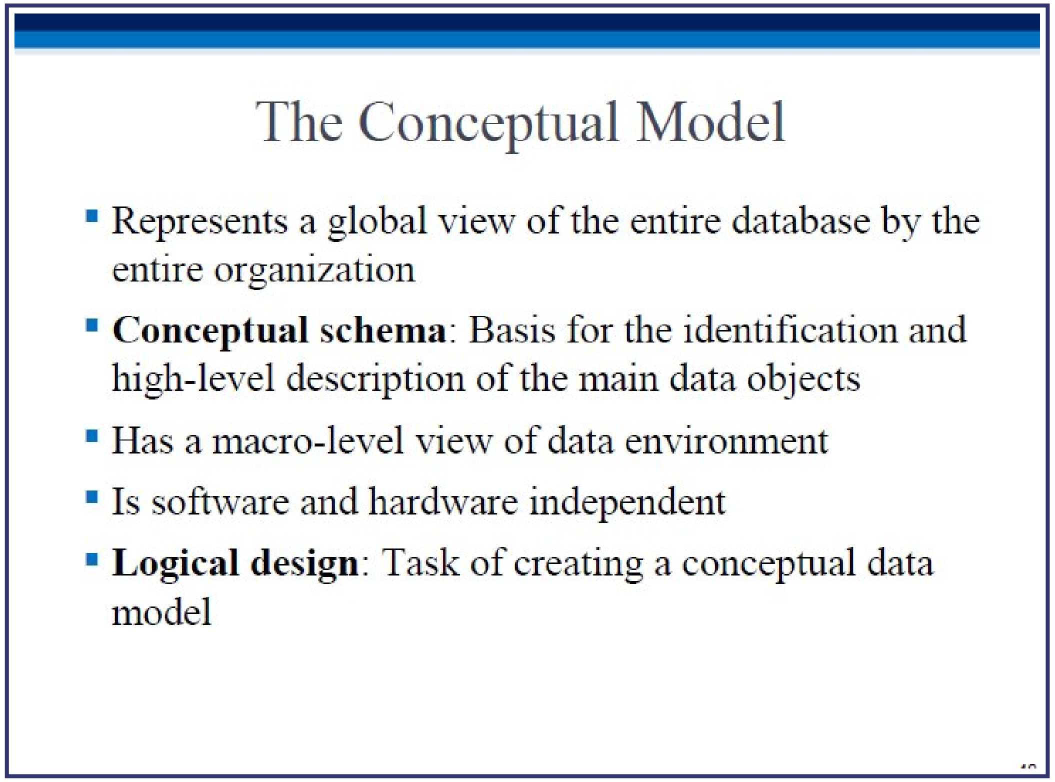
Conceptual model



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

Conceptual model

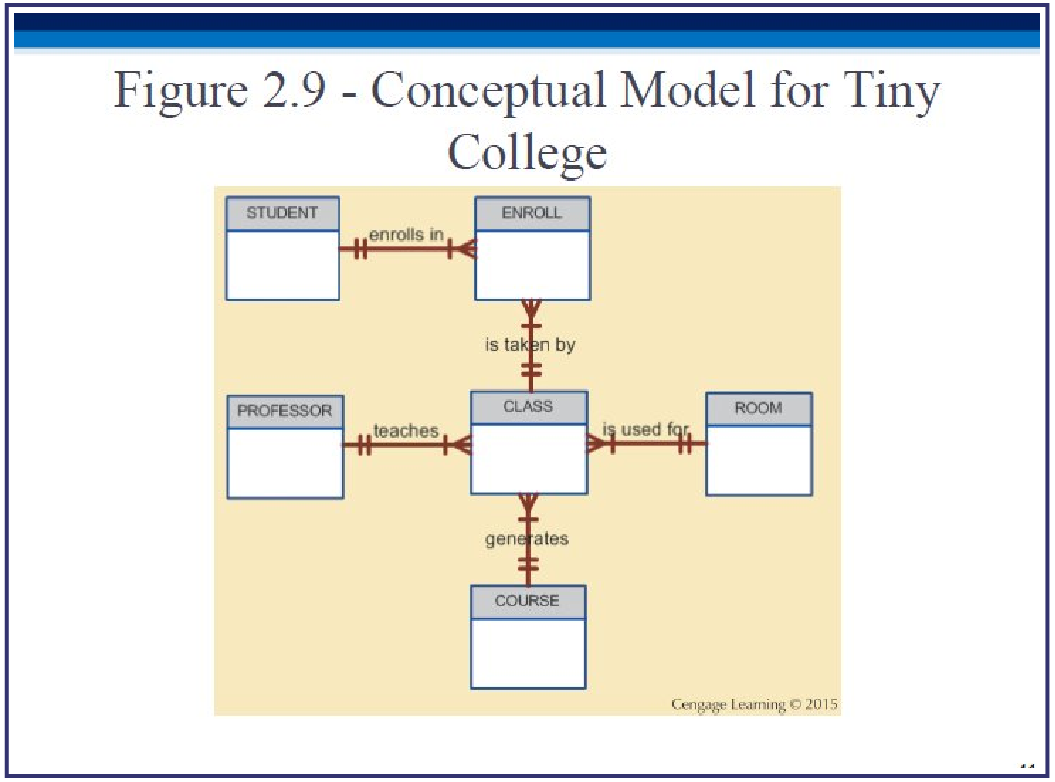
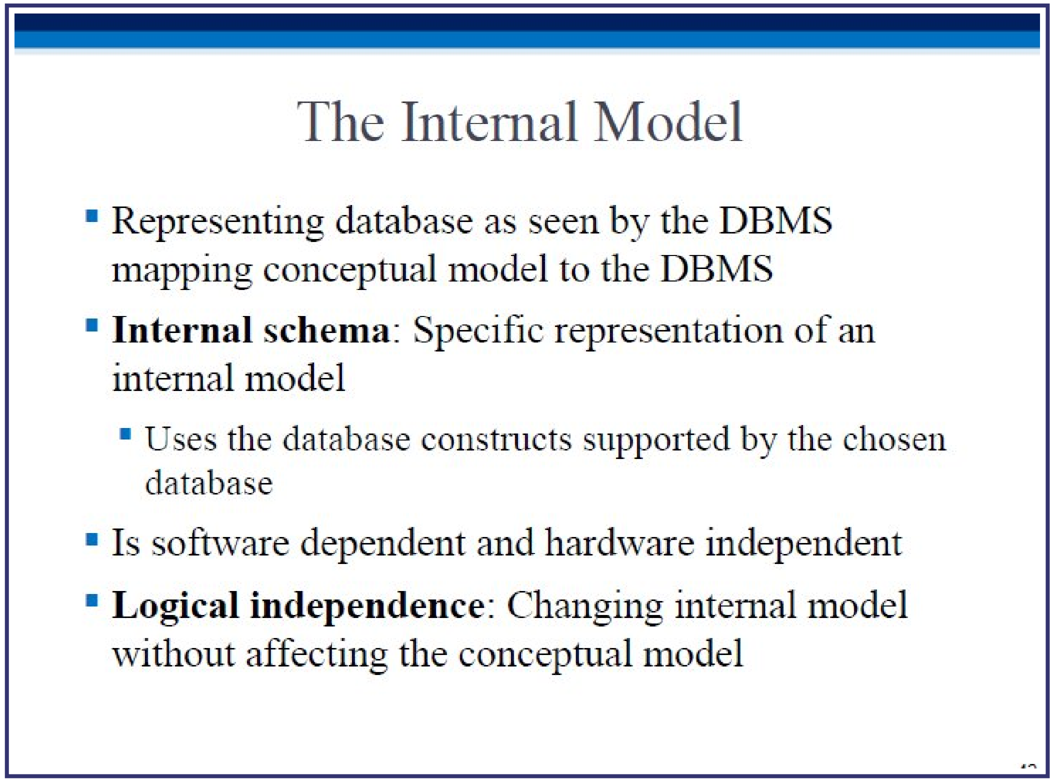


Figure 2.9 - Conceptual Model for Tiny College

A conceptual model unifies the external views into a cohesive one.

Internal model



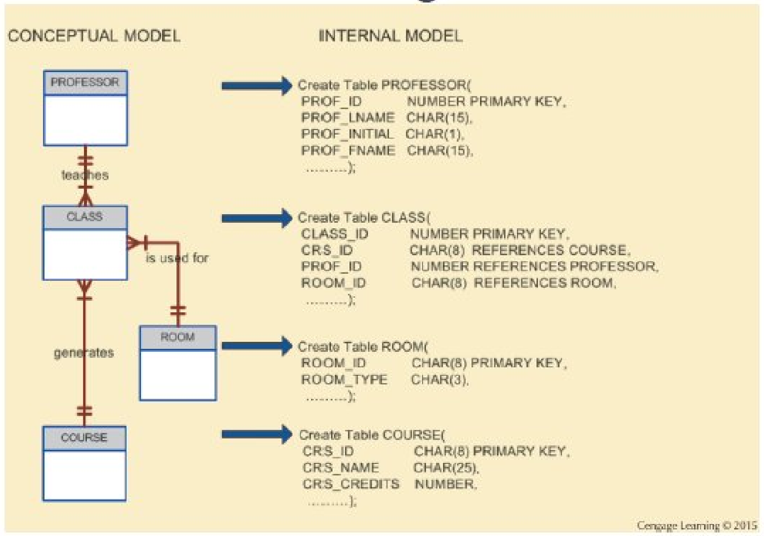
The Internal Model

- 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

An internal model specifies what type of modeling (eg. relational, NoSQL...) to use for storing the data.

Internal model

Figure 2.10 - Internal Model for Tiny College



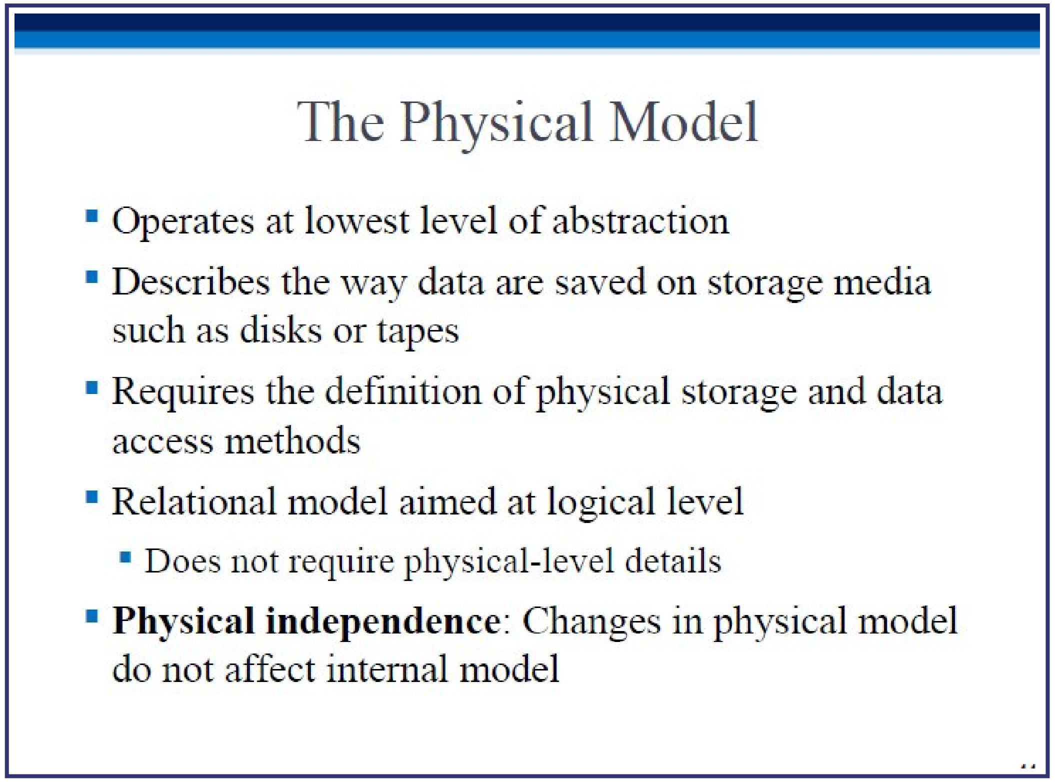
```
Create Table PROFESSOR(
 PROF_ID        NUMBER PRIMARY KEY,
 PROF_LNAME     CHAR(15),
 PROF_INITIAL   CHAR(1),
 PROF_FNAME     CHAR(15),
  .........);

Create Table CLASS(
 CLASS_ID       NUMBER PRIMARY KEY,
 CRS_ID         CHAR(8)  REFERENCES COURSE,
 PROF_ID        NUMBER REFERENCES PROFESSOR,
 ROOM_ID        CHAR(8)  REFERENCES ROOM,
  .........);

Create Table ROOM(
 ROOM_ID        CHAR(8) PRIMARY KEY,
 ROOM_TYPE      CHAR(3),
  .........);

Create Table COURSE(
 CRS_ID         CHAR(8) PRIMARY KEY,
 CRS_NAME       CHAR(25),
 CRS_CREDITS    NUMBER,
  .........);
```

Physical model



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

The physical model specifies actual data storage specifics (file format, APIs…).