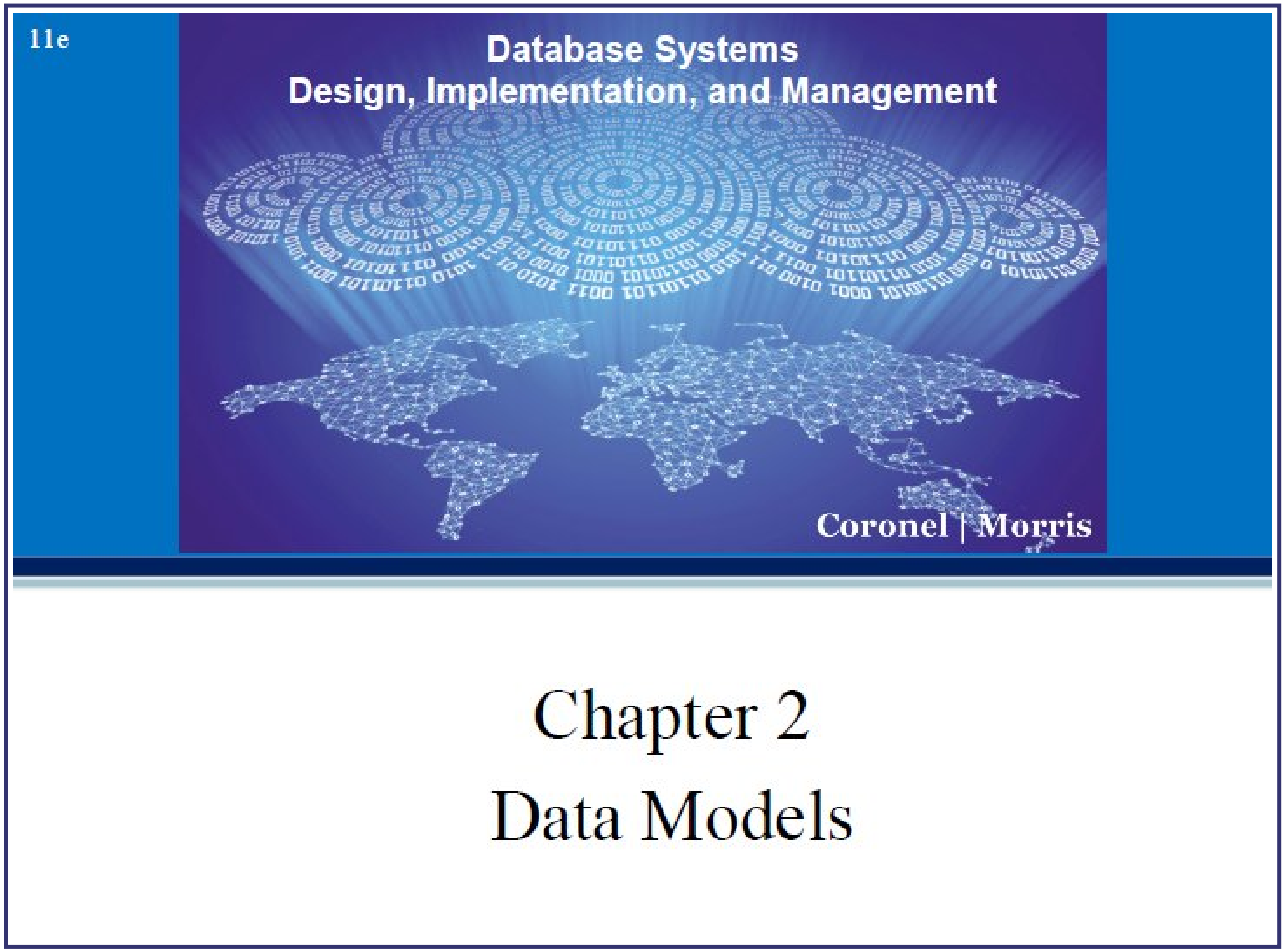
Data Modeling

- 
11e
Database Systems
Design, Implementation, and Management
Coronel | Morris
Chapter 2
Data Models

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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

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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

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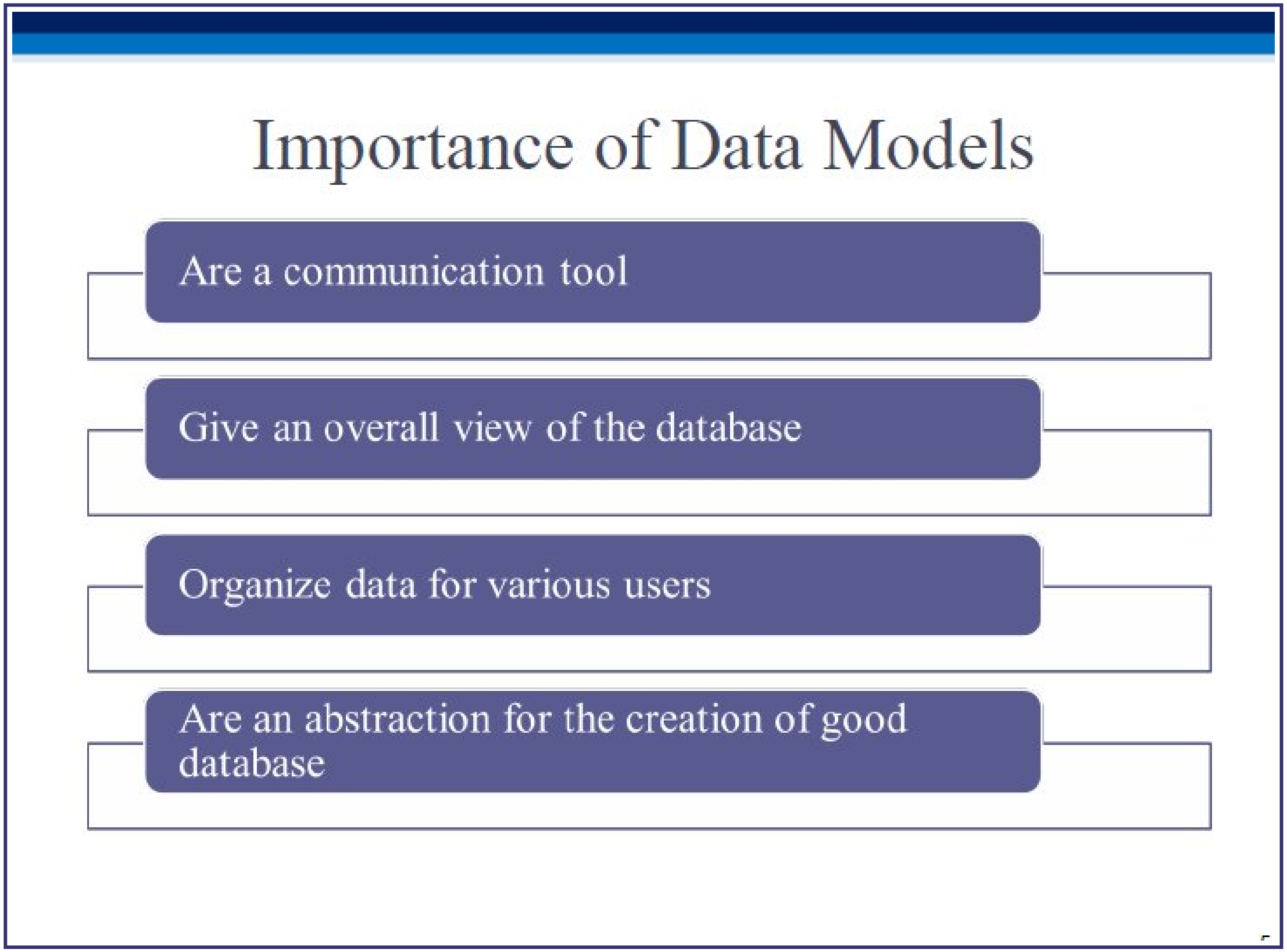
Data Modeling and Data Models

- **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

- 
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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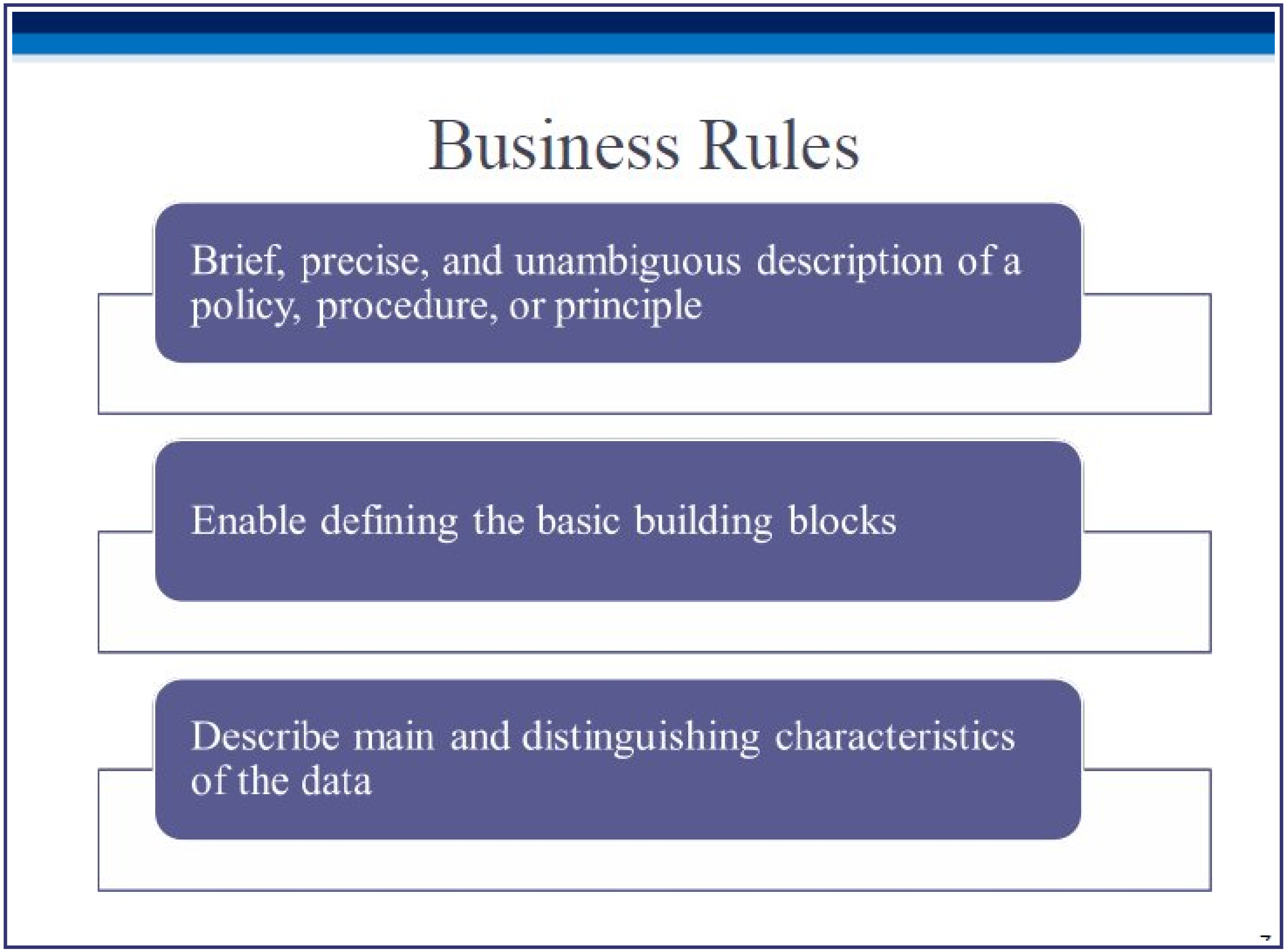
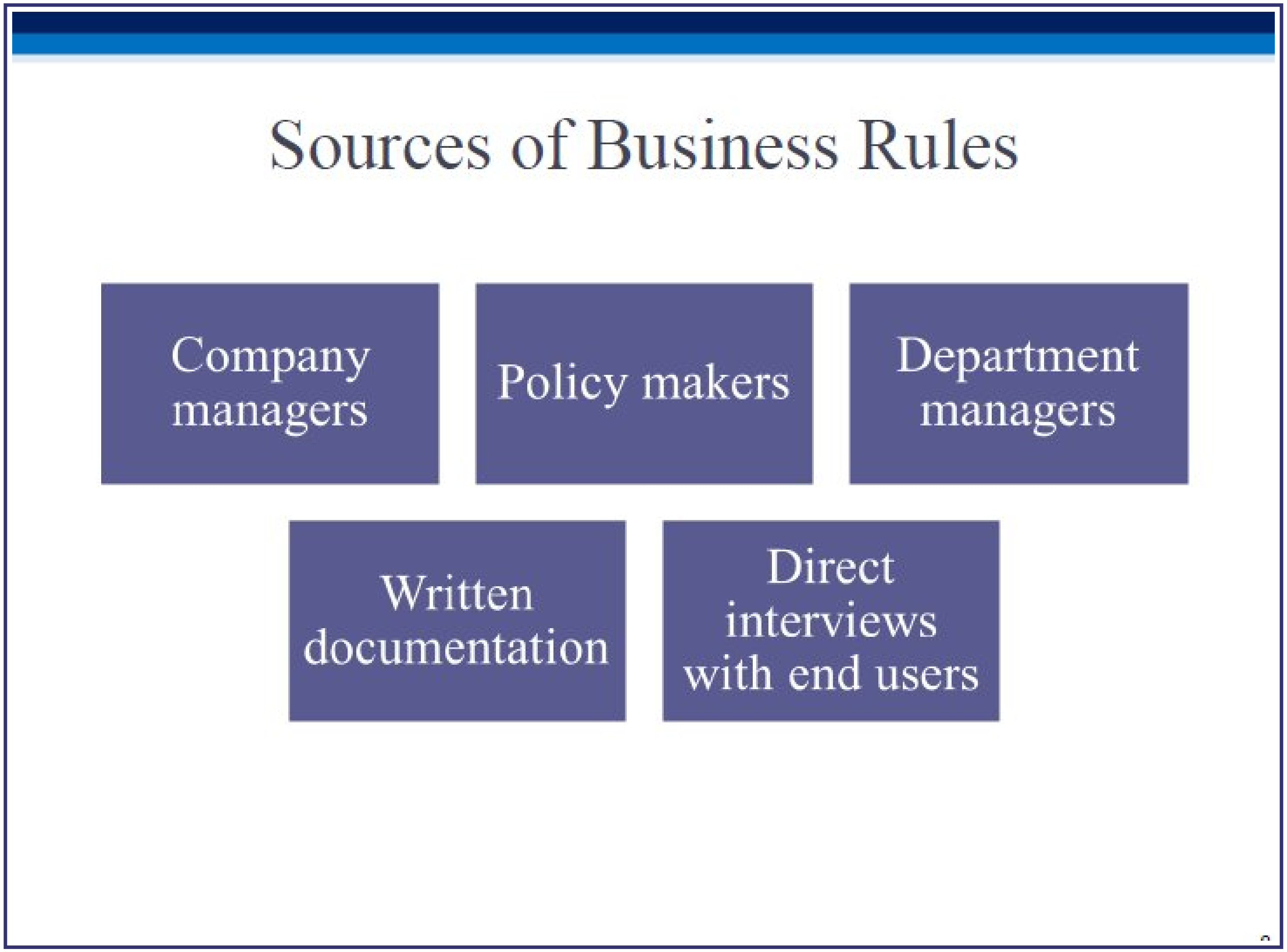
Data Model Basic Building Blocks

- **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

- 
Sources of Business Rules
Company managers
Policy makers
Department managers
Written documentation
Direct interviews with end users

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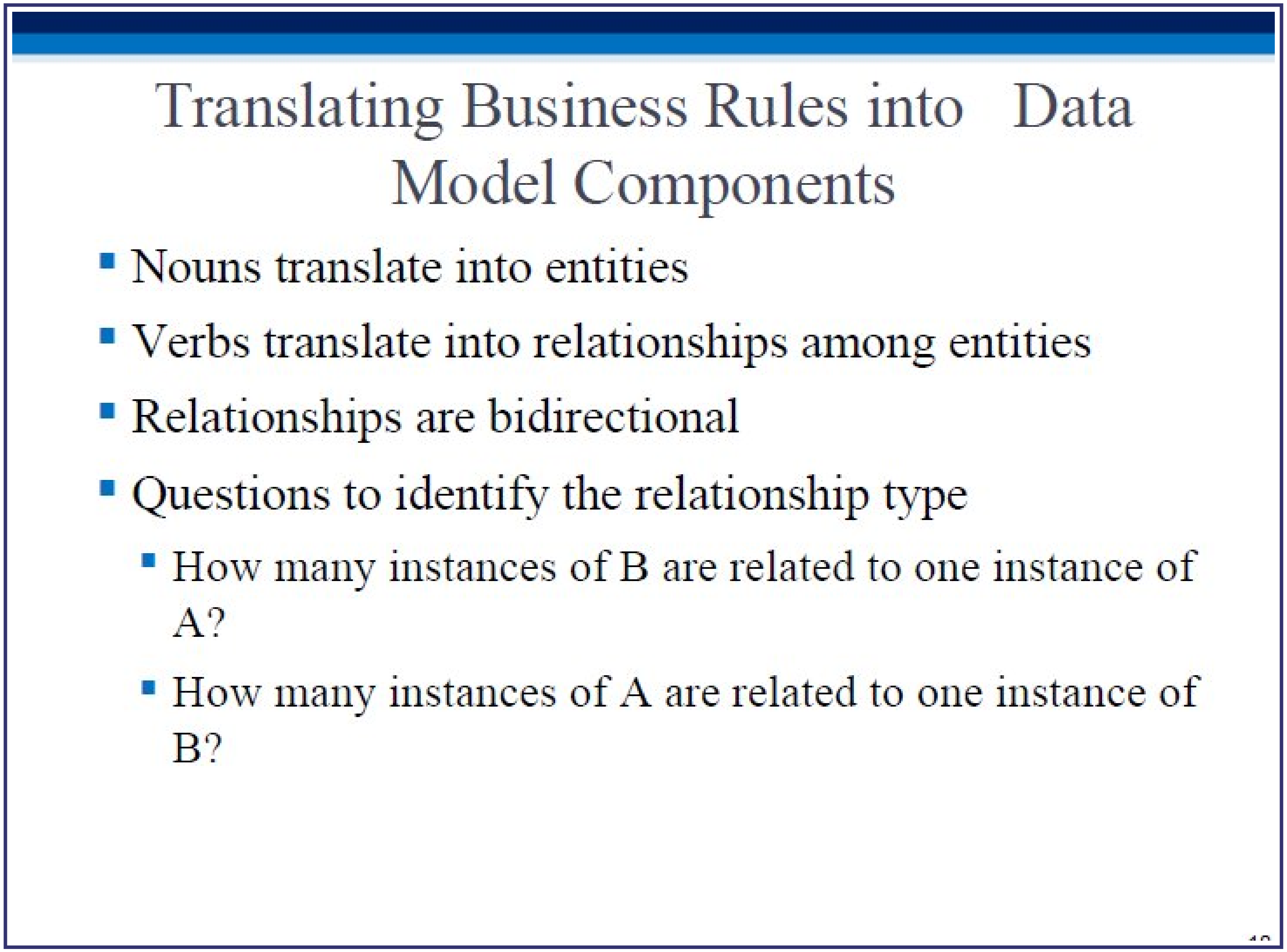
Reasons for Identifying and Documenting Business Rules

- 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?

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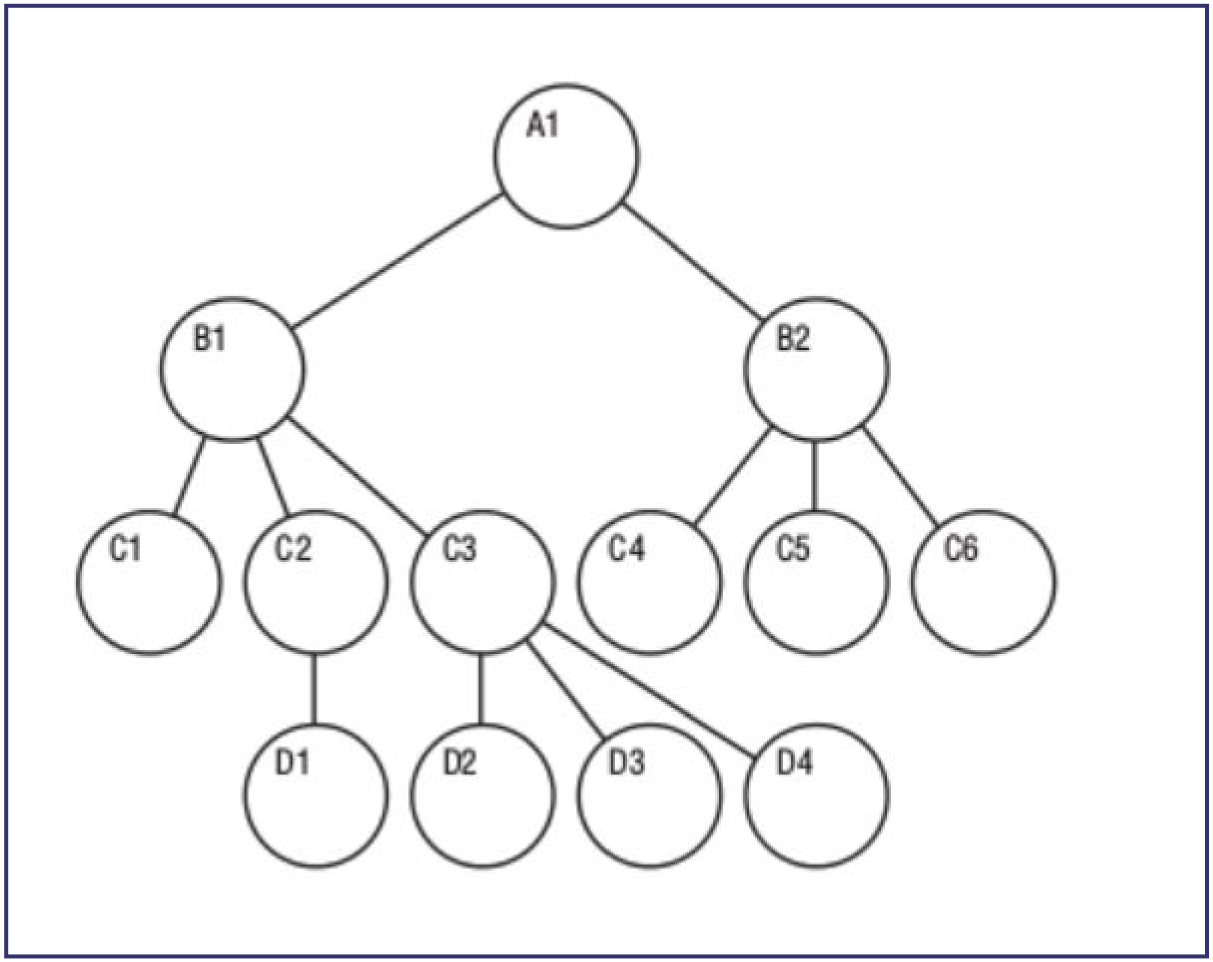
Naming Conventions

- 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

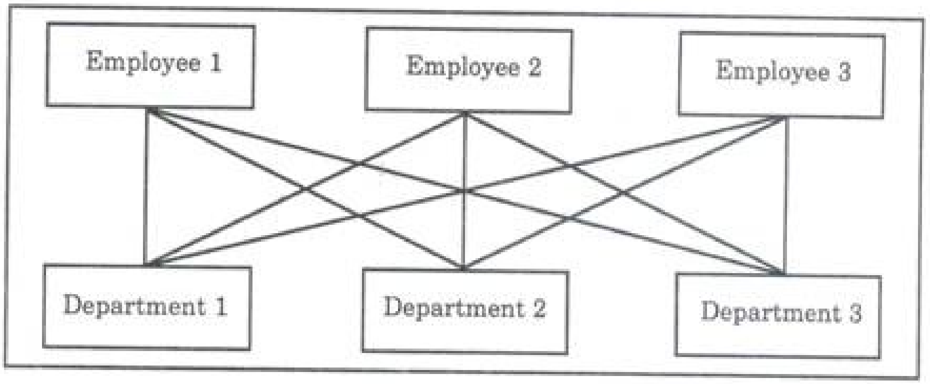


Fig. 9.5 Network model of employee information systems

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'].

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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

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)

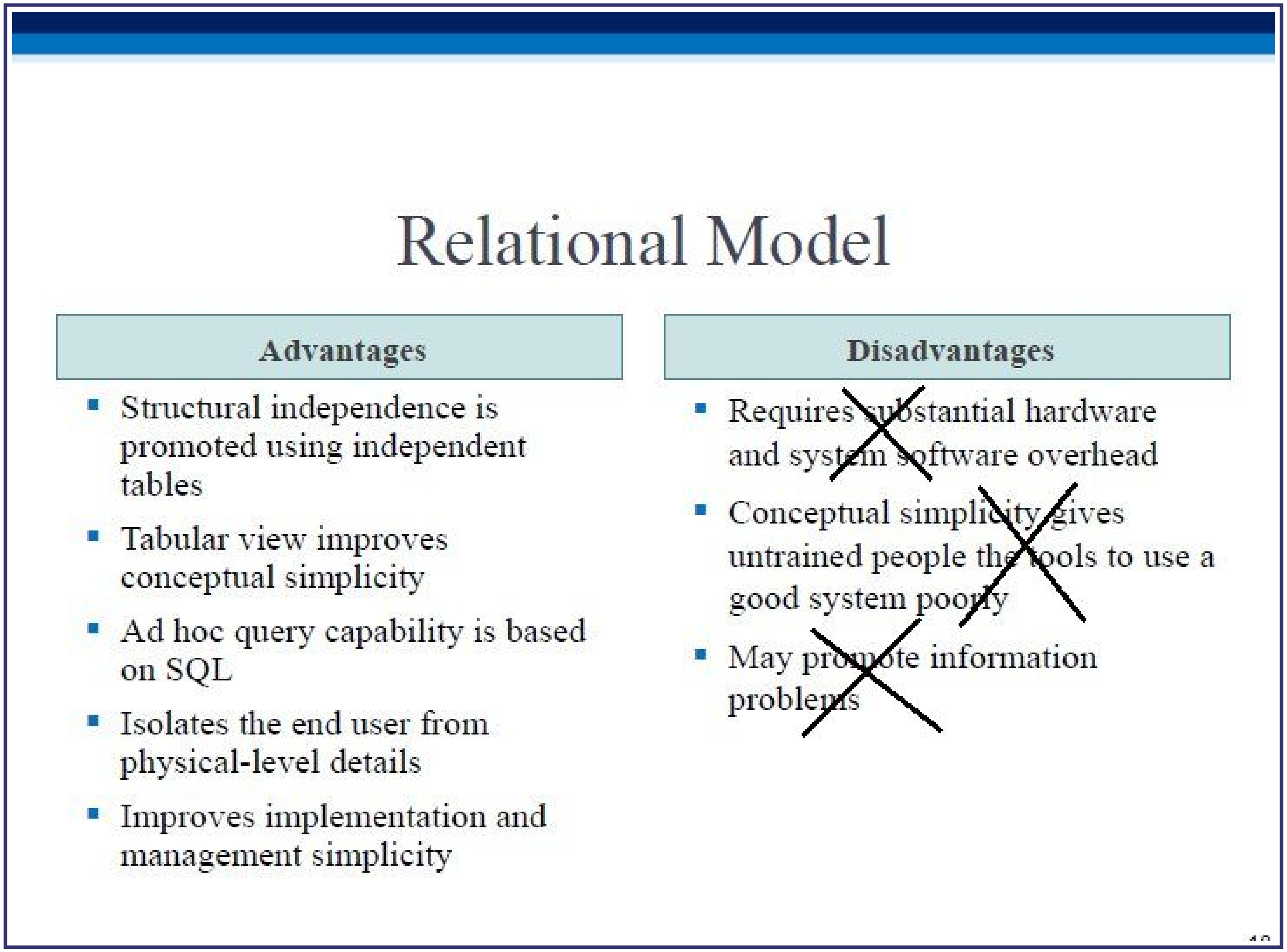
- Environment in which data can be managed and is used to work with the data in the database

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

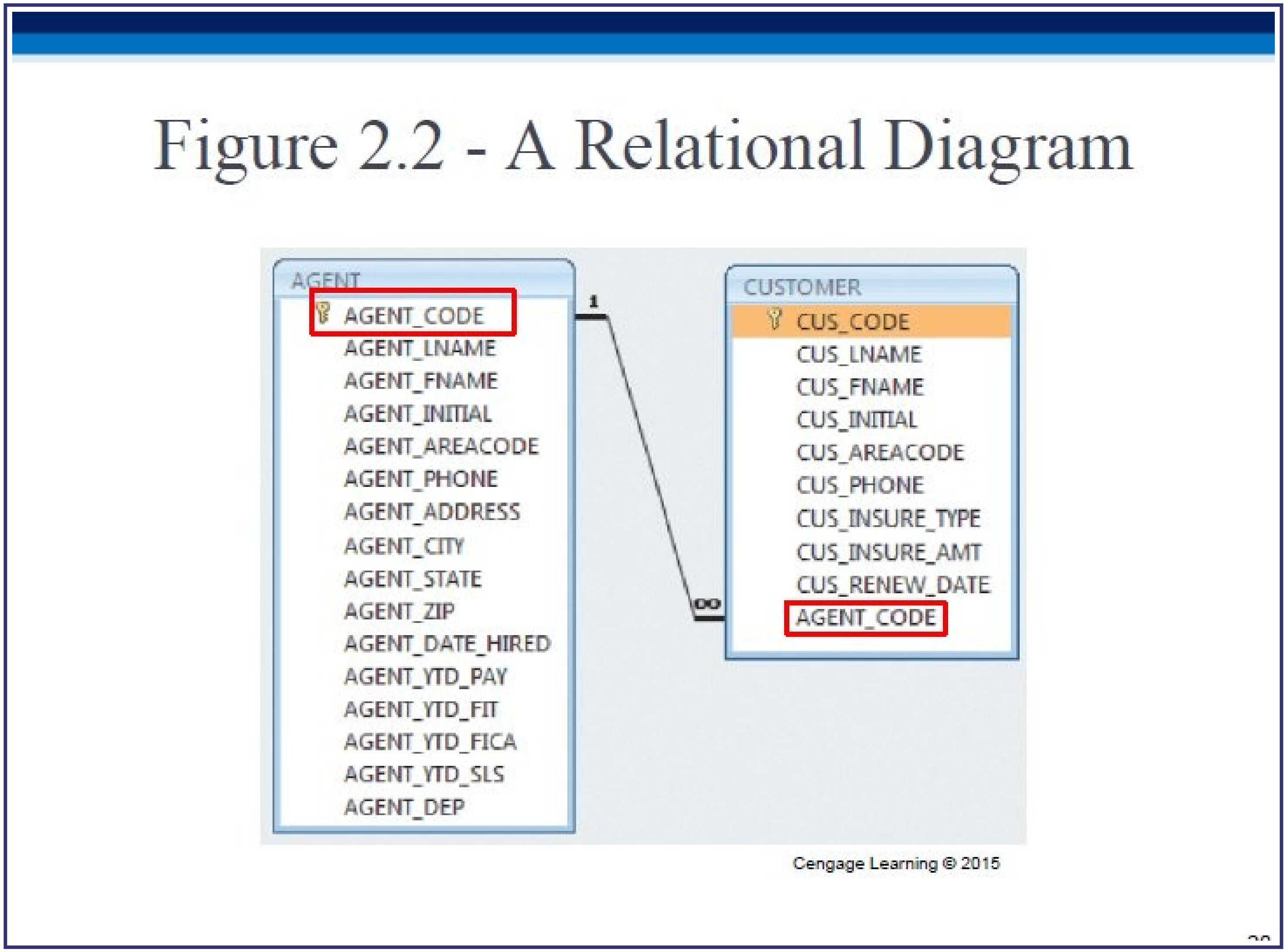


Relational DBMS

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



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

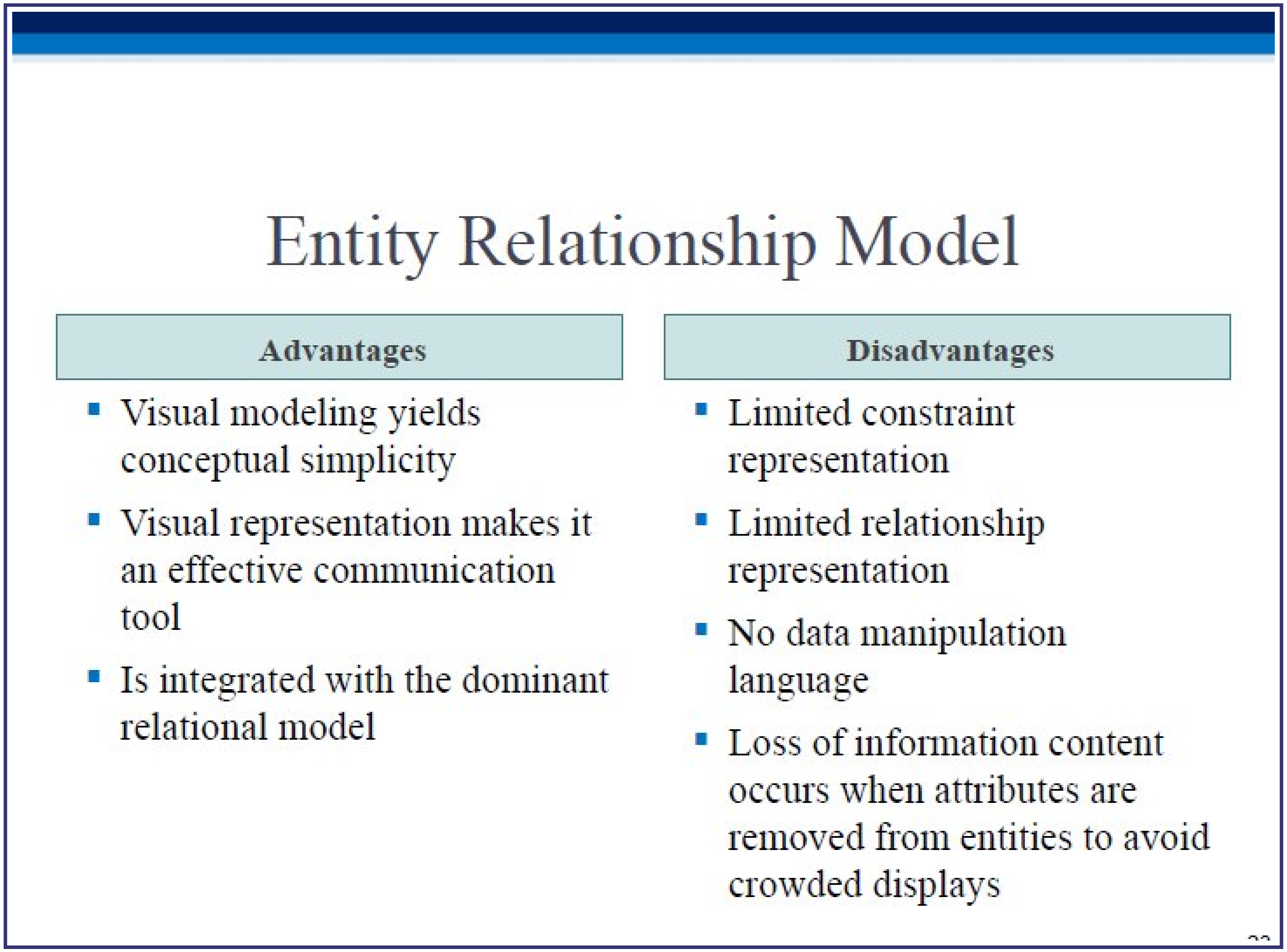
- End-user interface
  - Allows end user to interact with the data
- Collection of tables stored in the database
  - Each table is independent from another
  - Rows in different tables are related based on common values in common attributes
- SQL engine
  - Executes all queries

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
Visual modeling yields conceptual simplicity
Visual representation makes it an effective communication tool
Is integrated with the dominant relational model
Disadvantages
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

Notations

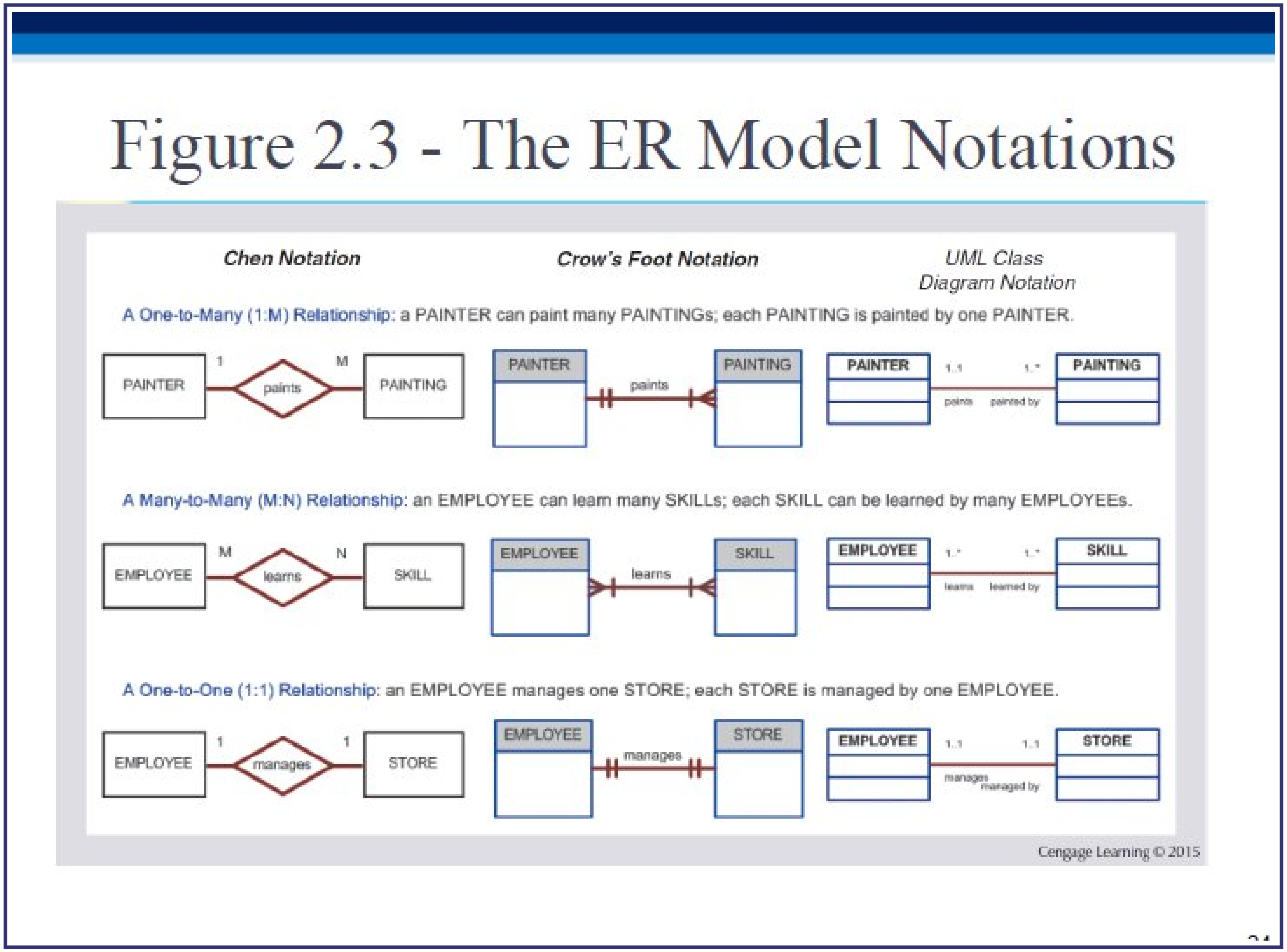


Figure 2.3 - The ER Model Notations
Chen Notation
Crow's Foot Notation
UML Class Diagram Notation
A One-to-Many (1:M) Relationship: a PAINTER can paint many PAINTINGs; each PAINTING is painted by one PAINTER.
PAINTER
1
paints
M
PAINTING
PAINTER
paints
PAINTING
PAINTER
1..1
1..*
PAINTING
paints
painted by
A Many-to-Many (M:N) Relationship: an EMPLOYEE can learn many SKILLs; each SKILL can be learned by many EMPLOYEEs.
EMPLOYEE
M
learns
N
SKILL
EMPLOYEE
learns
SKILL
EMPLOYEE
1..*
1..*
SKILL
learns
learned by
A One-to-One (1:1) Relationship: an EMPLOYEE manages one STORE; each STORE is managed by one EMPLOYEE.
EMPLOYEE
1
manages
1
STORE
EMPLOYEE
manages
STORE
EMPLOYEE
1..1
1..1
STORE
manages
managed by
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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").

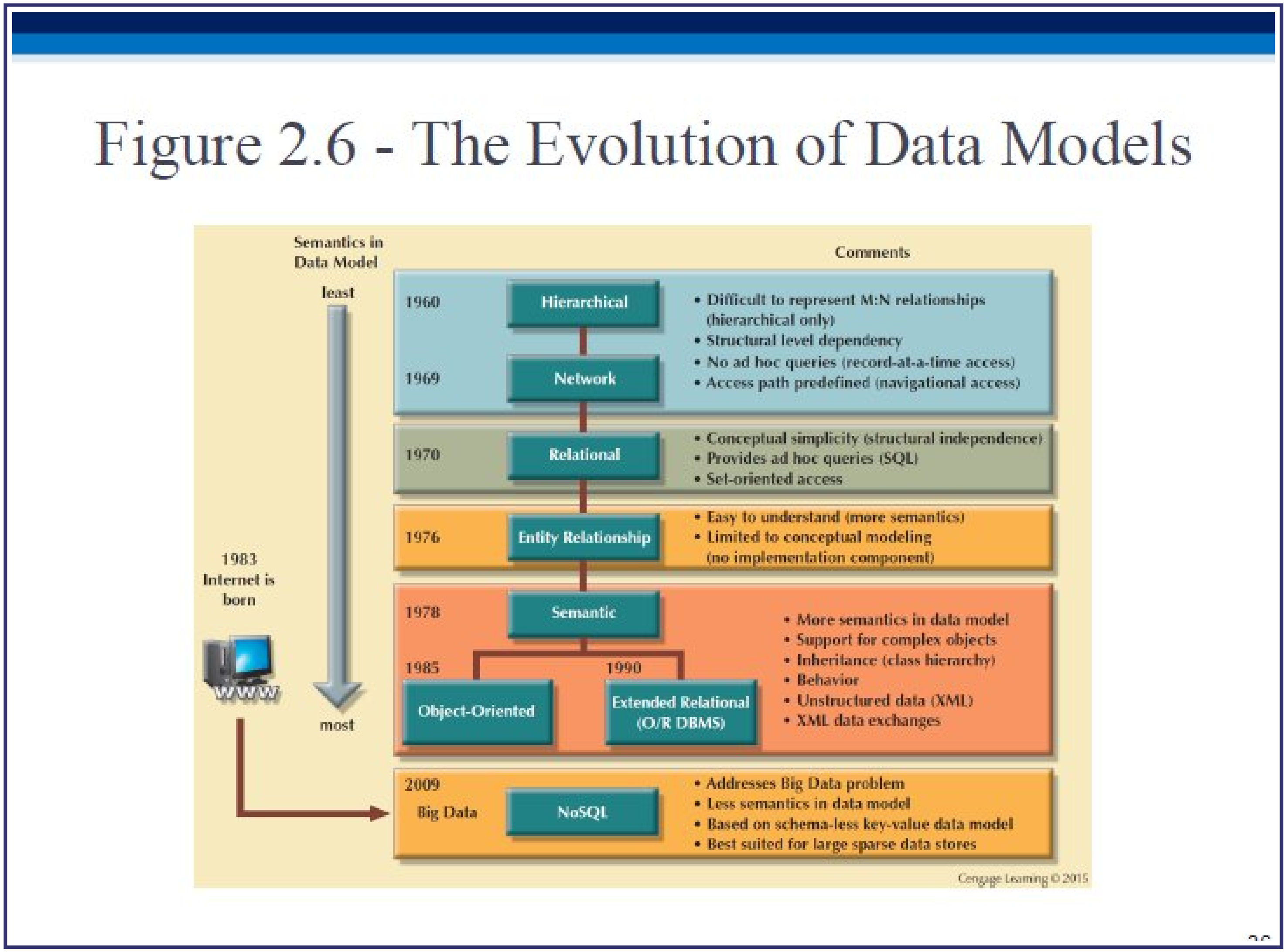
Benefits:

- 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

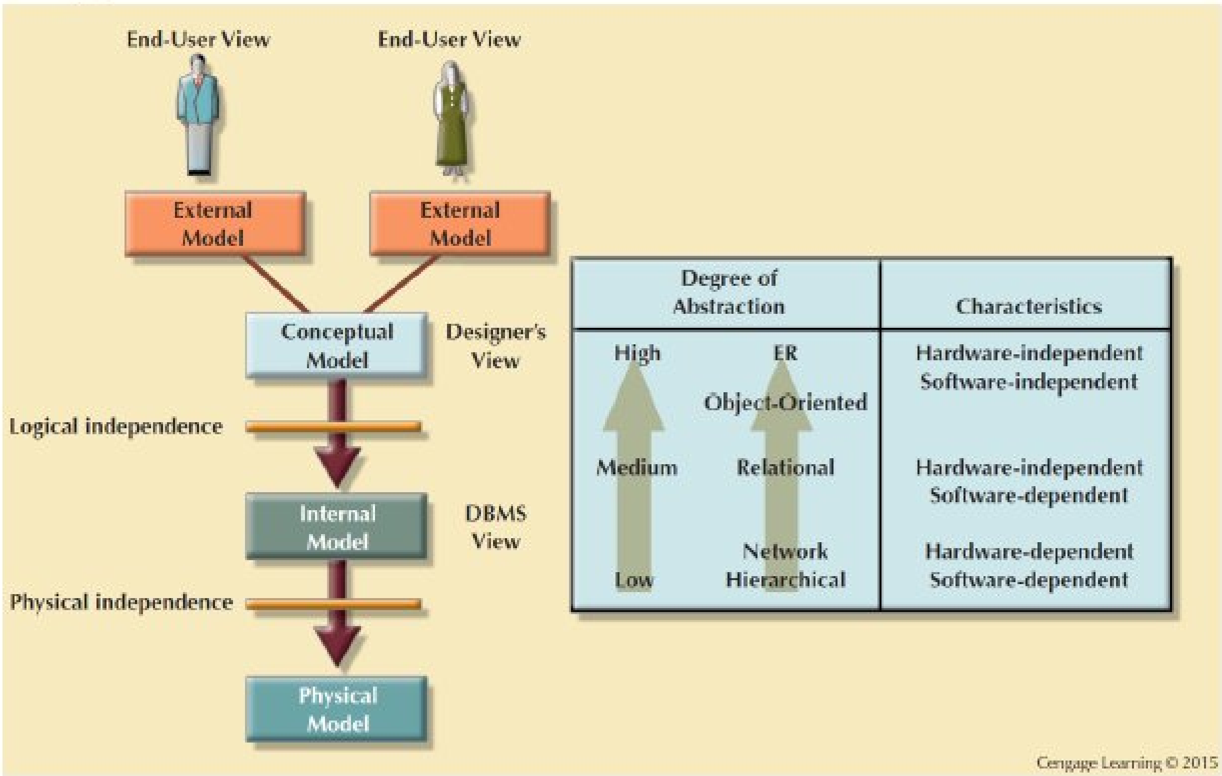
Data models: hierarchical => => NoSQL



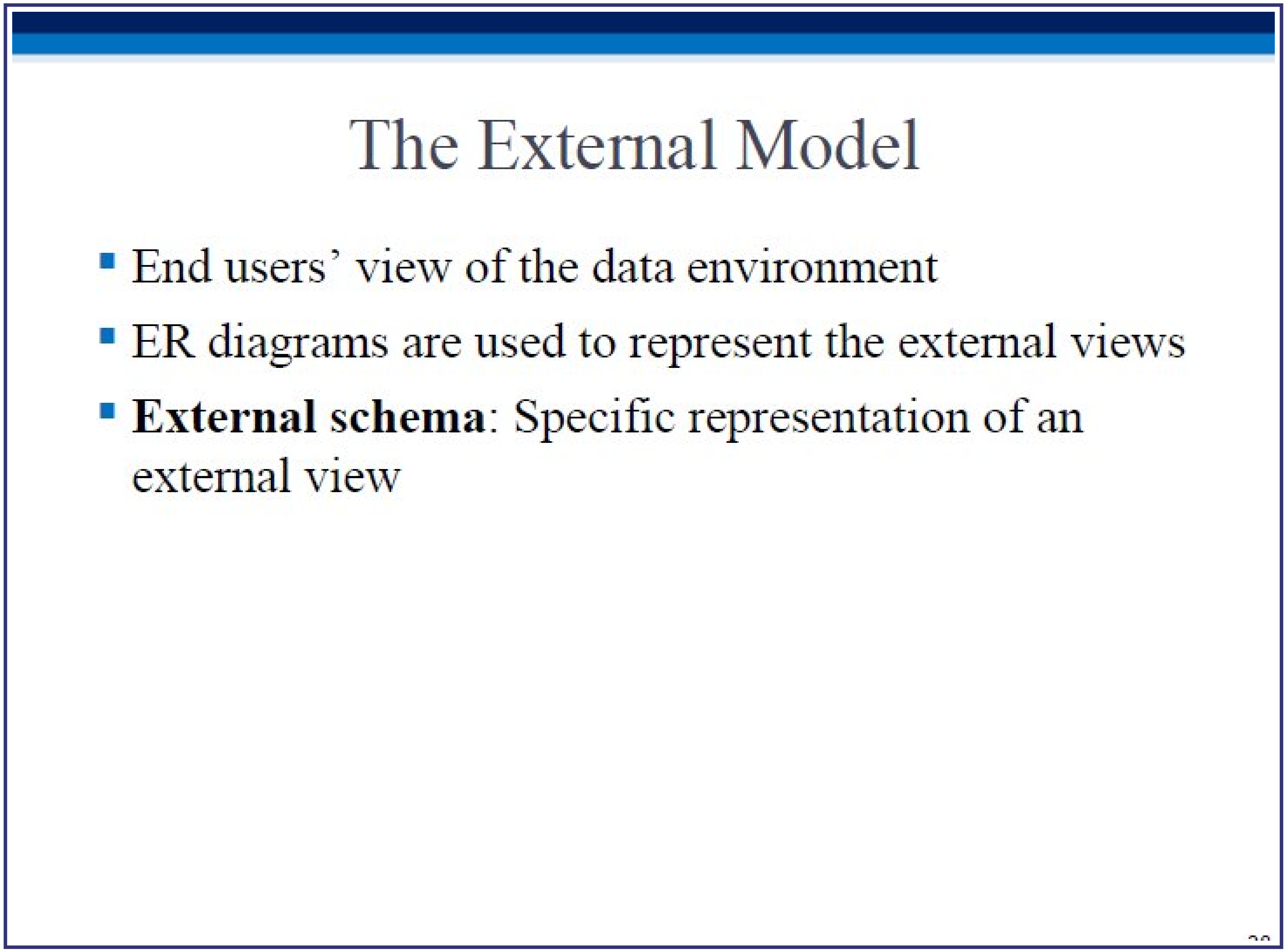
Data models have evolved - from 'hierarchical' (very rigid) to 'NoSQL' (VERY flexible).

Layered data abstraction

Figure 2.7 - Data Abstraction Levels



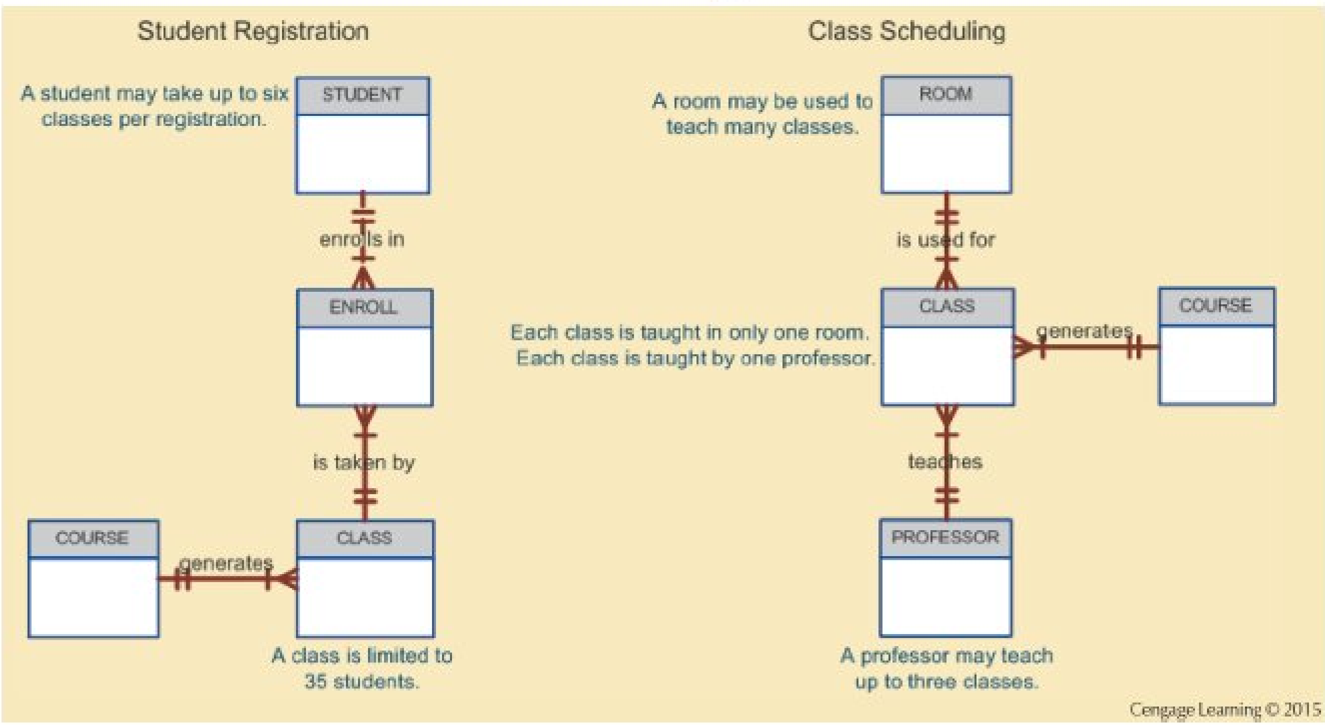
External model



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

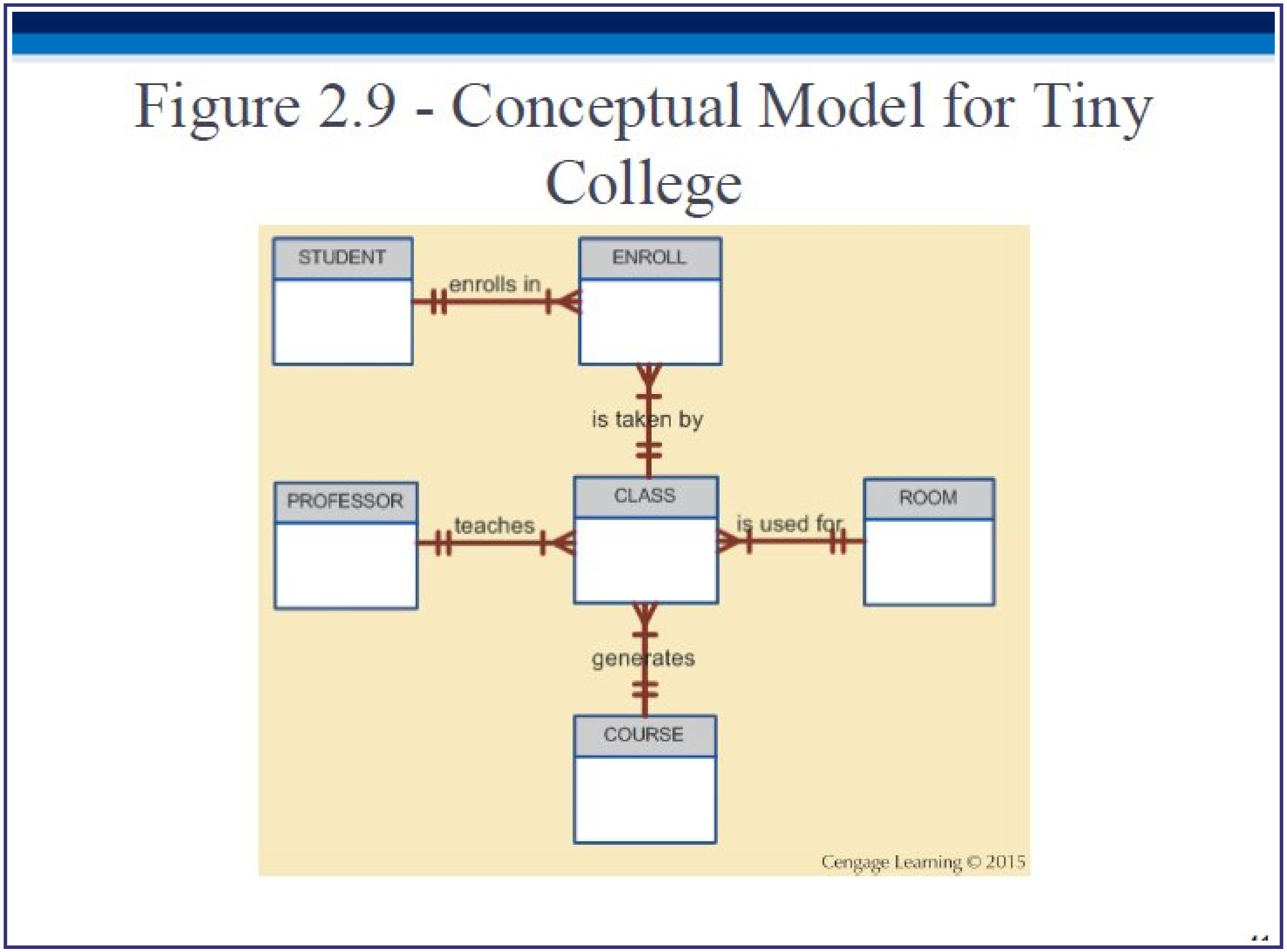


Conceptual model

The Conceptual Model

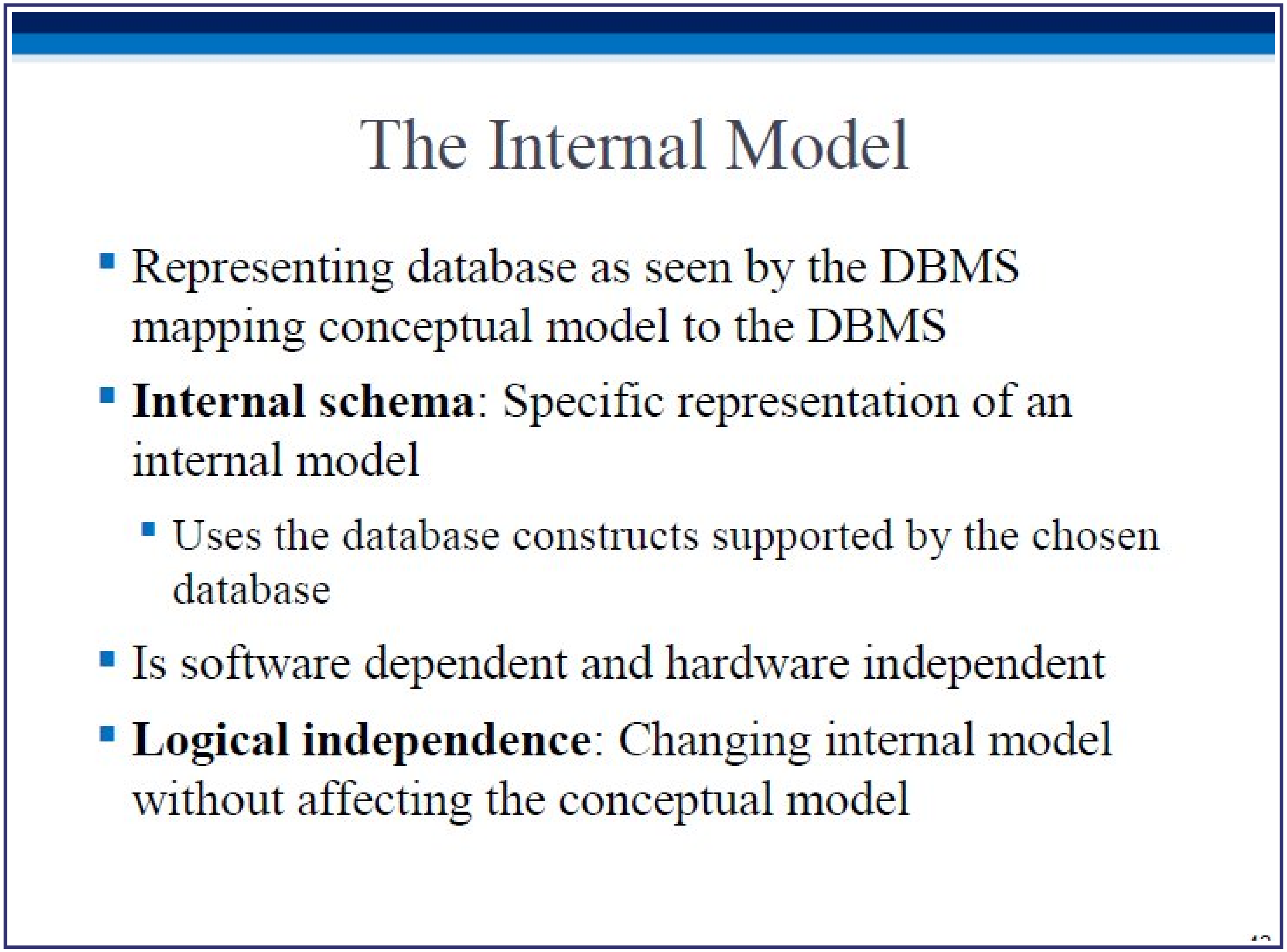
- Represents a global view of the entire database by the entire organization
- **Conceptual schema**: Basis for the identification and high-level description of the main data objects
- Has a macro-level view of data environment
- Is software and hardware independent
- **Logical design**: Task of creating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

Conceptual model



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

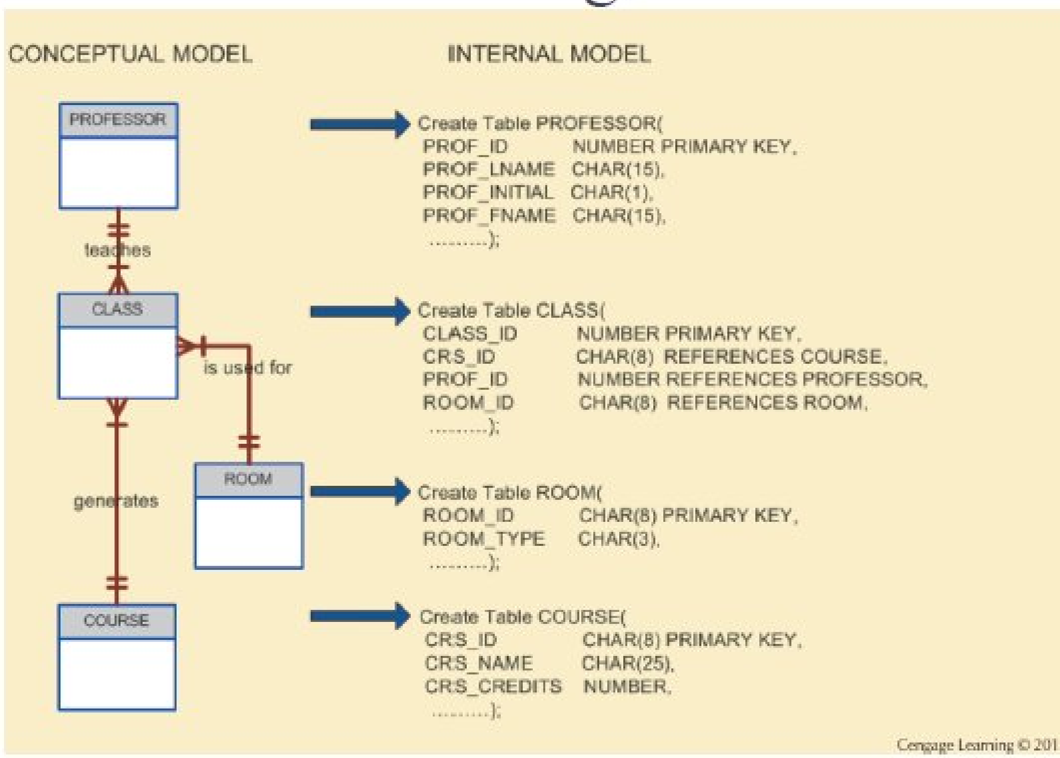
Internal model



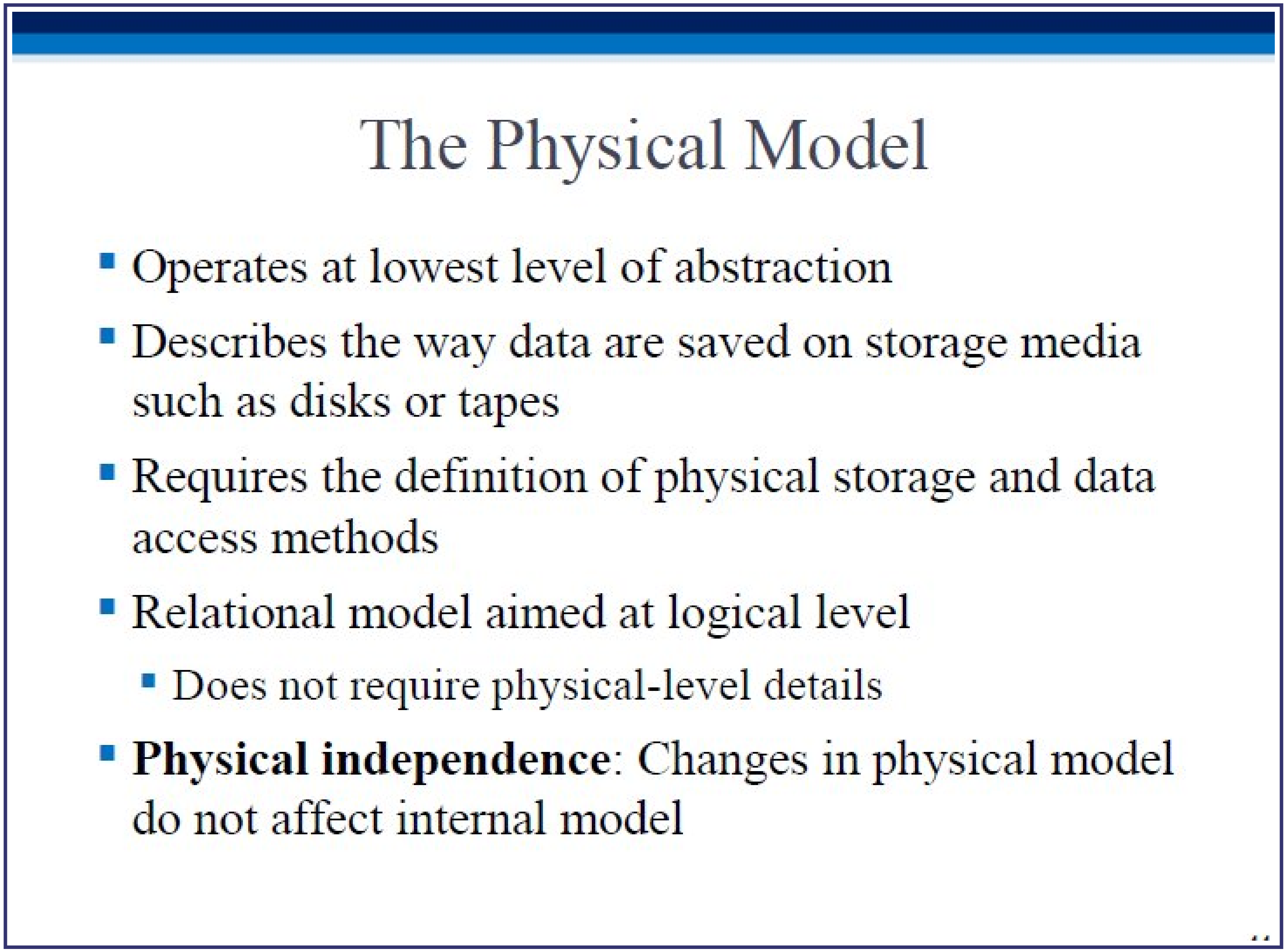
An internal model specifies what type of modeling (eg. relational, NoSQL...) to use for storing the data.

Internal model

Figure 2.10 - Internal Model for Tiny College



Physical model



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