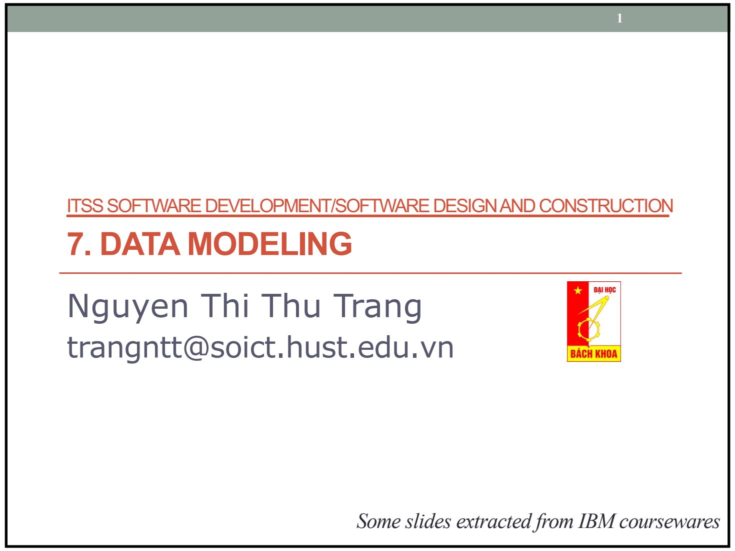

ITSS SOFTWARE DEVELOPMENT/SOFTWARE DESIGN AND CONSTRUCTION

7. DATA MODELING

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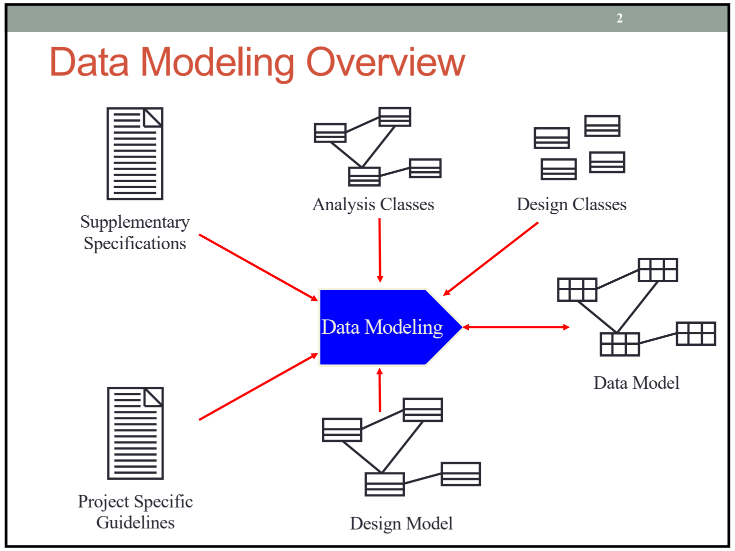
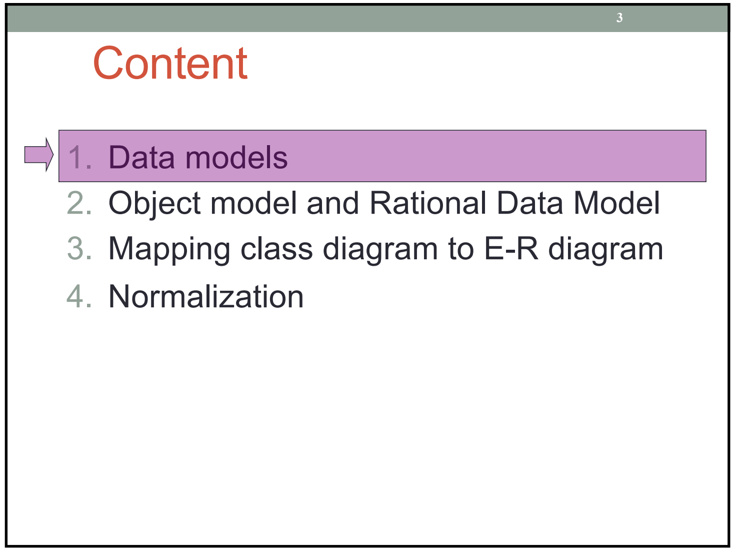
Some slides extracted from IBM coursewares

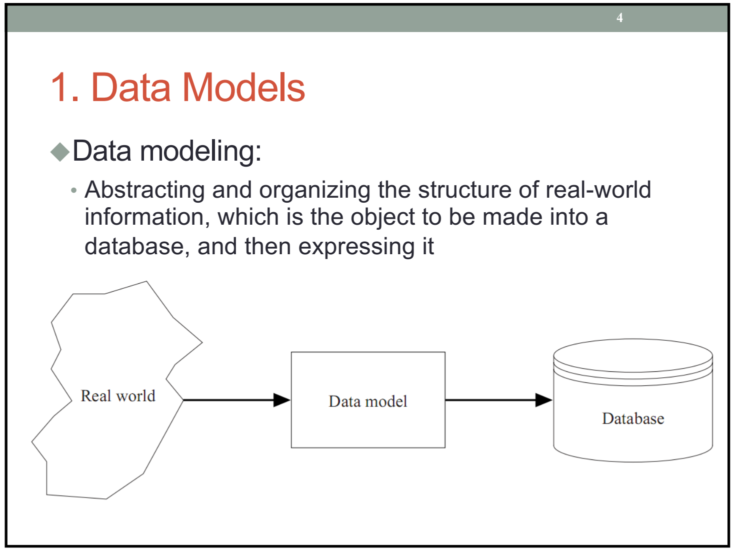


Data Modeling Overview



Content

1. Data models
2. Object model and Rational Data Model
3. Mapping class diagram to E-R diagram
4. Normalization

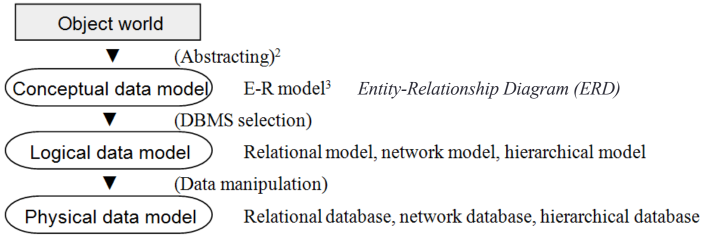


1. Data Models

- Data modeling:
  - Abstracting and organizing the structure of real-world information, which is the object to be made into a database, and then expressing it

1. Data Models (2)

- 3 types of data models



Object world

(Abstracting)[2]

Conceptual data model — E-R model[3] *Entity-Relationship Diagram (ERD)*

(DBMS selection)

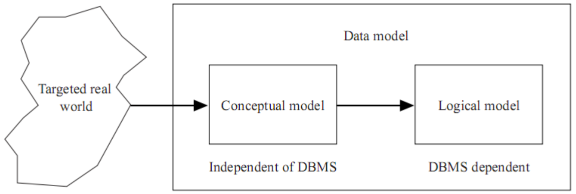
Logical data model — Relational model, network model, hierarchical model

(Data manipulation)

Physical data model — Relational database, network database, hierarchical database

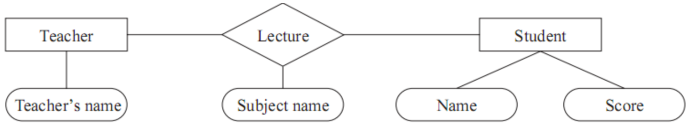
1.1. Conceptual data model

- Natural expressions without constraints imposed by DBMS
- E-R model
  - Expressed by E-R diagram



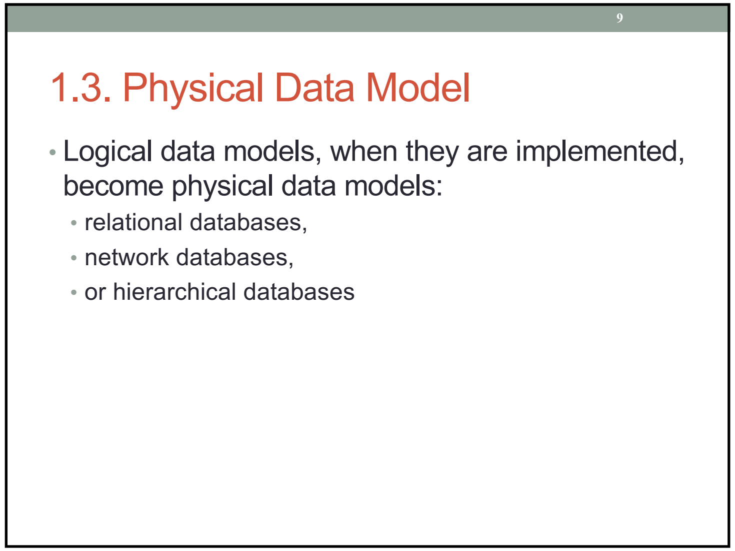
E-R Diagram

- Three elements
  - Entities
  - Relationships
  - Attributes



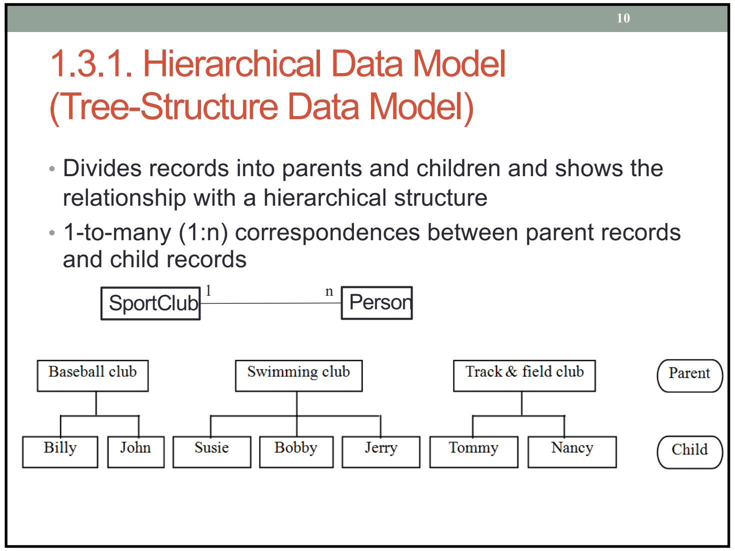
1.2. Logical Data Model

- 3 types
  - relational model,
  - network model,
  - and hierarchical model



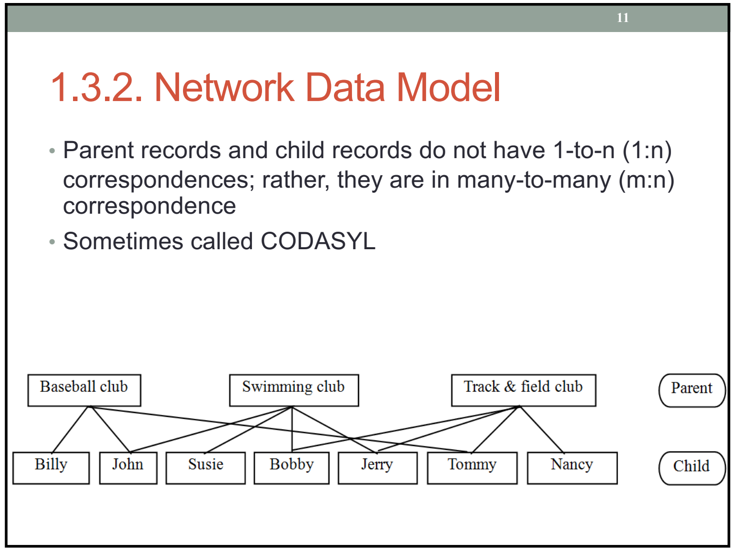
1.3. Physical Data Model

- Logical data models, when they are implemented, become physical data models:
  - relational databases,
  - network databases,
  - or hierarchical databases



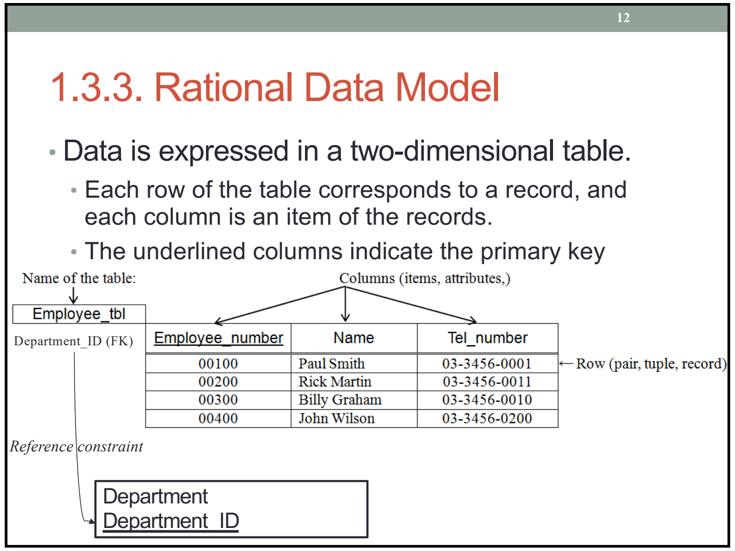
1.3.1. Hierarchical Data Model (Tree-Structure Data Model)

- Divides records into parents and children and shows the relationship with a hierarchical structure
- 1-to-many (1:n) correspondences between parent records and child records



1.3.2. Network Data Model

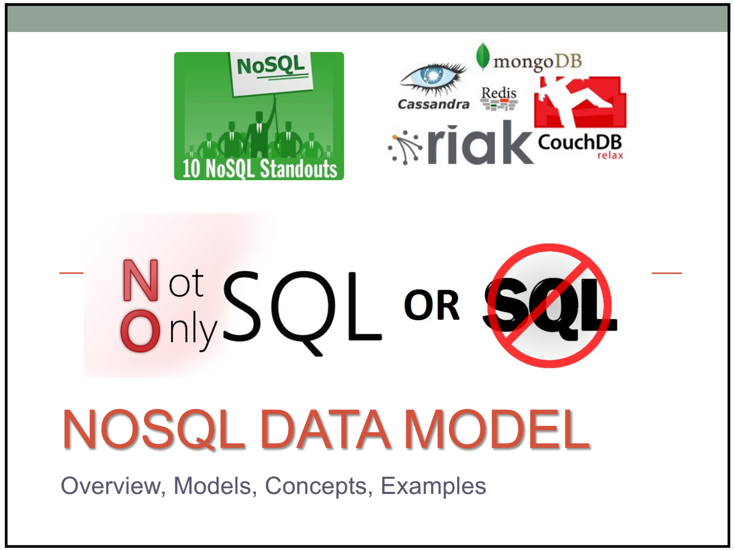
- Parent records and child records do not have 1-to-n (1:n) correspondences; rather, they are in many-to-many (m:n) correspondence
- Sometimes called CODASYL



1.3.3. Rational Data Model

- Data is expressed in a two-dimensional table.
  - Each row of the table corresponds to a record, and each column is an item of the records.
  - The underlined columns indicate the primary key

Employee_number	Name	Tel_number
00100	Paul Smith	03-3456-0001
00200	Rick Martin	03-3456-0011
00300	Billy Graham	03-3456-0010
00400	John Wilson	03-3456-0200



NOSQL DATA MODEL

Overview, Models, Concepts, Examples

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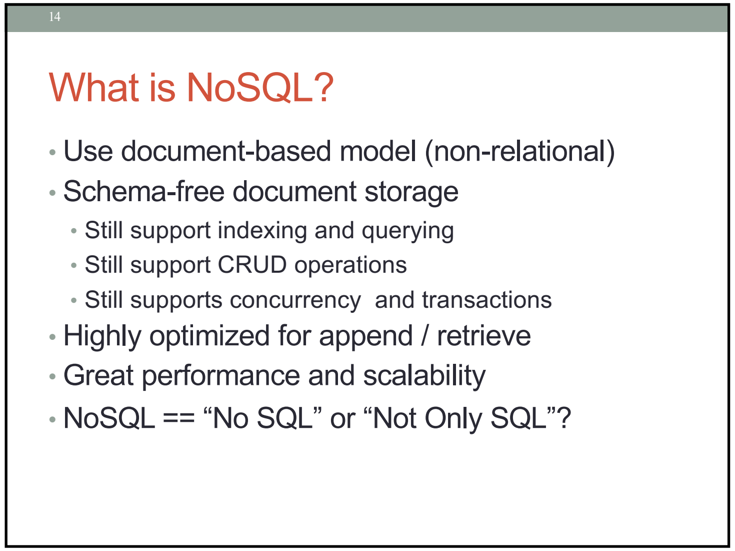

What is NoSQL?

- Use document-based model (non-relational)
- Schema-free document storage
  - Still support indexing and querying
  - Still support CRUD operations
  - Still supports concurrency and transactions
- Highly optimized for append / retrieve
- Great performance and scalability
- NoSQL == “No SQL” or “Not Only SQL”?

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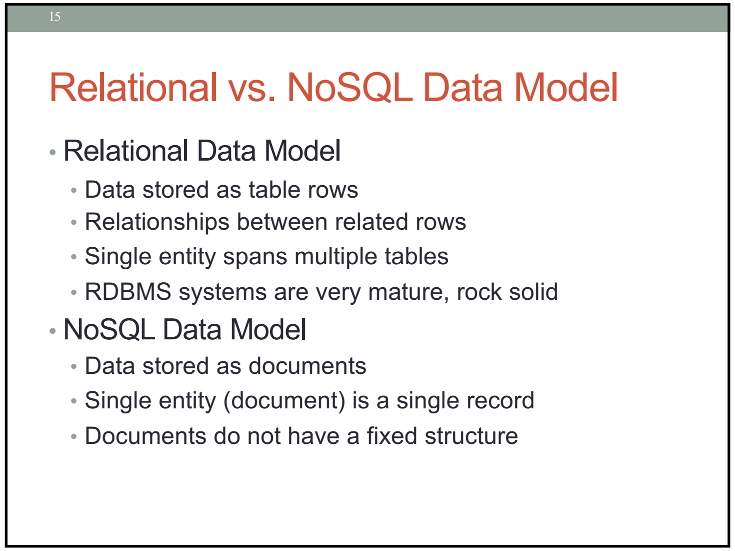

Relational vs. NoSQL Data Model

- Relational Data Model
  - Data stored as table rows
  - Relationships between related rows
  - Single entity spans multiple tables
  - RDBMS systems are very mature, rock solid
- NoSQL Data Model
  - Data stored as documents
  - Single entity (document) is a single record
  - Documents do not have a fixed structure

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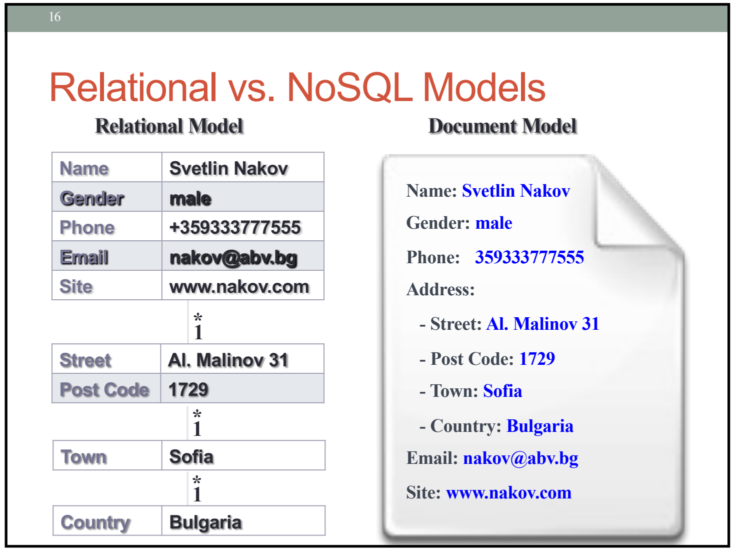

Relational vs. NoSQL Models

Relational Model

Name	Svetlin Nakov
Gender	male
Phone	+359333777555
Email	nakov@abv.bg
Site	www.nakov.com

Street	Al. Malinov 31
Post Code	1729

Town	Sofia

Country	Bulgaria

Document Model

Name: Svetlin Nakov
Gender: male
Phone: 359333777555
Address:
- Street: Al. Malinov 31
- Post Code: 1729
- Town: Sofia
- Country: Bulgaria

Email: nakov@abv.bg
Site: www.nakov.com

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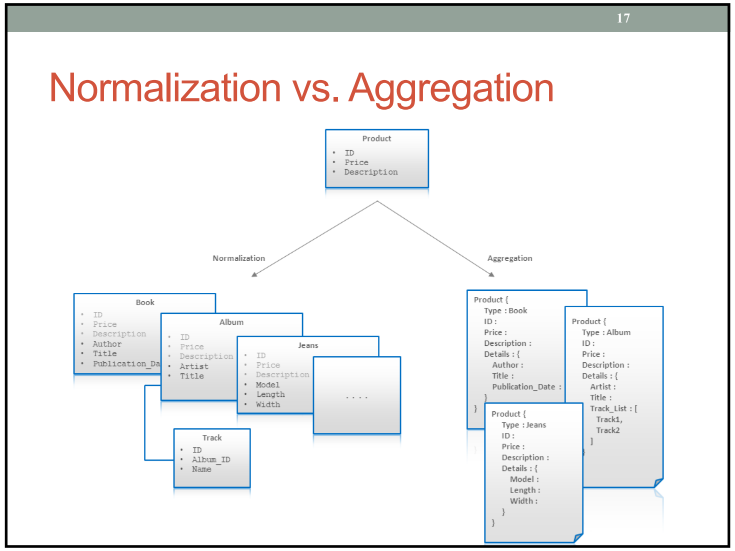

Normalization vs. Aggregation

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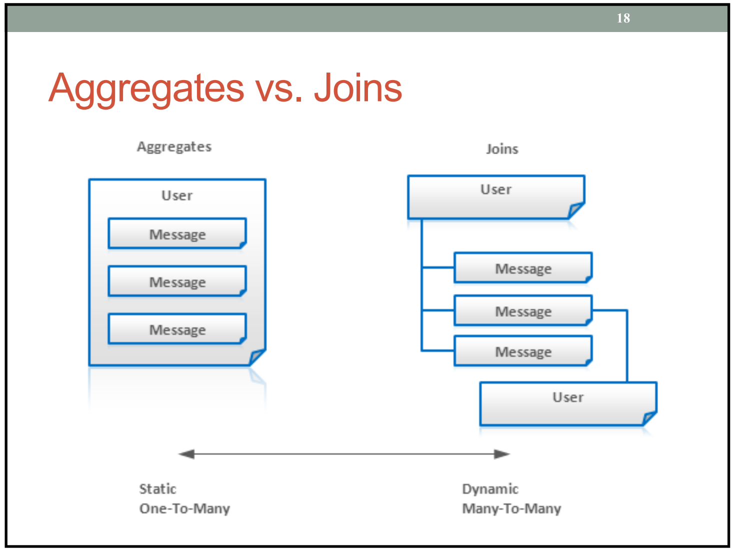

Aggregates vs. Joins

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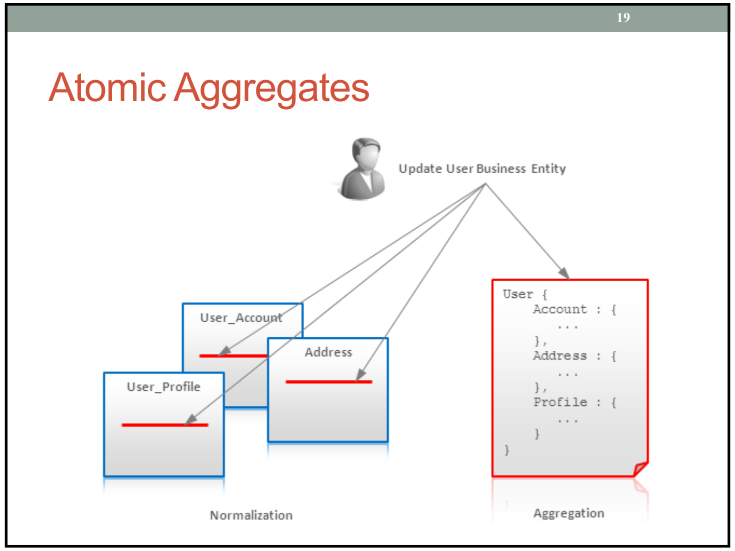

Atomic Aggregates

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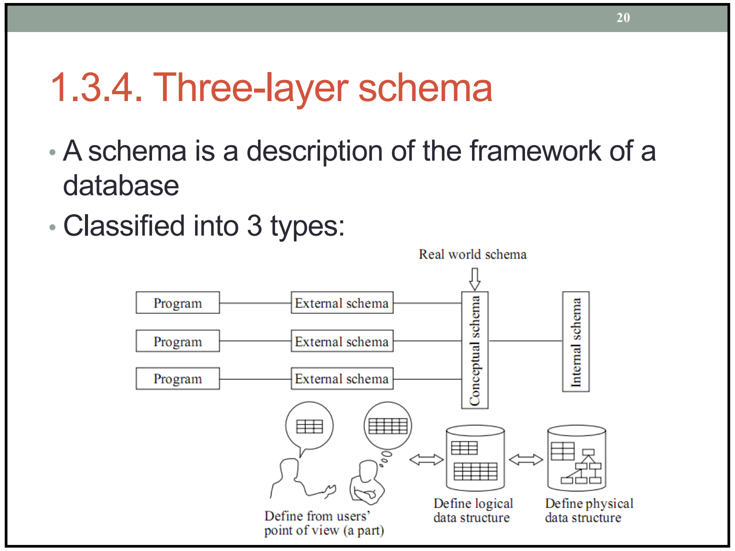

1.3.4. Three-layer schema

- A schema is a description of the framework of a database
- Classified into 3 types:

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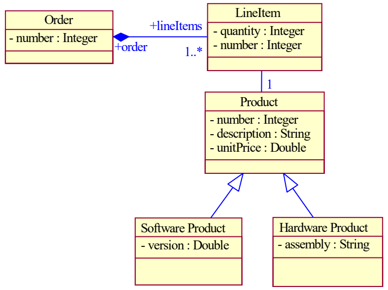
3. Mapping class diagram to E-R diagram
4. Normalization

2.1. Relational Data Model and Object Model

- RDBMS and Object Orientation are not entirely compatible
  - RDBMS
    - Focus is on data
    - Better suited for ad-hoc relationships and reporting application
    - Expose data (column values)
  - Object Model
    - Focus is on behavior
    - Better suited to handle state-specific behavior where data is secondary
    - Hide data (encapsulation)

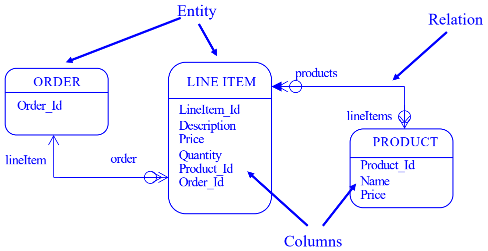
2.2. The Object Model

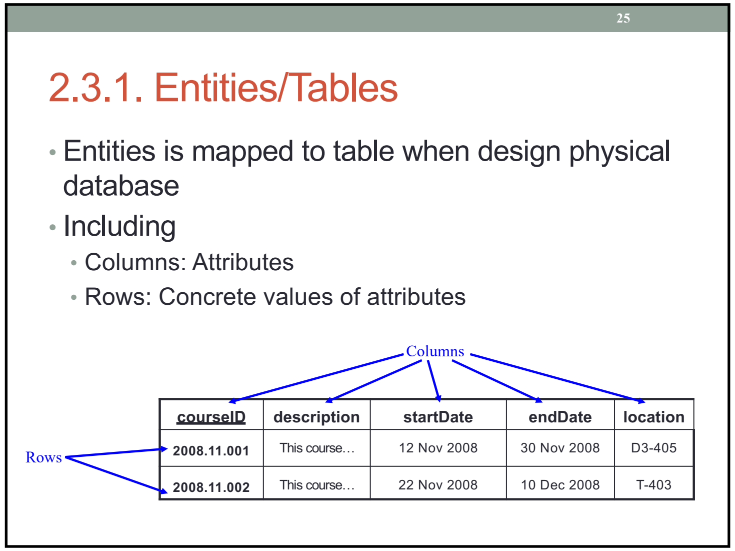
- The Object Model is composed of
  - Classes (attributes)
  - Relationships
    - Associations
    - Generalization



2.3. The Relational Data Model

- Relational data model is composed of
  - Entities - Table
  - Relations - Relationship
  - → **Also called E-R model**





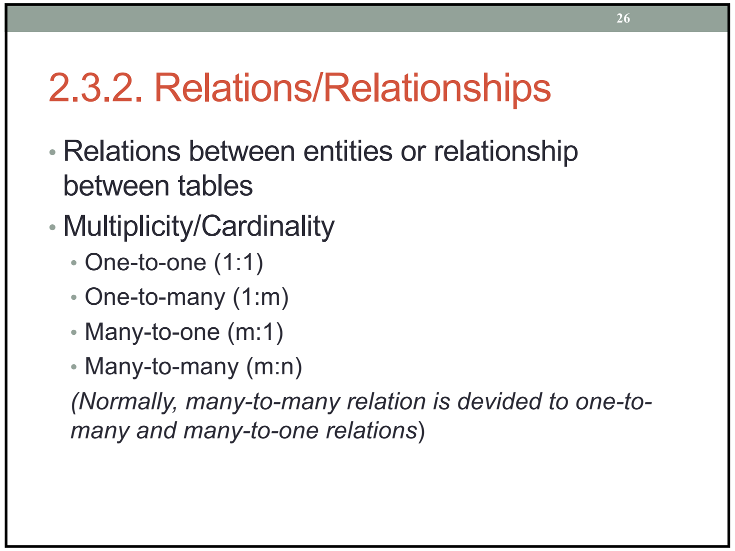
2.3.1. Entities/Tables

- Entities is mapped to table when design physical database
- Including
  - Columns: Attributes
  - Rows: Concrete values of attributes

Columns

Rows

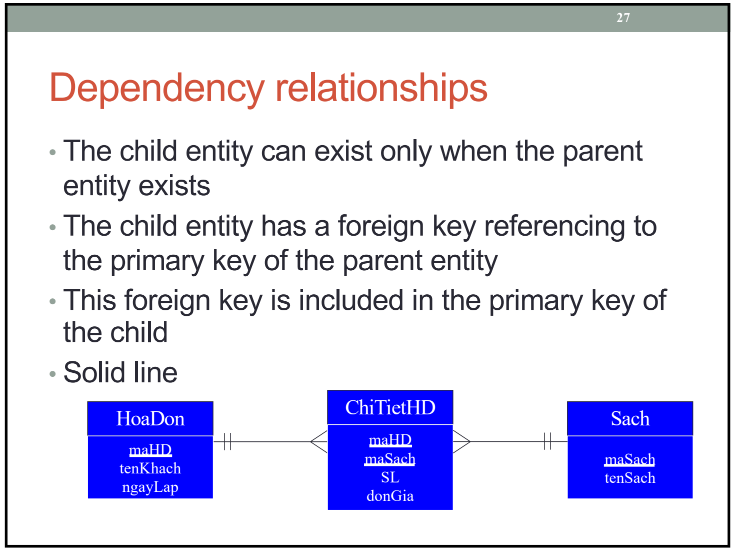
courseID	description	startDate	endDate	location
2008.11.001	This course…	12 Nov 2008	30 Nov 2008	D3-405
2008.11.002	This course…	22 Nov 2008	10 Dec 2008	T-403



2.3.2. Relations/Relationships

- Relations between entities or relationship between tables
- Multiplicity/Cardinality
  - One-to-one (1:1)
  - One-to-many (1:m)
  - Many-to-one (m:1)
  - Many-to-many (m:n)

  (Normally, many-to-many relation is devided to one-to-many and many-to-one relations)



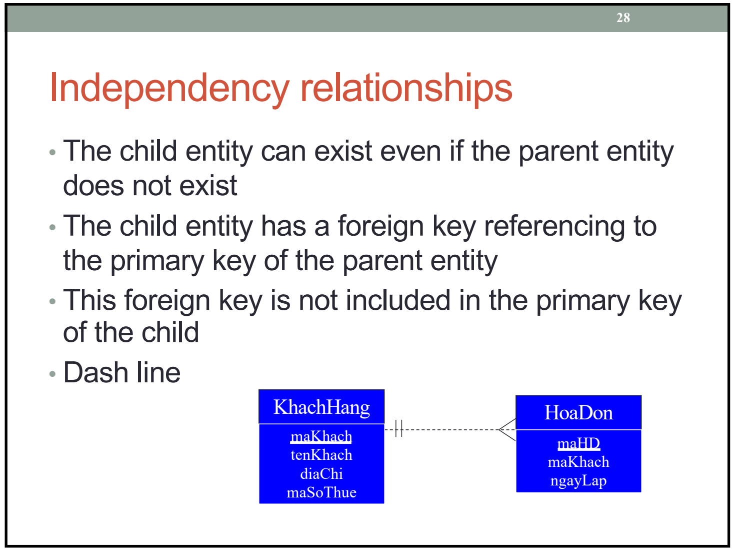
Dependency relationships

- The child entity can exist only when the parent entity exists
- The child entity has a foreign key referencing to the primary key of the parent entity
- This foreign key is included in the primary key of the child
- Solid line

HoaDon
maHD
tenKhach
ngayLap

ChiTietHD
maHD
maSach
SL
donGia

Sach
maSach
tenSach



Independency relationships

- The child entity can exist even if the parent entity does not exist
- The child entity has a foreign key referencing to the primary key of the parent entity
- This foreign key is not included in the primary key of the child
- Dash line

KhachHang
maKhach
tenKhach
diaChi
maSoThue

HoaDon
maHD
maKhach
ngayLap

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1. Data models
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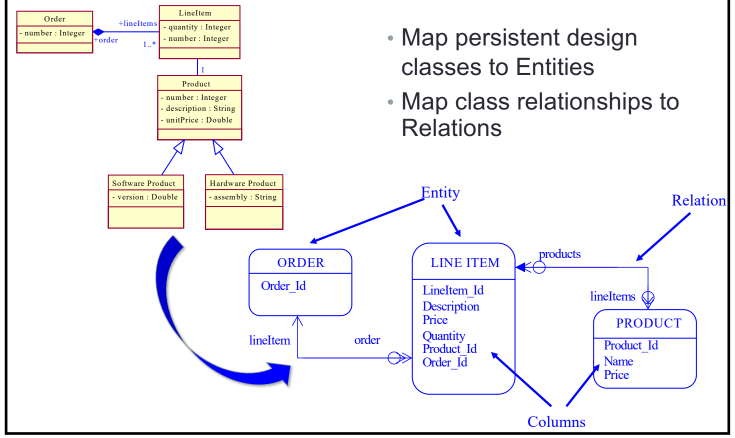
3. Mapping class diagram to E-R diagram
4. Normalization

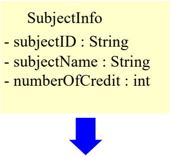
3. Mapping class diagram to E-R diagram

- Map persistent design classes to Entities
- Map class relationships to Relations



3.1. Mapping Persistent Design Classes to Entities

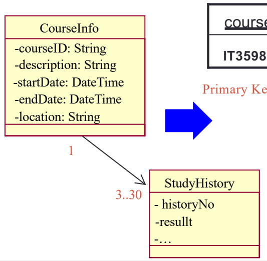
- In a relational database
  - Every row is regarded as an object
  - A column in a table is equivalent to a persistent attribute of a class



Attributes from object type	subjectID	subjectName	numberOfCredit
Object Instance	IT0001	CS Introduction	4

3.2. Mapping Associations Between Persistent Objects

- Associations between two persistent objects are realized as foreign keys to the associated objects.
  - A foreign key (not in primary key) is a column in one table that contains the primary key value of associated object
  - → Independency relationship



Course entity

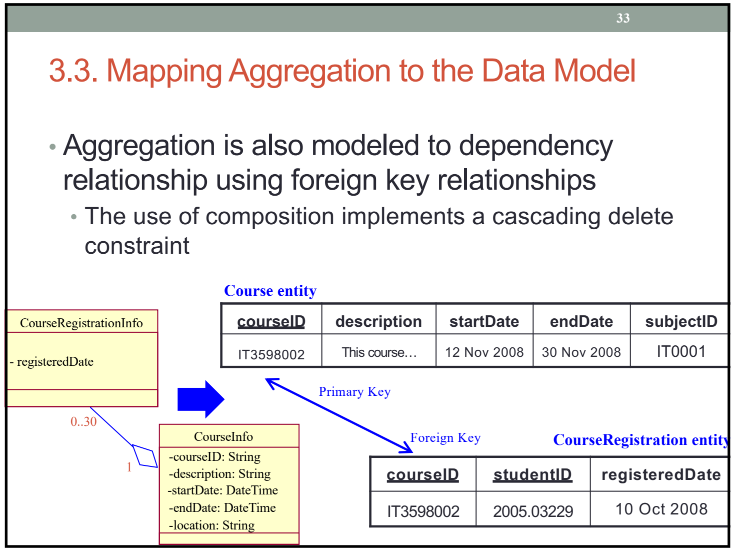
<u>courseID</u>	description	startDate	endDate	location
IT3598002	This course…	12 Nov 2008	30 Nov 2008	D3-405

Primary Key

Foreign Key

StudyHistory entity

<u>historyNo</u>	<u>studentID</u>	Result	courseID	…
5	2005.03229	A	**IT3598002**	



3.3. Mapping Aggregation to the Data Model

- Aggregation is also modeled to dependency relationship using foreign key relationships
  - The use of composition implements a cascading delete constraint

Course entity

courseID	description	startDate	endDate	subjectID
IT3598002	This course…	12 Nov 2008	30 Nov 2008	IT0001

CourseRegistration entity

courseID	studentID	registeredDate
IT3598002	2005.03229	10 Oct 2008

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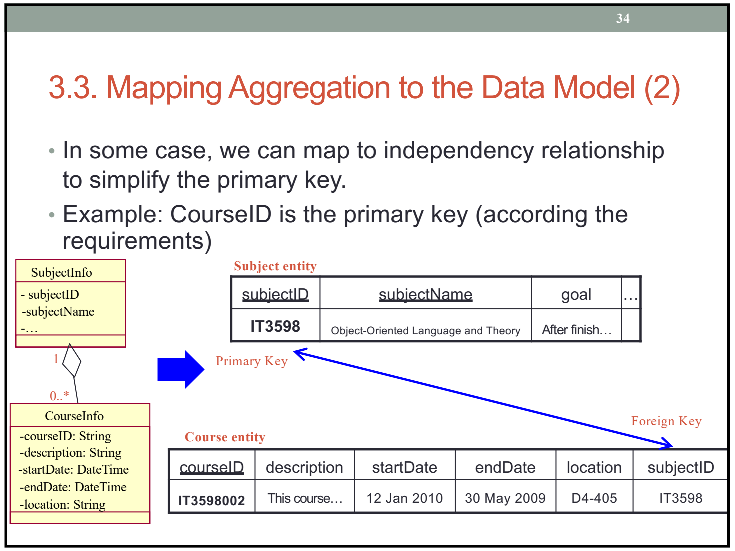

3.3. Mapping Aggregation to the Data Model (2)

- In some case, we can map to independency relationship to simplify the primary key.
- Example: CourseID is the primary key (according the requirements)

Subject entity

subjectID	subjectName	goal	…
IT3598	Object-Oriented Language and Theory	After finish…	

Course entity

courseID	description	startDate	endDate	location	subjectID
IT3598002	This course…	12 Jan 2010	30 May 2009	D4-405	IT3598

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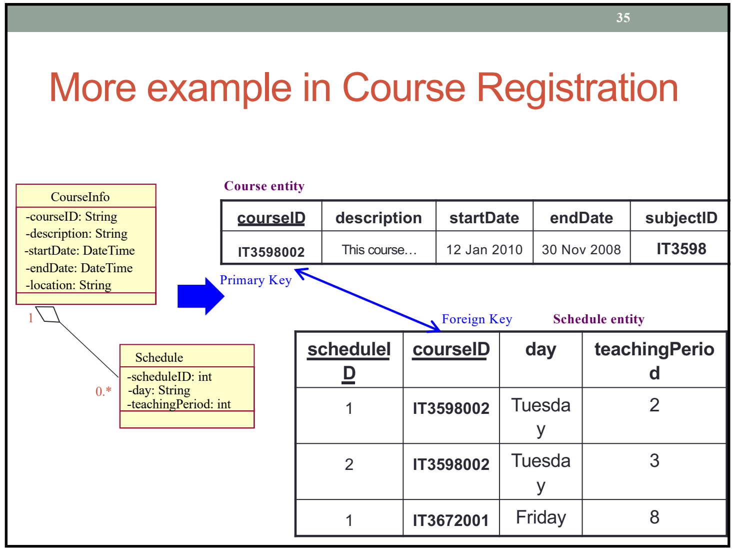

More example in Course Registration

Course entity

courseID	description	startDate	endDate	subjectID
IT3598002	This course…	12 Jan 2010	30 Nov 2008	IT3598

Schedule entity

scheduleID	courseID	day	teachingPeriod
1	IT3598002	Tuesday	2
2	IT3598002	Tuesday	3
1	IT3672001	Friday	8

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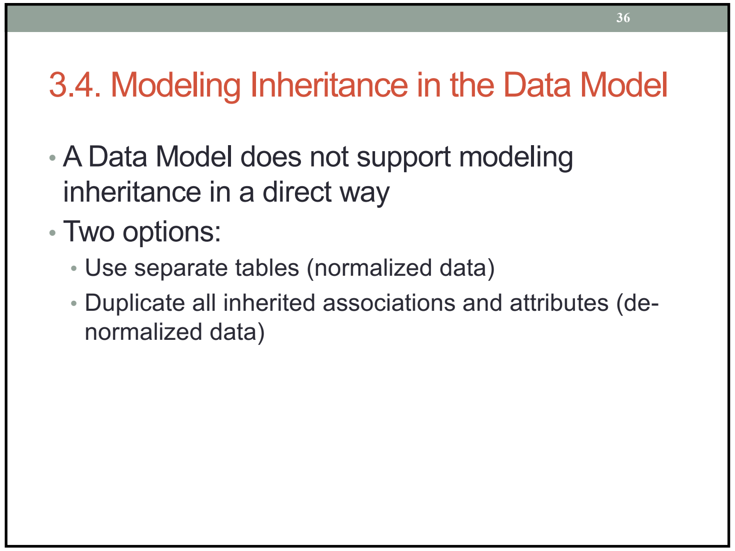

3.4. Modeling Inheritance in the Data Model

- A Data Model does not support modeling inheritance in a direct way
- Two options:
  - Use separate tables (normalized data)
  - Duplicate all inherited associations and attributes (de-normalized data)

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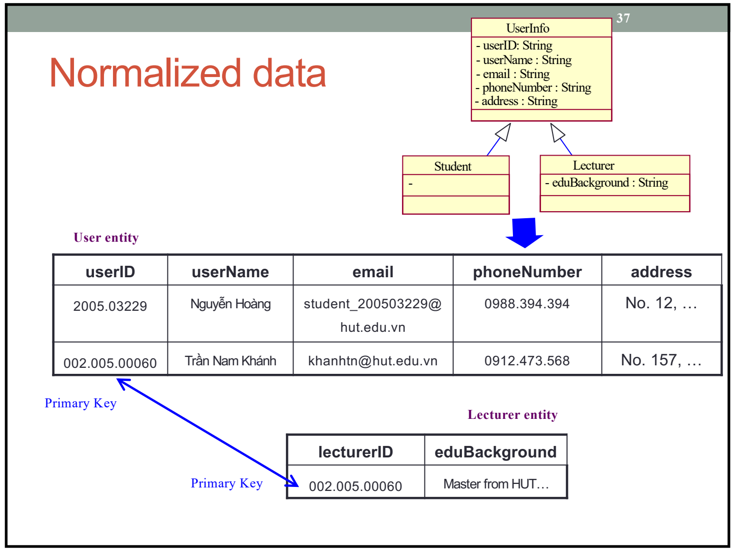

Normalized data

User entity

userID	userName	email	phoneNumber	address
2005.03229	Nguyễn Hoàng	student_200503229@ hut.edu.vn	0988.394.394	No. 12, …
002.005.00060	Trần Nam Khánh	khanhtn@hut.edu.vn	0912.473.568	No. 157, …

Lecturer entity

lecturerID	eduBackground
002.005.00060	Master from HUT…

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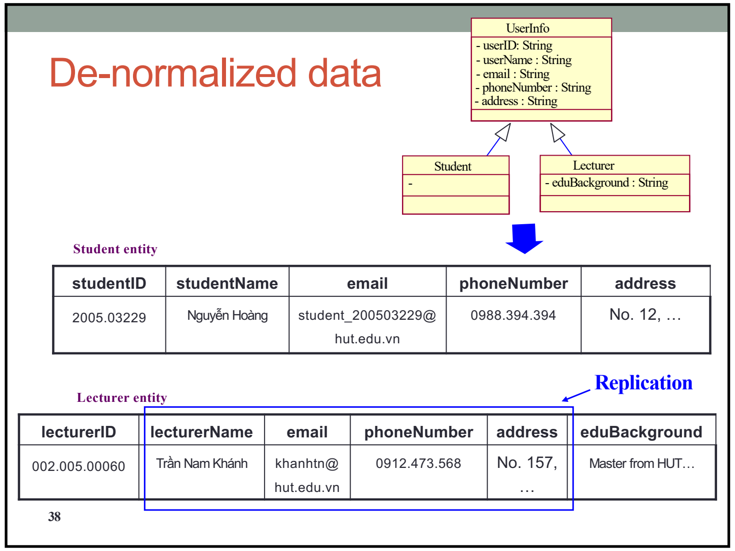

De-normalized data

Student entity

studentID	studentName	email	phoneNumber	address
2005.03229	Nguyễn Hoàng	student_200503229@ hut.edu.vn	0988.394.394	No. 12, …

Lecturer entity

lecturerID	lecturerName	email	phoneNumber	address	eduBackground
002.005.00060	Trần Nam Khánh	khanhtn@ hut.edu.vn	0912.473.568	No. 157, …	Master from HUT…

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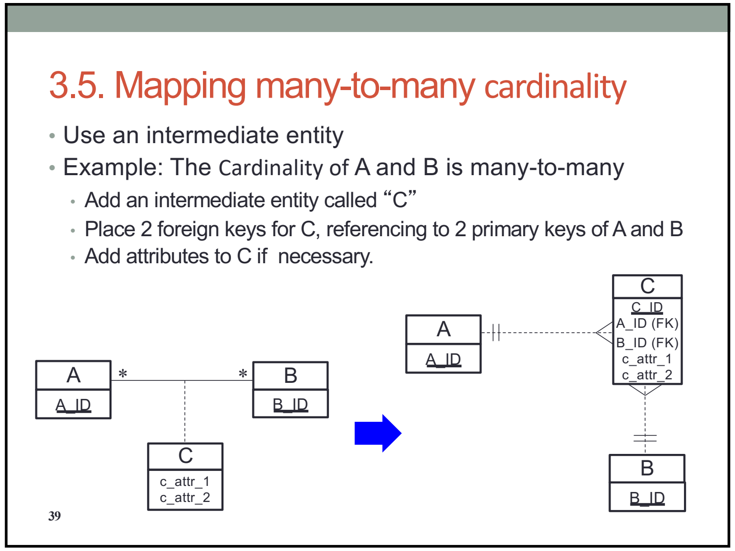

3.5. Mapping many-to-many cardinality

- Use an intermediate entity
- Example: The Cardinality of A and B is many-to-many
  - Add an intermediate entity called "C"
  - Place 2 foreign keys for C, referencing to 2 primary keys of A and B
  - Add attributes to C if necessary.

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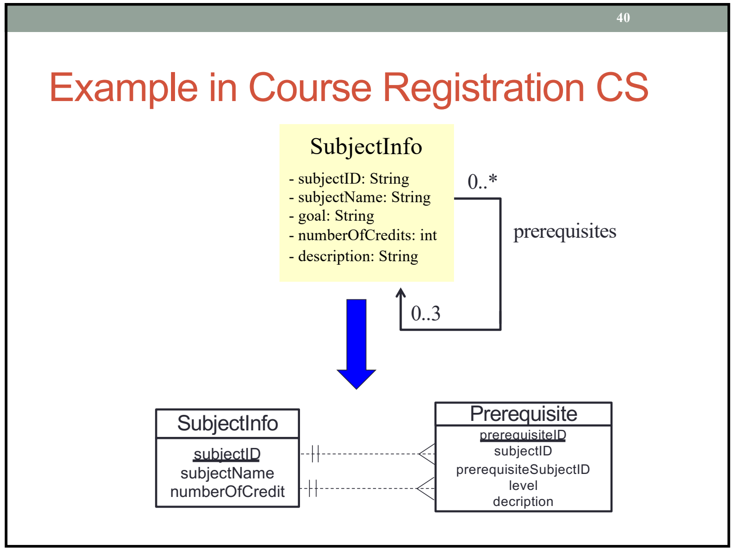

Example in Course Registration CS

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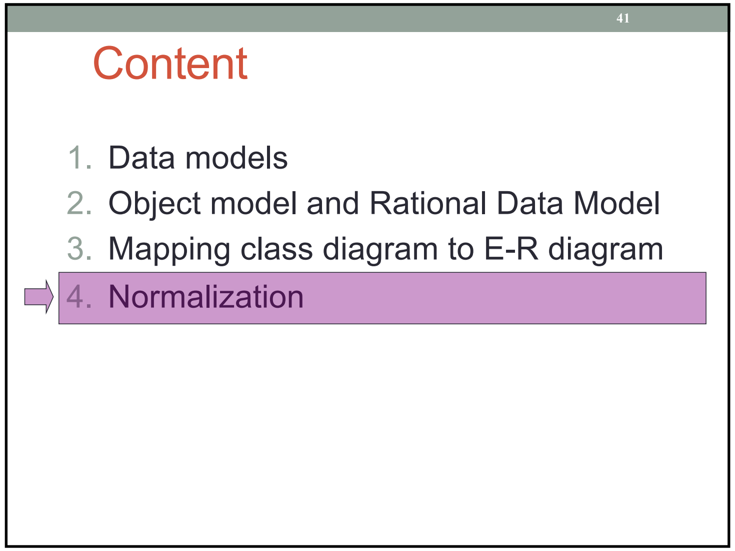

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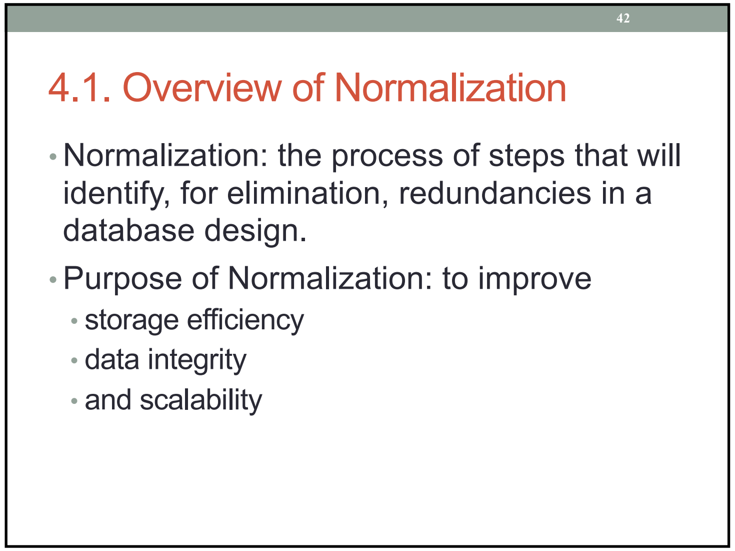

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4.1. Overview of Normalization

- Normalization: the process of steps that will identify, for elimination, redundancies in a database design.
- Purpose of Normalization: to improve
  - storage efficiency
  - data integrity
  - and scalability

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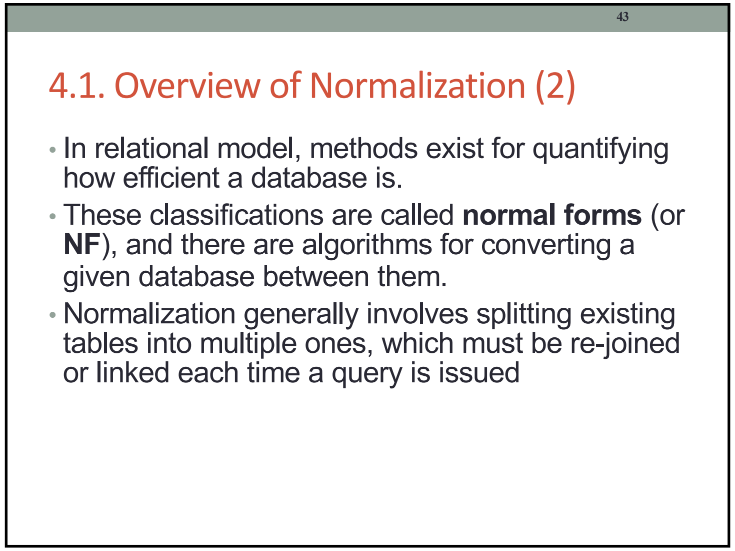

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4.1. Overview of Normalization (2)

- In relational model, methods exist for quantifying how efficient a database is.
- These classifications are called **normal forms** (or **NF**), and there are algorithms for converting a given database between them.
- Normalization generally involves splitting existing tables into multiple ones, which must be re-joined or linked each time a query is issued

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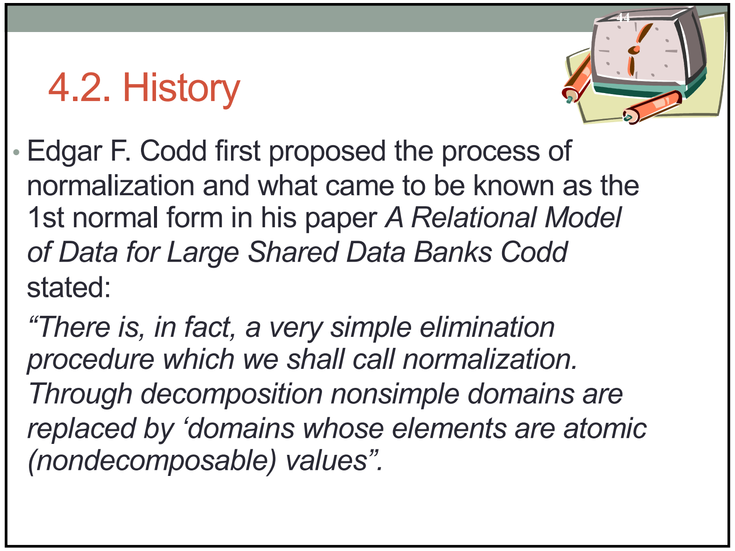

4.2. History

- Edgar F. Codd first proposed the process of normalization and what came to be known as the 1st normal form in his paper *A Relational Model of Data for Large Shared Data Banks Codd* stated:

  "There is, in fact, a very simple elimination procedure which we shall call normalization. Through decomposition nonsimple domains are replaced by 'domains whose elements are atomic (nondecomposable) values".

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4.3. Normal Forms

- Edgar F. Codd originally established three normal forms: 1NF, 2NF and 3NF.
- There are now others that are generally accepted, but 3NF is widely considered to be sufficient for most applications.
- Most tables when reaching 3NF are also in BCNF (Boyce-Codd Normal Form).

Functionally determines

- In a table, a set of columns X, functionally determines another column Y…

  X → Y

  … if and only if each X value is associated with at most one Y value in a table.

- i.e. if you know X then there is only **one** possibility for Y.

Normal forms so Far…

- First normal form
  - All data values are atomic, and so everything fits into a mathematical relation.
- Second normal form
  - As 1NF plus no *non-primary-key attribute* is partially dependant on the primary key
- Third normal form
  - As 2NF plus no non-primary-key attribute depends transitively on the primary key

Normalization Example

- Consider a table representing orders in an online store
- Each entry in the table represents an item on a particular order. (thinking in terms of records. Yuk.)
- **Columns**
  - Order
  - Product
  - Customer
  - Address
  - Quantity
  - UnitPrice
- Primary key is {Order, Product}

Functional Dependencies

- Each order is for a **single** customer {Order} → {Customer}
- Each customer has a **single** address {Customer} → {Address}
- Each product has a **single** price {Product} → {UnitPrice}
- FD's 1 and 2 are transitive {Order} → {Address}

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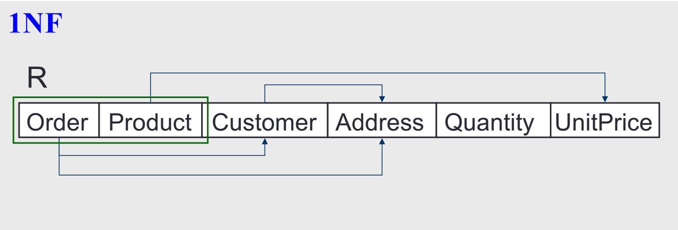
Example – FD Diagram



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Normalization to 2NF

- Remember 2nd normal form means no partial dependencies on the key. But we have:

  {Order} → {Customer, Address}
  {Product} → {UnitPrice}

  And a primary key of: {Order, Product}

- So to get rid of the first FD we *project* over:

  {Order, Customer, Address}

  and

  {Order, Product, Quantity and UnitPrice}

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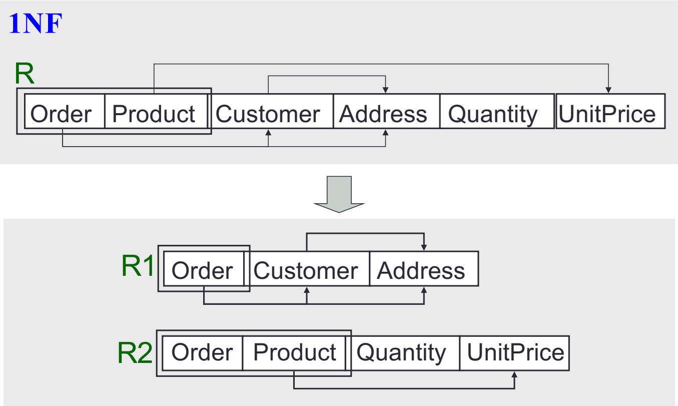
Normalization to 2NF



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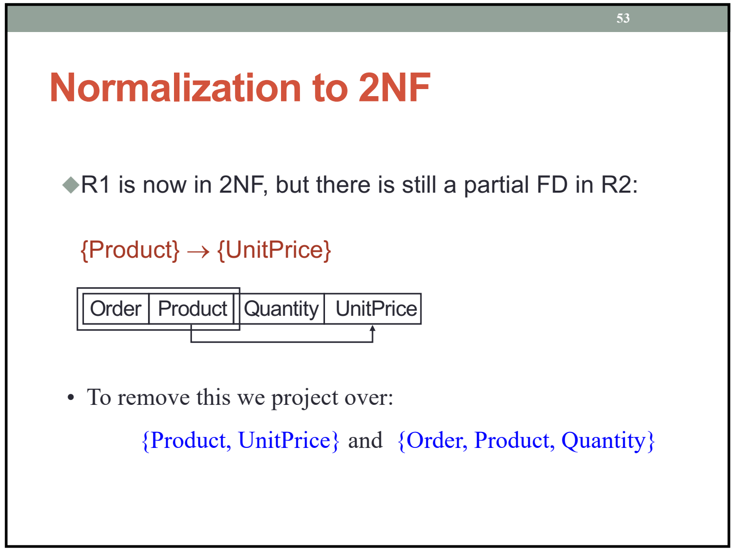


Normalization to 2NF

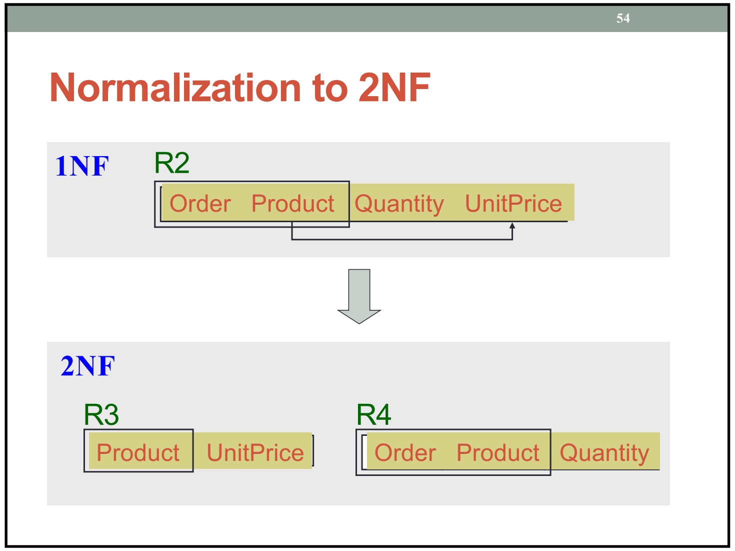
- R1 is now in 2NF, but there is still a partial FD in R2:

{Product} → {UnitPrice}

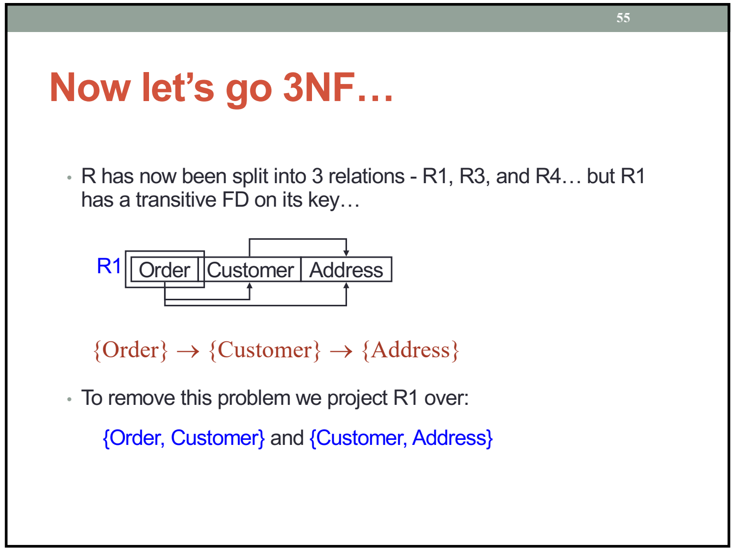
Order
Product
Quantity
UnitPrice

- To remove this we project over:

{Product, UnitPrice} and {Order, Product, Quantity}



Normalization to 2NF



Now let's go 3NF…

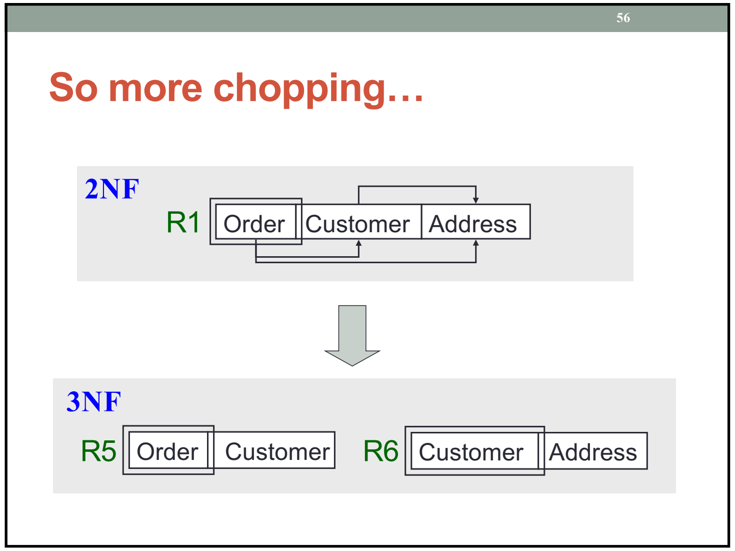
- R has now been split into 3 relations - R1, R3, and R4… but R1 has a transitive FD on its key…

R1
Order
Customer
Address

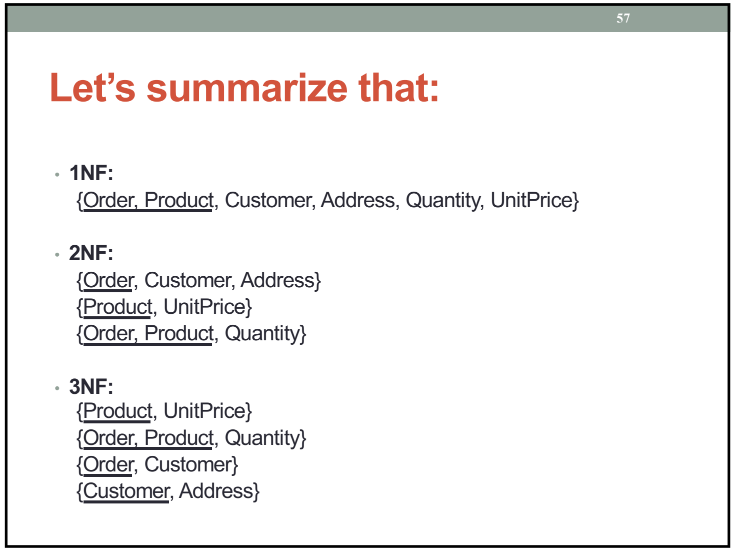
{Order} → {Customer} → {Address}

- To remove this problem we project R1 over:

{Order, Customer} and {Customer, Address}



So more chopping…



Let’s summarize that:

- **1NF:**
  {Order, Product, Customer, Address, Quantity, UnitPrice}
- **2NF:**
  {Order, Customer, Address}
  {Product, UnitPrice}
  {Order, Product, Quantity}
- **3NF:**
  {Product, UnitPrice}
  {Order, Product, Quantity}
  {Order, Customer}
  {Customer, Address}

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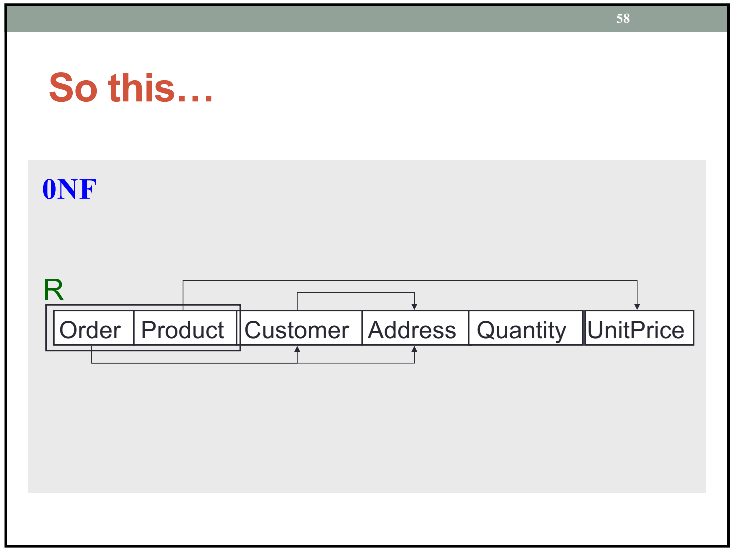

So this…

0NF

R

Order | Product | Customer | Address | Quantity | UnitPrice

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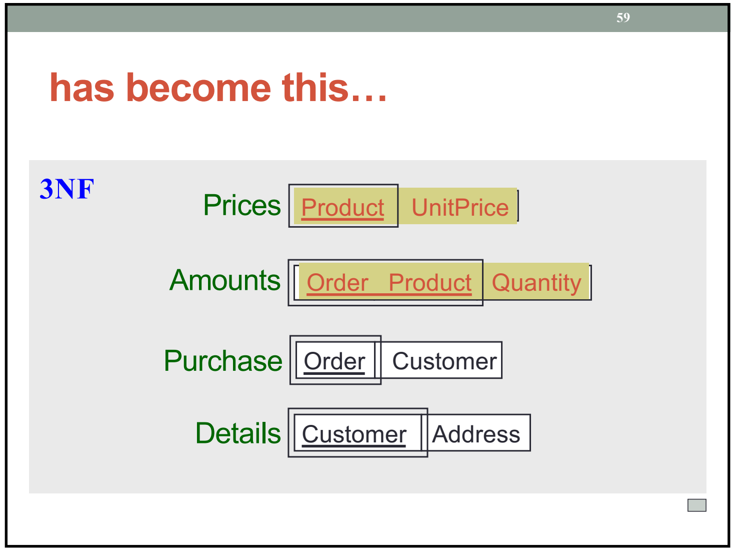

has become this…

3NF

Prices: Product | UnitPrice

Amounts: Order Product | Quantity

Purchase: Order | Customer

Details: Customer | Address

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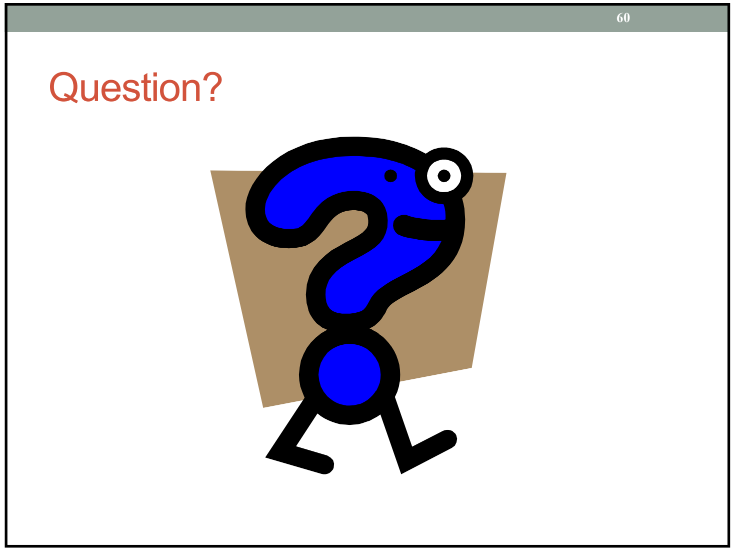

Question?

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