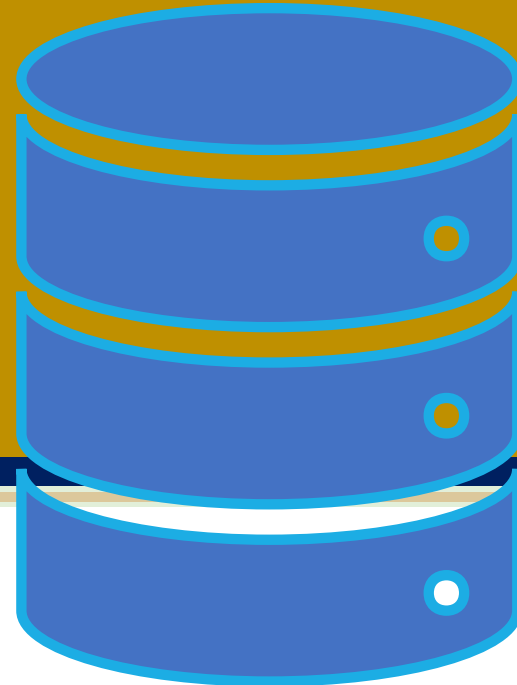
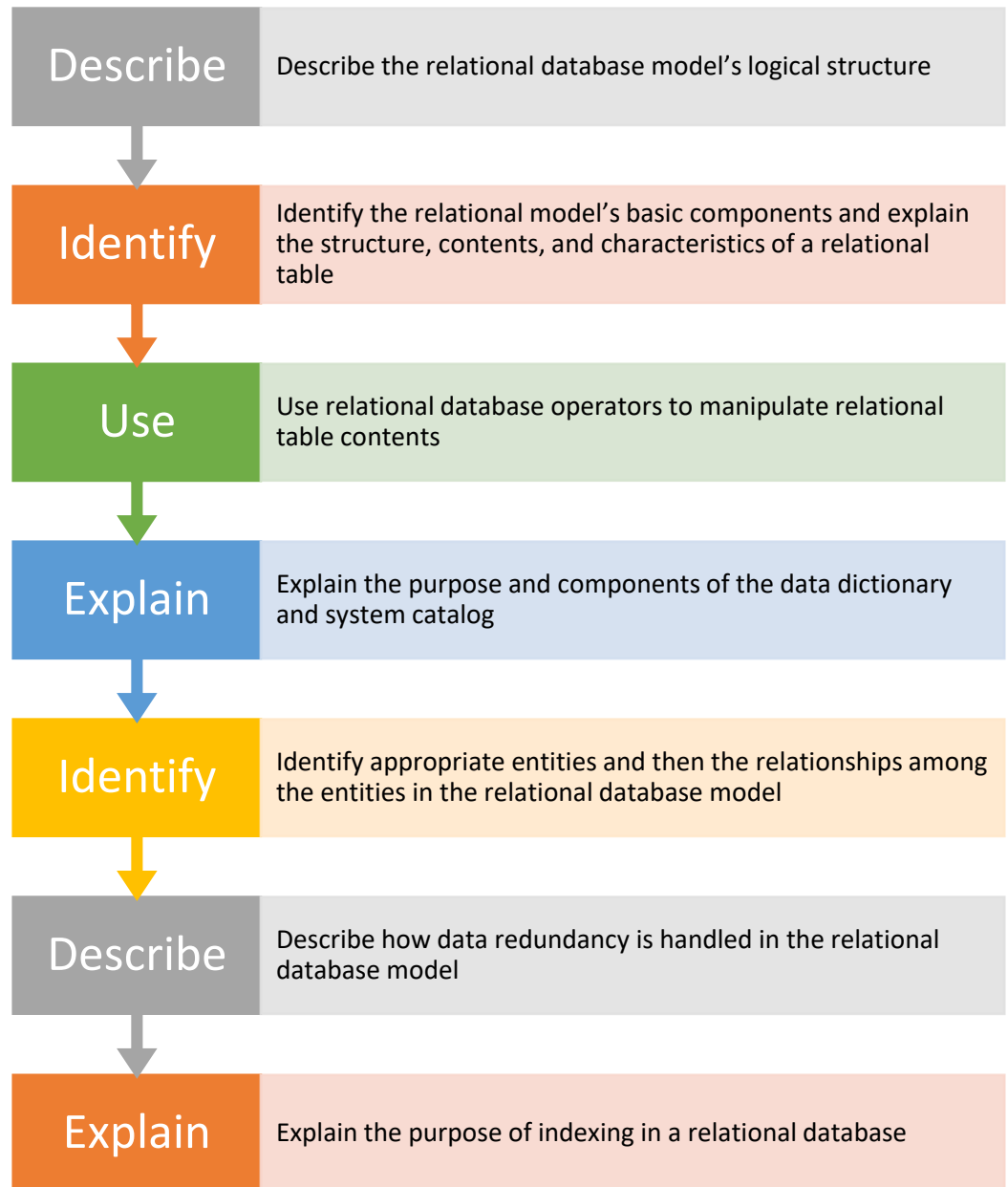


# 3. THE RELATIONAL DATABASE MODEL

Database Design & Business Application Development



# Learning Objectives



# A Logical View of Data

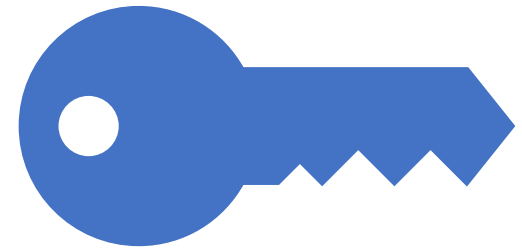
- Relational database model enables logical representation of the data and its relationships
  - Logical simplicity yields simple and effective database design methodologies
  - The logical view is facilitated by the creation of data relationships based on a logical construct called a relation

# Tables and Their Characteristics

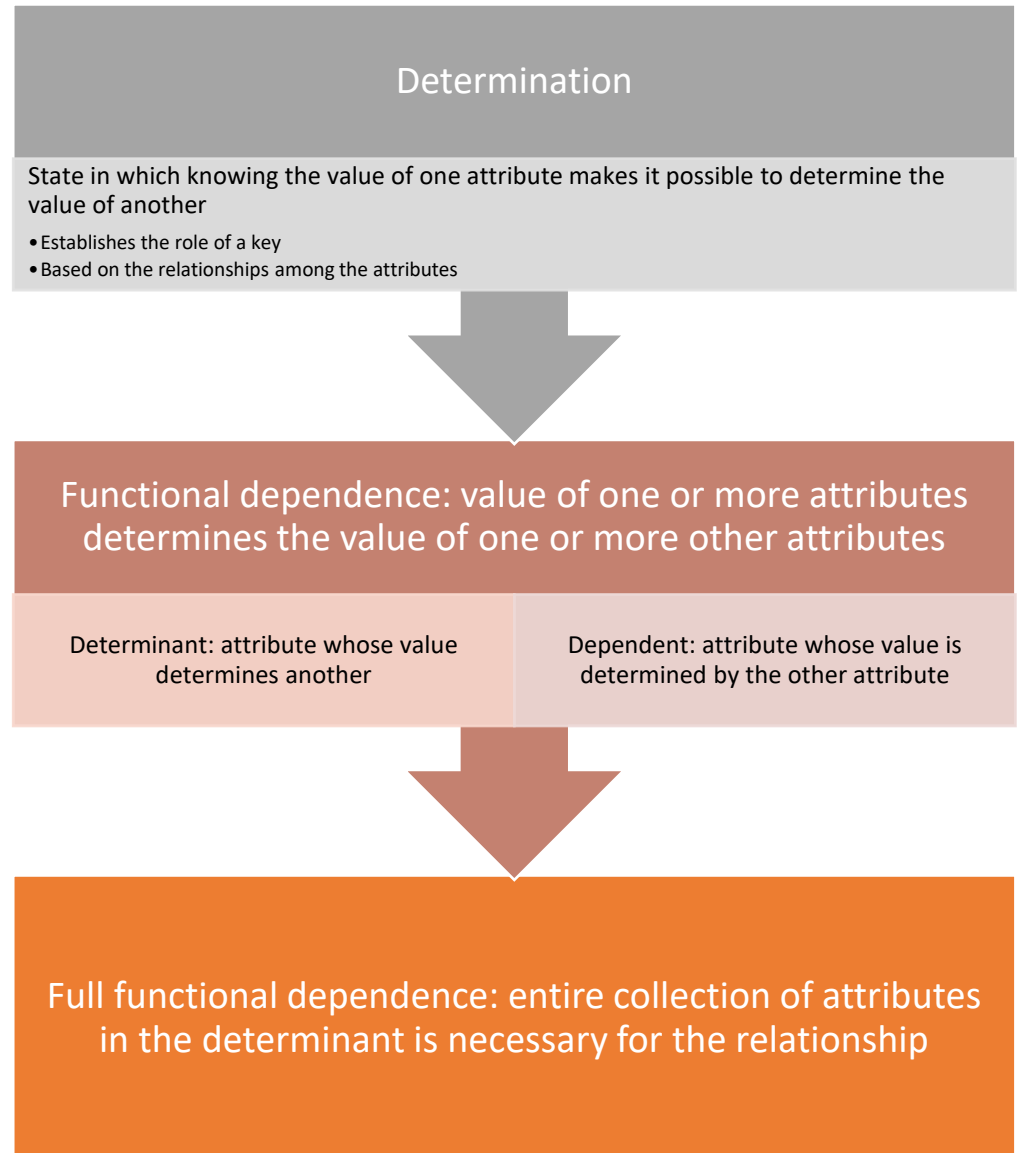
Table 3.1	Characteristics of a Relational Table
1	A table is perceived as a two-dimensional structure composed of rows and columns.
2	Each table row (tuple) represents a single entity occurrence within the entity set.
3	Each table column represents an attribute, and each column has a distinct name.
4	Each intersection of a row and column represents a single data value.
5	All values in a column must conform to the same data format.
6	Each column has a specific range of values known as the attribute domain.
7	The order of the rows and columns is immaterial to the DBMS.
8	Each table must have an attribute or combination of attributes that uniquely identifies each row.

# Keys

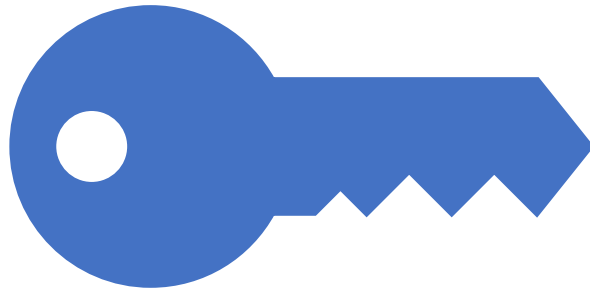
- Keys consist of one or more attributes that determine other attributes
  - Ensure that each row in a table is uniquely identifiable
  - Establish relationships among tables and to ensure the integrity of the data
- Primary key: attribute or combination of attributes that uniquely identifies a row



# Dependencies



# Types of Keys



Tuesday, June 7, 2022

- Several different types of keys are used in the relational model
  - Composite key: key that is composed of more than one attribute
  - Key attribute: attribute that is a part of a key
  - Superkey: key that can uniquely identify any row in the table
  - Candidate key: minimal superkey
  - Entity integrity: condition in which each row in the table has its own unique identity
    - All of the values in the primary key must be unique
    - No key attribute in the primary key can contain a null
  - Null: absence of any data value
    - Unknown attribute value, known but missing attribute value, or inapplicable condition
  - Referential integrity: every reference to an entity instance by another entity instance is valid
  - Foreign key: primary key of one table that has been placed into another table to create a common attribute
  - Secondary key: key used strictly for data retrieval purposes

**FIGURE 3.2 AN EXAMPLE OF A SIMPLE RELATIONAL DATABASE**

**Table name: PRODUCT**

**Primary key: PROD\_CODE**

**Foreign key: VEND\_CODE**

**Database name: Ch03\_SaleCo**

PROD_CODE	PROD_DESCRIPT	PROD_PRICE	PROD_ON_HAND	VEND_CODE
001278-AB	Claw hammer	12.95	23	232
123-21UUY	Houselite chain saw, 16-in. bar	189.99	4	235
QER-34256	Sledge hammer, 16-lb. head	18.63	6	231
SRE-657UG	Rat-tail file	2.99	15	232
ZZX/3245Q	Steel tape, 12-ft. length	6.79	8	235

link

**Table name: VENDOR**

**Primary key: VEND\_CODE**

**Foreign key: none**

VEND_CODE	VEND_CONTACT	VEND_AREACODE	VEND_PHONE
230	Shelly K. Smithson	608	555-1234
231	James Johnson	615	123-4536
232	Annelise Crystall	608	224-2134
233	Candice Wallace	904	342-6567
234	Arthur Jones	615	123-3324
235	Henry Ortozo	615	899-3425

## Types of Keys



## Types of Keys

**Table 3.3**

**Relational Database Keys**

Key Type	Definition
Superkey	An attribute or combination of attributes that uniquely identifies each row in a table.
Candidate key	A minimal (irreducible) superkey; a superkey that does not contain a subset of attributes that is itself a superkey.
Primary key	A candidate key selected to uniquely identify all other attribute values in any given row; cannot contain null entries.
Foreign key	An attribute or combination of attributes in one table whose values must either match the primary key in another table or be null.
Secondary key	An attribute or combination of attributes used strictly for data retrieval purposes.


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# Integrity Rules

- Relational database integrity rules are very important to good database design
  - Relational database management systems (RDBMSs) enforce integrity rules automatically
    - Much safer to make sure the application design conforms to entity and referential integrity rules



# Integrity Rules

TABLE 3.4      INTEGRITY RULES	
Entity Integrity	Description
Requirement	All primary key entries are unique, and no part of a primary key may be null.
Purpose	Each row will have a unique identity, and foreign key values can properly reference primary key values.
Example	No invoice can have a duplicate number, nor can it be null; in short, all invoices are uniquely identified by their invoice number.
Referential Integrity	Description
Requirement	A foreign key may have either a null entry, as long as it is not a part of its table's primary key, or an entry that matches the primary key value in a table to which it is related (every non-null foreign key value must reference an existing primary key value).
Purpose	It is possible for an attribute not to have a corresponding value, but it will be impossible to have an invalid entry; the enforcement of the referential integrity rule makes it impossible to delete a row in one table whose primary key has mandatory matching foreign key values in another table.
Example	A customer might not yet have an assigned sales representative (number), but it will be impossible to have an invalid sales representative (number).

# Integrity Rules

FIGURE 3.3 AN ILLUSTRATION OF INTEGRITY RULES

Table name: CUSTOMER

Database name: Ch03\_InsureCo

Primary key: CUS\_CODE

Foreign key: AGENT\_CODE

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_RENEW_DATE	AGENT_CODE
10010	Ramas	Alfred	A	05-Apr-2018	502
10011	Dunne	Leona	K	16-Jun-2018	501
10012	Smith	Kathy	W	29-Jan-2019	502
10013	Olowski	Paul	F	14-Oct-2018	
10014	Orlando	Myron		28-Dec-2018	501
10015	O'Brian	Amy	B	22-Sep-2018	503
10016	Brown	James	G	25-Mar-2019	502
10017	Williams	George		17-Jul-2018	503
10018	Farriss	Anne	G	03-Dec-2018	501
10019	Smith	Olette	K	14-Mar-2019	503

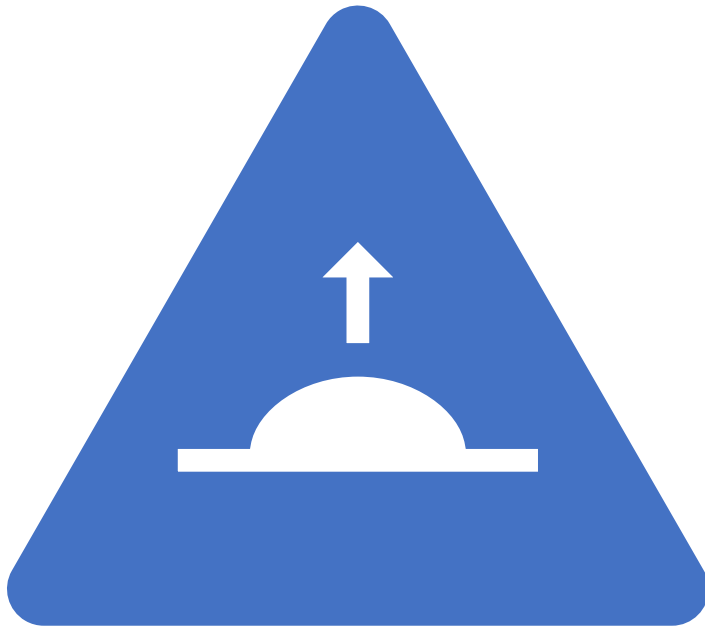
Table name: AGENT (only five selected fields are shown)

Primary key: AGENT\_CODE

Foreign key: none

AGENT_CODE	AGENT_AREACODE	AGENT_PHONE	AGENT_LNAME	AGENT_YTD_SLS
501	713	228-1249	Alby	132735.75
502	615	882-1244	Hahn	138967.35
503	615	123-5589	Okon	127093.45

# Integrity Rules



- Ways to handle nulls
  - Flags
    - Special codes used to indicate the absence of some value
  - Constraints
    - NOT NULL constraint: placed on a column to ensure that every row in the table has a value for that column
    - UNIQUE constraint: restriction placed on a column to ensure that no duplicate values exist for that column

# Relational Algebra

- Theoretical way of manipulating table contents using relational operators
  - Relvar: variable that holds a relation
    - Heading contains the names of the attributes
    - Body contains the relation
  - Relational operators have the property of closure
    - Closure: use of relational algebra operators on existing relations produces new relations



# Relational Set Operators

- Select (restrict)
  - Unary operator that yields a horizontal subset of a table
- Project
  - Unary operator that yields a vertical subset of a table
- Union
  - Combines all rows from two tables, excluding duplicate rows
  - Union-compatible: tables share the same number of columns, and their corresponding columns share compatible domains
- Intersect
  - Yields only the rows that appear in both tables
  - Tables must be union-compatible to yield valid results

FIGURE 3.4 SELECT

**Original table**

P_CODE	P_DESCRIPTION	PRICE
123456	Flashlight	5.26
123457	Lamp	25.15
123458	Box Fan	10.99
213345	9v battery	1.92
254467	100W bulb	1.47
311452	Powerdrill	34.99

**SELECT ALL yields**

**New table**

P_CODE	P_DESCRIPTION	PRICE
123456	Flashlight	5.26
123457	Lamp	25.15
123458	Box Fan	10.99
213345	9v battery	1.92
254467	100W bulb	1.47
311452	Powerdrill	34.99

**SELECT only PRICE less than \$2.00 yields**

P_CODE	P_DESCRIPTION	PRICE
213345	9v battery	1.92
254467	100W bulb	1.47

**SELECT only P\_CODE = 311452 yields**

P_CODE	P_DESCRIPTION	PRICE
311452	Powerdrill	34.99

# Relational Set Operators



# Relational Set Operators

FIGURE 3.5 PROJECT

**Original table**

P_CODE	P_DESCRIPT	PRICE
123456	Flashlight	5.26
123457	Lamp	25.15
123458	Box Fan	10.99
213345	9v battery	1.92
254467	100W bulb	1.47
311452	Powerdrill	34.99

**PROJECT PRICE yields**

**New table**

PRICE
5.26
25.15
10.99
1.92
1.47
34.99

**PROJECT P\_DESCRIPT and PRICE yields**

P_DESCRIPT	PRICE
Flashlight	5.26
Lamp	25.15
Box Fan	10.99
9v battery	1.92
100W bulb	1.47
Powerdrill	34.99

**PROJECT P\_CODE and PRICE yields**

P_CODE	PRICE
123456	5.26

# Relational Set Operators

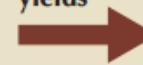
FIGURE 3.6 UNION

P_CODE	P_DESCRIPTION	PRICE
123456	Flashlight	5.26
123457	Lamp	25.15
123458	Box Fan	10.99
213345	9v battery	1.92
254467	100W bulb	1.47
311452	Powerdrill	34.99

UNION

P_CODE	P_DESCRIPTION	PRICE
345678	Microwave	160.00
345679	Dishwasher	500.00
123458	Box Fan	10.99

yields



P_CODE	P_DESCRIPTION	PRICE
123456	Flashlight	5.26
123457	Lamp	25.15
123458	Box Fan	10.99
213345	9v battery	1.92
254467	100W bulb	1.47
311452	Powerdrill	34.99
345678	Microwave	160
345679	Dishwasher	500

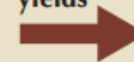
FIGURE 3.7 INTERSECT

STU_FNAME	STU_LNAME
George	Jones
Jane	Smith
Peter	Robinson
Franklin	Johnson
Martin	Lopez

INTERSECT

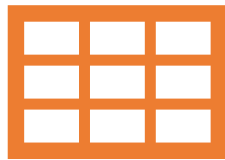
EMP_FNAME	EMP_LNAME
Franklin	Lopez
William	Turner
Franklin	Johnson
Susan	Rogers

yields



STU_FNAME	STU_LNAME
Franklin	Johnson

# Relational Set Operators



## Difference

Yields all rows in one table that are not found in the other table

Tables must be union-compatible to yield valid results



## Product

Yields all possible pairs of rows from two tables

# Relational Set Operators

FIGURE 3.8 DIFFERENCE

STU_FNAME	STU_LNAME	DIFFERENCE	EMP_FNAME	EMP_LNAME	yields	STU_FNAME	STU_LNAME
George	Jones		Franklin	Lopez		George	Jones
Jane	Smith		William	Turner		Jane	Smith
Peter	Robinson		Franklin	Johnson		Peter	Robinson
Franklin	Johnson		Susan	Rogers		Martin	Lopez
Martin	Lopez						

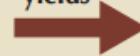
FIGURE 3.9 PRODUCT

P_CODE	P_DESCRIPTION	PRICE
123456	Flashlight	5.26
123457	Lamp	25.15
123458	Box Fan	10.99
213345	9v battery	1.92
254467	100W bulb	1.47
311452	Powerdrill	34.99

PRODUCT

STORE	AISE	SHELF
23	W	5
24	K	9
25	Z	6

yields



P_CODE	P_DESCRIPTION	PRICE	STORE	AISE	SHELF
123456	Flashlight	5.26	23	W	5
123456	Flashlight	5.26	24	K	9
123456	Flashlight	5.26	25	Z	6
123457	Lamp	25.15	23	W	5
123457	Lamp	25.15	24	K	9
123457	Lamp	25.15	25	Z	6
123458	Box Fan	10.99	23	W	5
123458	Box Fan	10.99	24	K	9
123458	Box Fan	10.99	25	Z	6
213345	9v battery	1.92	23	W	5
213345	9v battery	1.92	24	K	9
213345	9v battery	1.92	25	Z	6
311452	Powerdrill	34.99	23	W	5
311452	Powerdrill	34.99	24	K	9
311452	Powerdrill	34.99	25	Z	6
254467	100W bulb	1.47	23	W	5
254467	100W bulb	1.47	24	K	9
254467	100W bulb	1.47	25	Z	6

## Relational Set Operators

- Joins allow information to be intelligently combined from two or more tables
  - Natural join: links tables by selecting only the rows with common values in their common attribute
  - Equijoin: links tables on the basis of an equality condition that compares specified columns of each table
  - Theta join: links tables using an inequality comparison operator
  - Inner join: only returns matched records from the tables that are being joined
  - Outer join: matched pairs are retained and unmatched values in the other table are left null
    - Left outer join: yields all of the rows in the first table, including those that do not have a matching value in the second table
    - Right outer join: yields all of the rows in the second table, including those that do not have matching values in the first table

## Relational Set Operators

# Relational Set Operators

- Divide
  - Uses one double-column table as the dividend and one single-column table as the divisor
  - Output is a single column that contains all values from the second column of the dividend that are associated with every row in the divisor

**FIGURE 3.10 TWO TABLES THAT WILL BE USED IN JOIN ILLUSTRATIONS**

**Table name: CUSTOMER**

CUS_CODE	CUS_LNAME	CUS_ZIP	AGENT_CODE
1132445	Walker	32145	231
1217782	Adares	32145	125
1312243	Rakowski	34129	167
1321242	Rodriguez	37134	125
1542311	Smithson	37134	421
1657399	Vanloo	32145	231

**Table name: AGENT**

AGENT_CODE	AGENT_PHONE
125	6152439887
167	6153426778
231	6152431124
333	9041234445

## Relational Set Operators



# Relational Set Operators

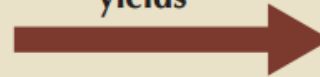
FIGURE 3.16 DIVIDE

P_CODE	CUS_CODE
123456	10400
123456	11501
123456	10030
123456	12550
234567	12350
234567	10040
234567	10900
234567	10030
234567	12550
345678	10400
345678	11530
345678	12550
456789	11530
567890	10900
567890	10030
567890	12550
678901	11500
678901	10400
678901	11530

**DIVIDE**

P_CODE
123456
234567
567890

yields



CUS_CODE
10030
12550

# Data Dictionary and the System Catalog



## Data dictionary

Description of all tables in the database created by the user and designer



## System catalog

System data dictionary that describes all objects within the database



## Homonyms and synonyms must be avoided to lessen confusion

Homonym: same name is used to label different attributes

Synonym: different names are used to describe the same attribute

# Relationships within the Relational Database

## One-to-many (1:M)

- Norm for relational databases

## One-to-one (1:1)

- One entity can be related to only one other entity and vice versa

## Many-to-many (M:N)

- Implemented by creating a new entity in 1:M relationships with the original entities
- Composite entity (i.e., bridge or associative entity): helps avoid problems inherent to M:N relationships
  - Includes the primary keys of tables to be linked

# Relationships within the Relational Database

FIGURE 3.21 THE 1:1 RELATIONSHIP BETWEEN PROFESSOR AND DEPARTMENT

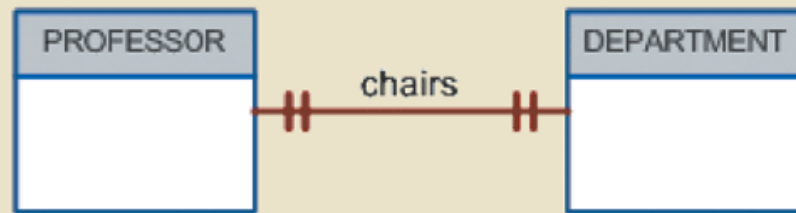
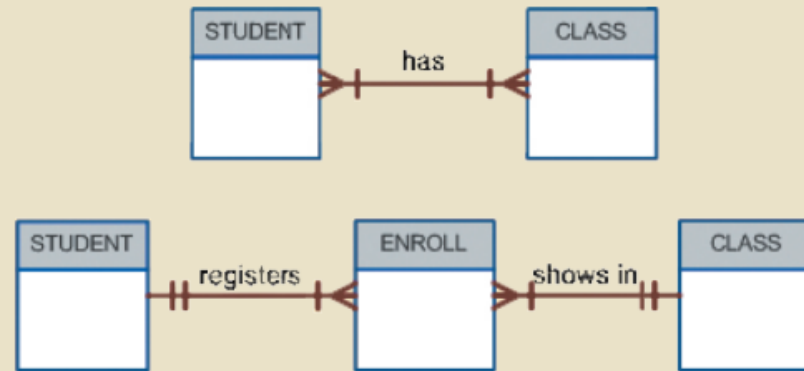


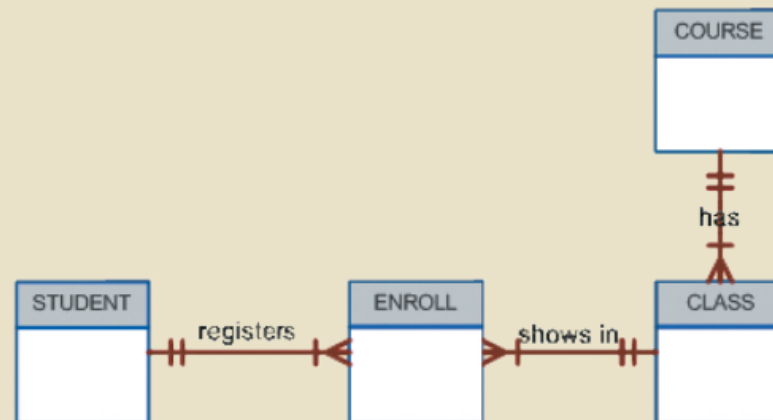
FIGURE 3.26 CHANGING THE M:N RELATIONSHIPS TO TWO 1:M RELATIONSHIPS



Relationships within the Relational Database

# Relationships within the Relational Database

FIGURE 3.27 THE EXPANDED ER MODEL



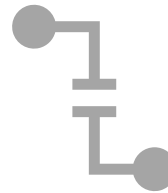
# Data Redundancy Revisited

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**The relational database facilitates control of data redundancies through use of foreign keys**

Common attributes that are shared by tables



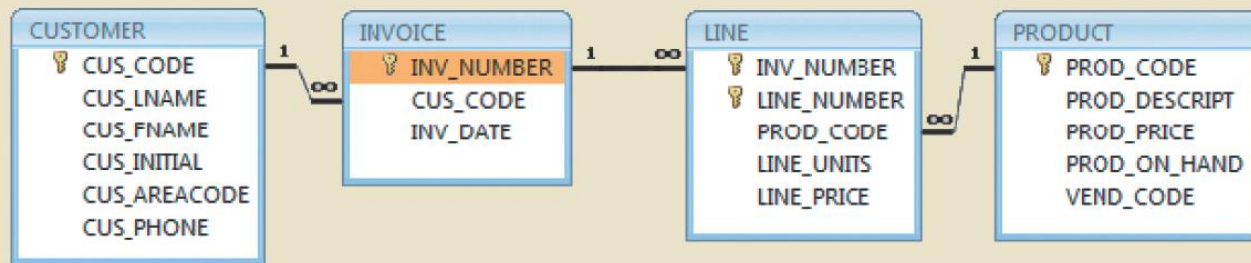
**To be controlled except the following circumstances:**

Sometimes data redundancy must be increased to make the database serve crucial information purposes

Sometimes data redundancy exists to preserve the historical accuracy of data

# Data Redundancy Revisited

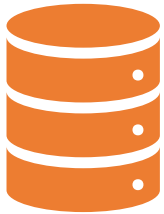
FIGURE 3.30 THE RELATIONAL DIAGRAM FOR THE INVOICING SYSTEM





# Indexes

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## **Orderly arrangement to logically access rows in a table**

Index key: index's reference point that leads to data location identified by the key

Unique index: index key can have only one pointer value associated with it



## **Each index is associated with only one table**

The index key can have multiple attributes

# Codd's Relational Database Rules

TABLE 13.8 DR. CODD'S 12 RELATIONAL DATABASE RULES

Rule	Rule Name	Description
1	Information	All information in a relational database must be logically represented as column values in rows within tables.
2	Guaranteed access	Every value in a table is guaranteed to be accessible through a combination of table name, primary key value, and column name.
3	Systematic treatment of nulls	Nulls must be represented and treated in a systematic way, independent of data type.
4	Dynamic online catalog based on the relational model	The metadata must be stored and managed as ordinary data—that is, in tables within the database; such data must be available to authorized users using the standard database relational language.
5	Comprehensive data sublanguage	The relational database may support many languages; however, it must support one well-defined, declarative language as well as data definition, view definition, data manipulation (interactive and by program), integrity constraints, authorization, and transaction management (begin, commit, and rollback).
6	View updating	Any view that is theoretically updatable must be updatable through the system.
7	High-level insert, update, and delete	The database must support set-level inserts, updates, and deletes.

# Codd's Relational Database Rules

Table 13.8	Dr. Codd's 12 Relational Database Rules	
Rule	Rule Name	Description
8	Physical data independence	Application programs and ad hoc facilities are logically unaffected when physical access methods or storage structures are changed.
9	Logical data independence	Application programs and ad hoc facilities are logically unaffected when changes are made to the table structures that preserve the original table values (changing order of columns or inserting columns).
10	Integrity independence	All relational integrity constraints must be definable in the relational language and stored in the system catalog, not at the application level.
11	Distribution independence	The end users and application programs are unaware of and unaffected by the data location (distributed vs. local databases).
12	Nonsubversion	If the system supports low-level access to the data, users must not be allowed to bypass the integrity rules of the database.
13	Rule zero	All preceding rules are based on the notion that to be considered relational, a database must use its relational facilities exclusively for management.

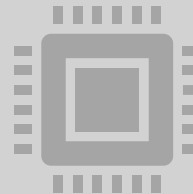
# Summary



## **Tables are the basic building blocks of a relational database**

Keys are central to the use of relational tables

- Each table row must have a primary key
- Although tables are independent, they can be linked by common attributes



## **The relational model supports several relational algebra functions**

A relational database performs much of the data manipulation work behind the scenes

Once you know the basics of relational databases, you can concentrate on design

# References

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