DATABASE MANAGEMENT SYSTEM

Basic Definitions

- **Database:**
  - A logical coherent collection of data representing the mini-world such that change in the mini-world brings about change in database collected for a particular purpose and for a group of intended users.
- **Data:**
  - Meaningful facts, text, graphics, images, sound, video segments that can be recorded and have an implicit meaning.
- **Metadata:**
  - Data that describes data
- **File Processing System**
  - A collection of application programs that perform services for the end-users such as production of reports
  - Each program defines and manages its own data
- **Database Management System (DBMS):**
  - A software package/ system to facilitate the creation and maintenance of a computerized database.
- **Database System:**
  - The DBMS software together with the data itself. Sometimes, the applications are also included. Database + DBMS

Simplified database system environment

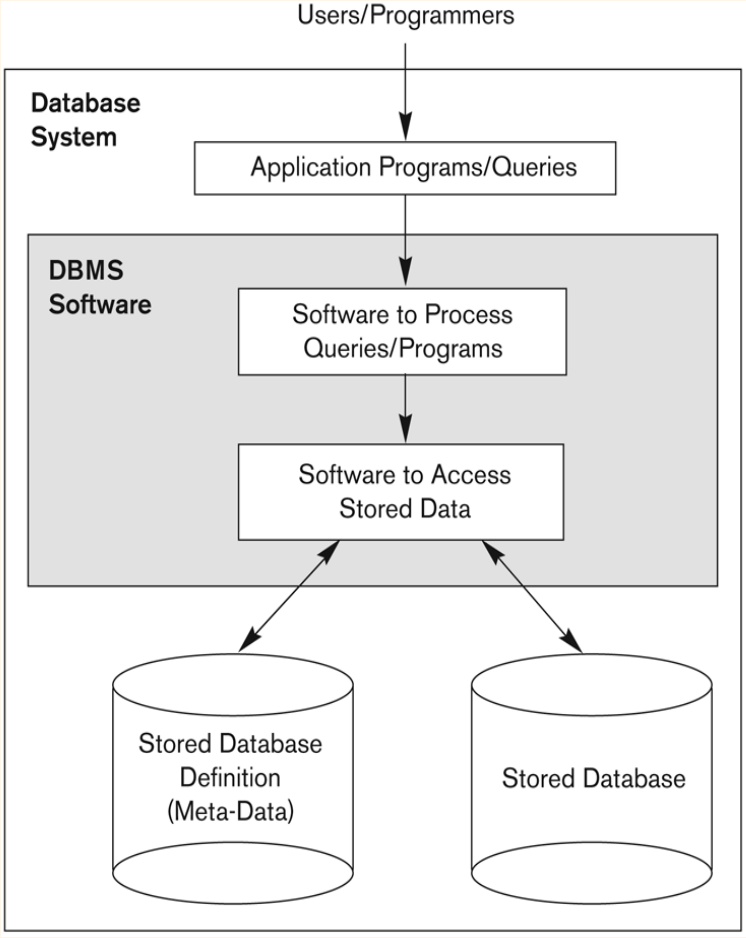


Figure 1.1
A simplified database system environment.

Evolution of DB Systems

- Flat files - 1960s - 1980s
- Hierarchical – 1970s - 1990s
- Network – 1970s - 1990s
- Relational – 1980s - present
- Object-oriented – 1990s - present
- Object-relational – 1990s - present
- Data warehousing – 1980s - present
- Web-enabled – 1990s - present

Purpose of Database Systems

Database management systems were developed to handle the difficulties of typical file-processing systems supported by conventional operating systems

Disadvantages of File Processing

- **Program-Data Dependence**
  - **File structure is defined in the program code.**
  - **All programs maintain metadata for each file they use**
- **Duplication of Data (Data Redundancy)**
  - **Different systems/programs have separate copies of the same data**
  - **Same data is held by different programs.**
  - **Wasted space and potentially different values and/or different formats for the same item.**
- **Limited Data Sharing**
  - **No centralized control of data**
  - **Programs are written in different languages, and so cannot easily access each other's files.**
- **Lengthy Development Times**
  - **Programmers must design their own file formats**
- **Excessive Program Maintenance**
  - **80% of of information systems budget**
- **Vulnerable to Inconsistency**
  - **Change in one table need changes in corresponding tables as well otherwise data will be inconsistent**

Advantages of Database Approach

- Data independence and efficient access.
- Data integrity and security.
- Uniform data administration.
- Concurrent access, recovery from crashes.
- Replication control
- Reduced application development time.
- Improved Data Sharing
  - Different users get different views of the data
- Enforcement of Standards
  - All data access is done in the same way
- Improved Data Quality
  - Constraints, data validation rules
- Better Data Accessibility/ Responsiveness
  - Use of standard data query language (SQL)
- Security, Backup/Recovery, Concurrency
  - Disaster recovery is easier

Costs and Risks of the Database Approach

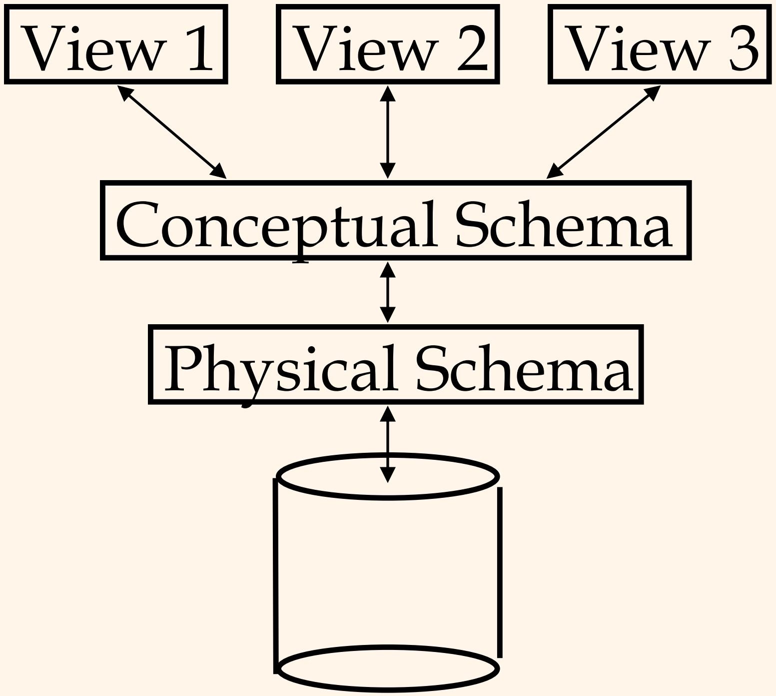
- Up-front costs:
  - Installation Management Cost and Complexity
  - Conversion Costs
- Ongoing Costs
  - Requires New, Specialized Personnel
  - Need for Explicit Backup and Recovery
- Organizational Conflict
  - Old habits die hard

Database Applications

- Database Applications:
  - Banking: all transactions
  - Airlines: reservations, schedules
  - Universities: registration, grades
  - Sales: customers, products, purchases
  - Manufacturing: production, inventory, orders, supply chain
  - Human resources: employee records, salaries, tax deductions
- Databases touch all aspects of our lives

Levels of Abstraction

- Many *views*, single *conceptual (logical) schema* and *physical schema*.
  - Views describe how users see the data.
  - Conceptual schema defines logical structure
  - Physical schema describes the files and indexes used.



☛ *Schemas are defined using DDL; data is modified/queried using DML.*

Example: University Database

- Conceptual schema:
  - *Students(sid: string, name: string, login: string, age: integer, gpa:real)*
  - *Courses(cid: string, cname:string, credits:integer)*
  - *Enrolled(sid:string, cid:string, grade:string)*
- Physical schema:
  - Relations stored as unordered files.
  - Index on first column of Students.
- External Schema (View):
  - *Course_info(<u>cid:string</u>, enrollment:integer)*

Instances and Schemas

- Similar to types and variables in programming languages
- Schema – the logical structure of the database (e.g., set of customers and accounts and the relationship between them)
- Instance – the actual content of the database at a particular point in time

Data Independence

- Ability to modify a schema definition in one level without affecting a schema definition in the other levels.
- The interfaces between the various levels and components should be well defined so that changes in some parts do not seriously influence others.
- Two levels of data independence
  - Physical data independence:- Protection from changes in *logical* structure of data.
  - Logical data independence:- Protection from changes in physical structure of data.

Instances and Schemas

- Similar to types and variables in programming languages
- **Schema** – the logical structure of the database
  - e.g., the database consists of information about a set of customers and accounts and the relationship between them)
  - Analogous to type information of a variable in a program
  - **Physical schema**: database design at the physical level
  - **Logical schema**: database design at the logical level
- **Instance** – the actual content of the database at a particular point in time
  - Analogous to the value of a variable
- **Physical Data Independence** – the ability to modify the physical schema without changing the logical schema
  - Applications depend on the logical schema
  - In general, the interfaces between the various levels and components should be well defined so that changes in some parts do not seriously influence others.

Database Languages

Data Definition Language (DDL)

- Specification notation for defining the database schema
- DDL compiler generates a set of tables stored in a data dictionary
- Data dictionary contains ***metadata*** (data about data)
- Data storage and definition language – special type of DDL in which the storage structure and access methods used by the database system are specified

Data Manipulation Language (DML)

- Language for accessing and manipulating the data organized by the appropriate data model
- Two classes of languages
  - Procedural – user specifies what data is required and how to get those data
  - Nonprocedural – user specifies what data is required without specifying how to get those data

Database Users

- Users are differentiated by the way they expect to interact with the system
- Application programmers – interact with system through DML calls
- Sophisticated users – form requests in a database query language
- Specialized users – write specialized database applications that do not fit into the traditional data processing framework
- Naïve users – invoke one of the permanent application programs that have been written previously
  - E.g. people accessing database over the web, bank tellers, clerical staff

Database Administrator

- Coordinates all the activities of the database system; the database administrator has a good understanding of the enterprise's information resources and needs.
- Database administrator's duties include:
  - Schema definition
  - Storage structure and access method definition
  - Schema and physical organization modification
  - Granting user authority to access the database
  - Specifying integrity constraints
  - Acting as liaison with users
  - Monitoring performance and responding to changes in requirements

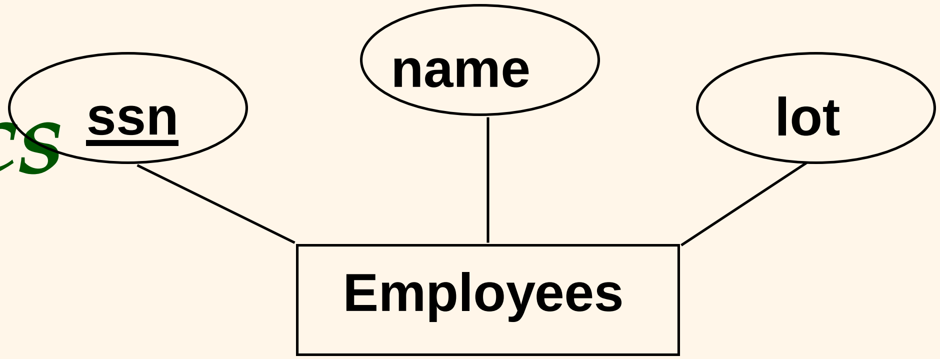
Data Models

- A collection of tools for describing:
  - Data
  - Data relationships
  - Data semantics
  - Data constraints
- Object-based logical models
  - Entity-relationship model
  - Object-oriented model
  - Semantic model
  - Functional model
- Record-based logical models
  - Relational model (e.g., SQL/DS, DB2)
  - Network model
  - Hierarchical model (e.g., IMS)

Entity-Relationship Model

- The basics of Entity-Relationship modelling
  - Entities (objects)
    - E.g. customers, accounts, bank branch
  - Attributes
  - Relationships between entities
    - E.g. Account A-101 is held by customer Johnson
    - Relationship set *depositor* associates customers with accounts
- Widely used for database design
  - Database design in E-R model usually converted to design in the relational model which is used for storage and processing

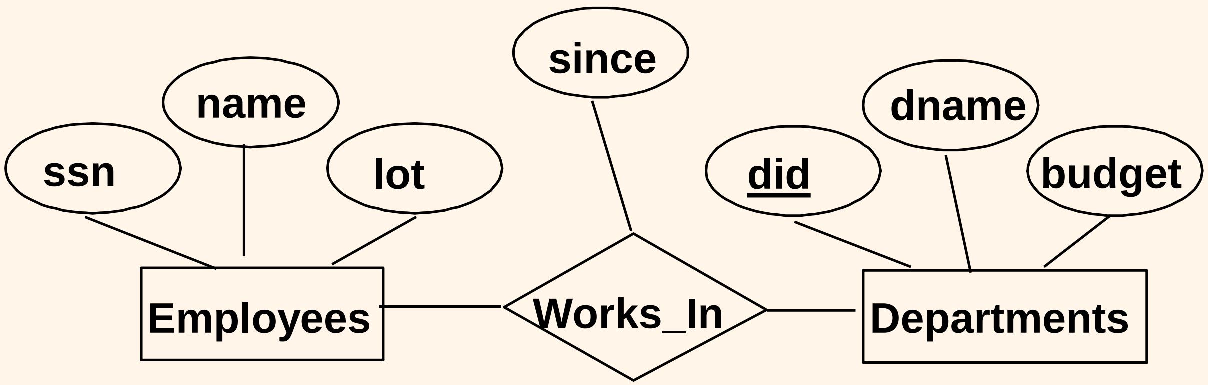
ER Model Basics

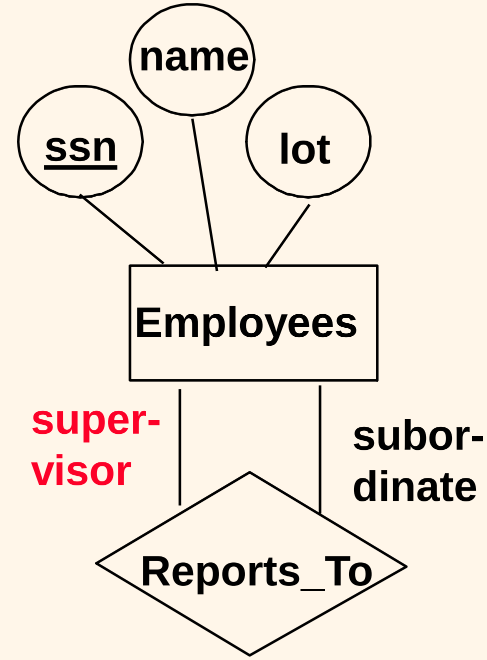


- *Entity:* Real-world object distinguishable from other objects. An entity is described using a set of *attributes*. Each attribute has a *domain*.
- *Entity Set*: A collection of similar entities. E.g., all employees.
  - All entities in an entity set have the same set of attributes. (Until we consider ISA hierarchies, anyway!)
  - Each entity set has a *key*.

  Weak Entities: A *weak entity* can be identified uniquely only by considering the primary key of another (*owner*) entity.

ER Model Basics

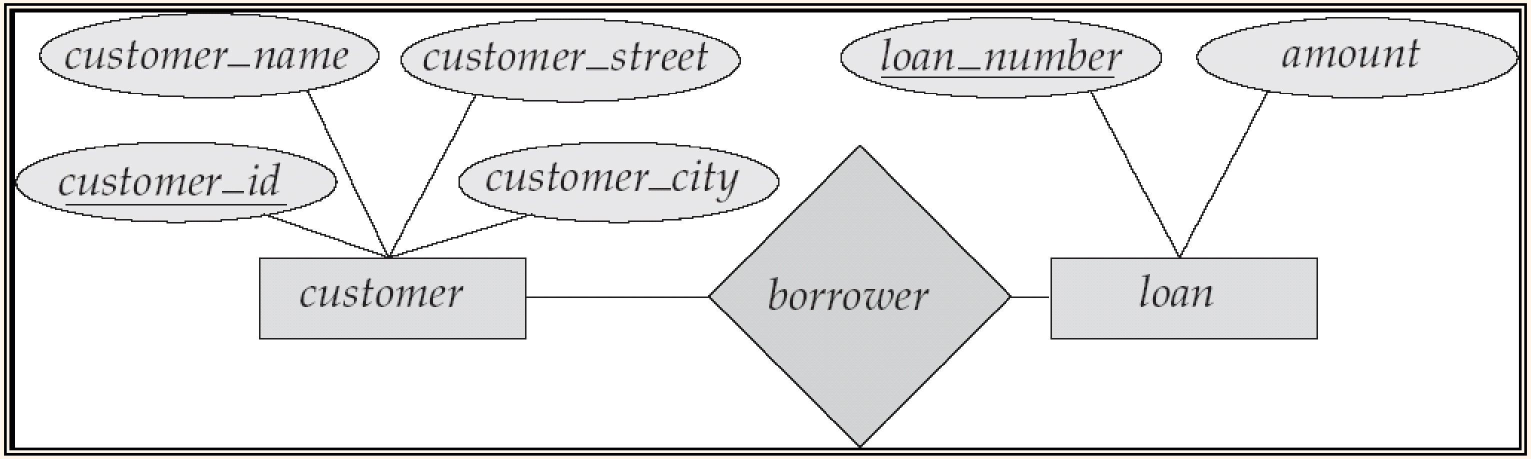




- *Relationship*: Association among two or more entities. E.g., Attishoo works in Pharmacy department.

- *Relationship Set*: Collection of similar relationships.
  - An n-ary relationship set R relates n entity sets E1 ... En; each relationship in R involves entities e1 E1, ..., en En
  - Same entity set could participate in different relationship sets, or in different "roles" in same set.

E-R Diagrams

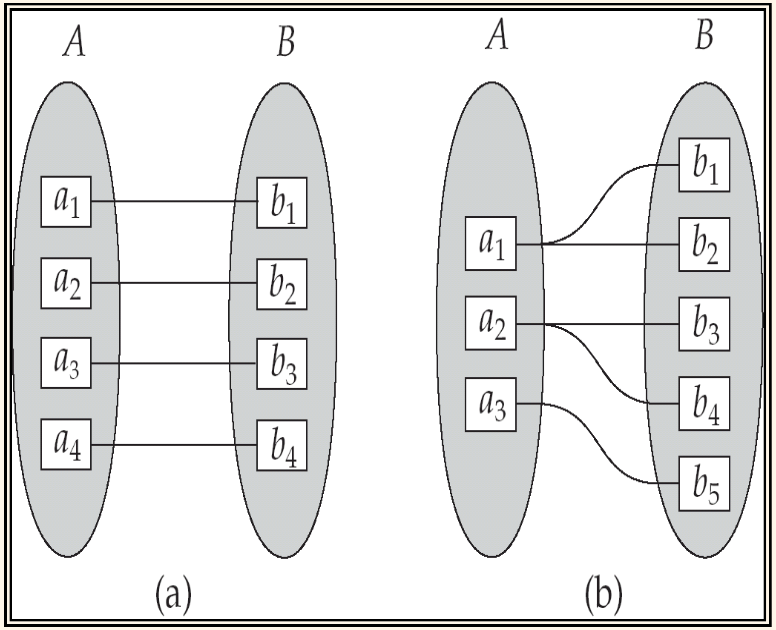


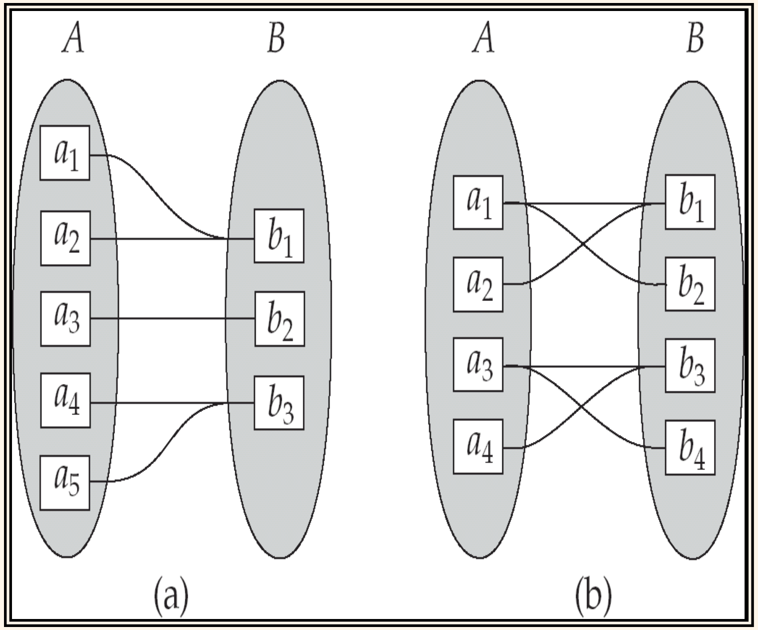
- Rectangles represent entity sets.
- Diamonds represent relationship sets.
- Lines link attributes to entity sets and entity sets to relationship sets.
- Ellipses represent attributes
  - Double ellipses represent multivalued attributes.
  - Dashed ellipses denote derived attributes.
- Underline indicates primary key attributes (will study later)

Mapping Cardinality Constraints

- Express the number of entities to which another entity can be associated via a relationship set.
- Most useful in describing binary relationship sets.
- For a binary relationship set the mapping cardinality must be one of the following types:
  - One to one
  - One to many
  - Many to one
  - Many to many

Mapping Cardinalities

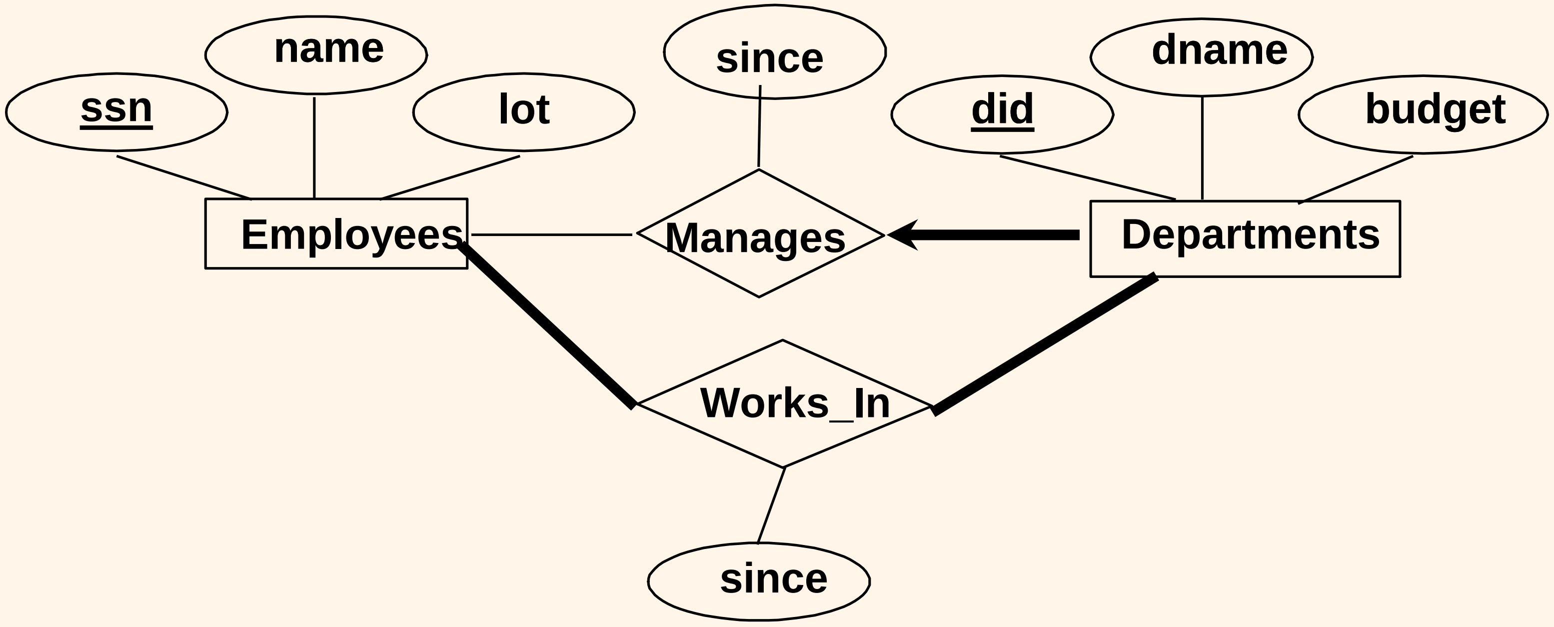




One to one One to many Many to one Many to many

Participation Constraints

- Does every department have a manager?
  - If so, this is a *participation constraint*: the participation of Departments in Manages is said to be *total* (vs. *partial*).
- Every Department entity must appear in an instance of the relationship Works_In (have an employee) and every Employee must be in a Department
- Both Employees and Departments participate totally in Works_In



Keys

- A **super key** of an entity set is a set of one or more attributes whose values uniquely determine each entity.
- A **candidate key** of an entity set is a minimal super key
  - *Customer_id* is candidate key of *customer*
  - *account_number* is candidate key of *account*
- Although several candidate keys may exist, one of the candidate keys is selected to be the **primary key**.
- Alternate key **is t**he candidate key which are not selected as primary key.
- Foreign key are the attributes of an entity that points to the primary key of another entity. They act as a cross-reference between entities.
- Composite Key consists of two or more attributes that uniquely identify an entity.
  Non-key attributes are the attributes or fields of a table, other than candidate key attributes/fields in a table.
- Non-prime Attributes are attributes other than Primary Key attribute(s)..

Relational Model

Example of tabular data in the relational model:

name	ssn	street	city	account-number
Johnson	192-83-7465	Alma	Palo Alto	A-101
Smith	019-28-3746	North	Rye	A-215
Johnson	192-83-7465	Alma	Palo Alto	A-201
Jones	321-12-3123	Main	Harrison	A-217
Smith	019-28-3746	North	Rye	A-201

account-number	balance
A-101	500
A-201	900
A-215	700
A-217	750

Relational Model (Basic)

The **relational model** used the basic **concept** of a relation or table.

Tuple:- A tuple is a row in a table.

Attribute:- An attribute is the named column of a relation.

Domain:- A domain is the set of allowable values for one or more attributes.

Degree:- The number of columns in a table is called the degree of relation.

Cardinality:- The number of rows in a relation,is called the cardinality of the relation.

Integrity Constraints

Integrity constraints guard against accidental damage to the database, by ensuring that authorized changes

to the database do not result in a loss of data consistency.

- Domain Constraints:- It specifies that the value of each attribute x must be an atomic value from the domain of x.
- Key Constraints:- Primary Key must have unique value in the relational table.
- Referential Integrity:-It states that if a foreign key in table A refers to the primary key of table B then, every value of the foreign key in table A must be null or be available in table B.
- Entity Integrity:- It states that no attribute of a primary key can have a null value.

A Sample Relational Database

customer-id	*customer-name*	*customer-street*	*customer-city*
192-83-7465	Johnson	12 Alma St.	Palo Alto
019-28-3746	Smith	4 North St.	Rye
677-89-9011	Hayes	3 Main St.	Harrison
182-73-6091	Turner	123 Putnam Ave.	Stamford
321-12-3123	Jones	100 Main St.	Harrison
336-66-9999	Lindsay	175 Park Ave.	Pittsfield
019-28-3746	Smith	72 North St.	Rye

(a) The *customer* table

account-number	*balance*
A-101	500
A-215	700
A-102	400
A-305	350
A-201	900
A-217	750
A-222	700

(b) The *account* table

customer-id	*account-number*
192-83-7465	A-101
192-83-7465	A-201
019-28-3746	A-215
677-89-9011	A-102
182-73-6091	A-305
321-12-3123	A-217
336-66-9999	A-222
019-28-3746	A-201

(c) The *depositor* table

SQL Introduction

Standard language for querying and manipulating data

Structured **Q**uery **L**anguage

Many standards out there:

- ANSI SQL, SQL92 (a.k.a. SQL2), SQL99 (a.k.a. SQL3), ….
- Vendors support various subsets: watch for fun discussions in class !

SQL

- Data Definition Language (DDL)
  - Create/alter/delete tables and their attributes
  - Following lectures...
- Data Manipulation Language (DML)
  - Query one or more tables – discussed next !
  - Insert/delete/modify tuples in tables

Tables in SQL

Table name

Attribute names

Product

PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

Tuples or rows

Tables Explained

- The *schema* of a table is the table name and its attributes:

Product(PName, Price, Category, Manfacturer)

- A *key* is an attribute whose values are unique; we underline a key

Product(PName, Price, Category, Manfacturer)

Data Types in SQL

- Atomic types:
  - Characters: CHAR(20), VARCHAR(50)
  - Numbers: INT, BIGINT, SMALLINT, FLOAT
  - Others: MONEY, DATETIME, …
- Every attribute must have an atomic type
  - Hence tables are flat
  - Why ?

Tables Explained

- A tuple = a record
  - Restriction: all attributes are of atomic type
- A table = a set of tuples
  - Like a list…
  - …but it is unorderd:
    no **first()**, no **next()**, no **last()**.

SQL Query

Basic form: (plus many many more bells and whistles)

```
SELECT  <attributes>
FROM    <one or more relations>
WHERE   <conditions>
```

Simple SQL Query

Product

PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

```
SELECT   *
FROM     Product
WHERE    category='Gadgets'
```

PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks

"selection"

Simple SQL Query

Product

PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

```
SELECT   PName, Price, Manufacturer
FROM     Product
WHERE    Price > 100
```

PName	Price	Manufacturer
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

"selection" and "projection"

Notation

Input Schema

Product(PName, Price, Category, Manfacturer)

```
SELECT   PName, Price, Manufacturer
FROM     Product
WHERE    Price > 100
```

Answer(PName, Price, Manfacturer)

Output Schema

Keys and Foreign Keys

Company

<u>CName</u>	StockPrice	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

Key

Product

<u>PName</u>	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

Foreign key

Joins

Product (pname, price, category, manufacturer)
Company (cname, stockPrice, country)

Find all products under $200 manufactured in Japan;
return their names and prices.

Join between Product and Company

```
SELECT   PName, Price
FROM     Product, Company
WHERE    Manufacturer=CName AND Country='Japan'
         AND Price <= 200
```

Joins

Product

PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

Company

Cname	StockPrice	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

```
SELECT   PName, Price
FROM     Product, Company
WHERE    Manufacturer=CName AND Country='Japan'
         AND Price <= 200
```

PName	Price
SingleTouch	$149.99

More Joins

Product (pname, price, category, manufacturer)
Company (cname, stockPrice, country)

Find all Chinese companies that manufacture products both in the ‘electronic’ and ‘toy’ categories

```
SELECT   cname

FROM

WHERE
```

NULLS in SQL

- Whenever we don’t have a value, we can put a NULL
- Can mean many things:
  - Value does not exists
  - Value exists but is unknown
  - Value not applicable
  - Etc.
- The schema specifies for each attribute if can be null (*nullable* attribute) or not
- How does SQL cope with tables that have NULLs ?

Outer Joins

- Left outer join:
  - Include the left tuple even if there's no match
- Right outer join:
  - Include the right tuple even if there's no match
- Full outer join:
  - Include the both left and right tuples even if there's no match

Modifying the Database

Three kinds of modifications

- Insertions
- Deletions
- Updates

Sometimes they are all called "updates"

Insertions

General form:

```
INSERT   INTO   R(A1,…., An)   VALUES  (v1,…., vn)
```

Example: Insert a new purchase to the database:

```
INSERT  INTO  Purchase(buyer, seller, product, store)
        VALUES  (‘Joe’, ‘Fred’, ‘wakeup-clock-espresso-machine’,
                 ‘The Sharper Image’)
```

Missing attribute → NULL.

May drop attribute names if give them in order.

Insertions

```
INSERT   INTO   PRODUCT(name)

    SELECT  DISTINCT  Purchase.product
    FROM      Purchase
    WHERE    Purchase.date > "10/26/01"
```

The query replaces the VALUES keyword.
Here we insert *many* tuples into PRODUCT

Insertion: an Example

Product(<u>name</u>, listPrice, category)
Purchase(prodName, buyerName, price)

prodName is foreign key in Product.name

Suppose database got corrupted and we need to fix it:

Product

name	listPrice	category
gizmo	100	gadgets

Purchase

prodName	buyerName	price
camera	John	200
gizmo	Smith	80
camera	Smith	225

Task: insert in Product all prodNames from Purchase

Insertion: an Example

```
INSERT INTO Product(name)

SELECT DISTINCT prodName
FROM Purchase
WHERE prodName NOT IN (SELECT name FROM Product)
```

name	listPrice	category
gizmo	100	Gadgets
camera	-	-

Insertion: an Example

```
INSERT   INTO   Product(name, listPrice)

 SELECT  DISTINCT  prodName, price
 FROM  Purchase
 WHERE   prodName  NOT IN (SELECT  name FROM  Product)
```

name	listPrice	category
gizmo	100	Gadgets
camera	200	-
camera ??	225 ??	-

← Depends on the implementation

Deletions

Example:

```
DELETE   FROM   PURCHASE

WHERE    seller = 'Joe'   AND
         product = 'Brooklyn Bridge'
```

Factoid about SQL: there is no way to delete only a single occurrence of a tuple that appears twice in a relation.

Updates

Example:

```
UPDATE   PRODUCT
SET    price = price/2
WHERE  Product.name  IN
                   (SELECT product
                    FROM    Purchase
                    WHERE  Date ='Oct, 25, 1999');
```