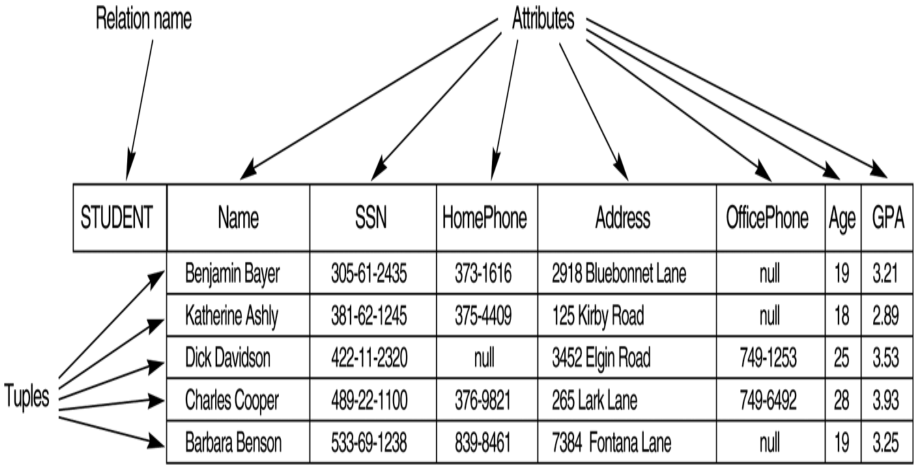
The Relational Model

- database consists of several tables (relations)
- columns in each table are named by attributes
- each attribute has an associated domain (set of allowed values)
- data in each table consists of a set of rows (tuples) providing values for the attributes

Example



STUDENT	Name	SSN	HomePhone	Address	OfficePhone	Age	GPA
	Benjamin Bayer	305-61-2435	373-1616	2918 Bluebonnet Lane	null	19	3.21
	Katherine Ashly	381-62-1245	375-4409	125 Kirby Road	null	18	2.89
	Dick Davidson	422-11-2320	null	3452 Elgin Road	749-1253	25	3.53
	Charles Cooper	489-22-1100	376-9821	265 Lark Lane	749-6492	28	3.93
	Barbara Benson	533-69-1238	839-8461	7384 Fontana Lane	null	19	3.25

Relation Schema

"type declaration"

- Relation name
- Set of attributes
- Domain of each attribute
- Integrity constraints

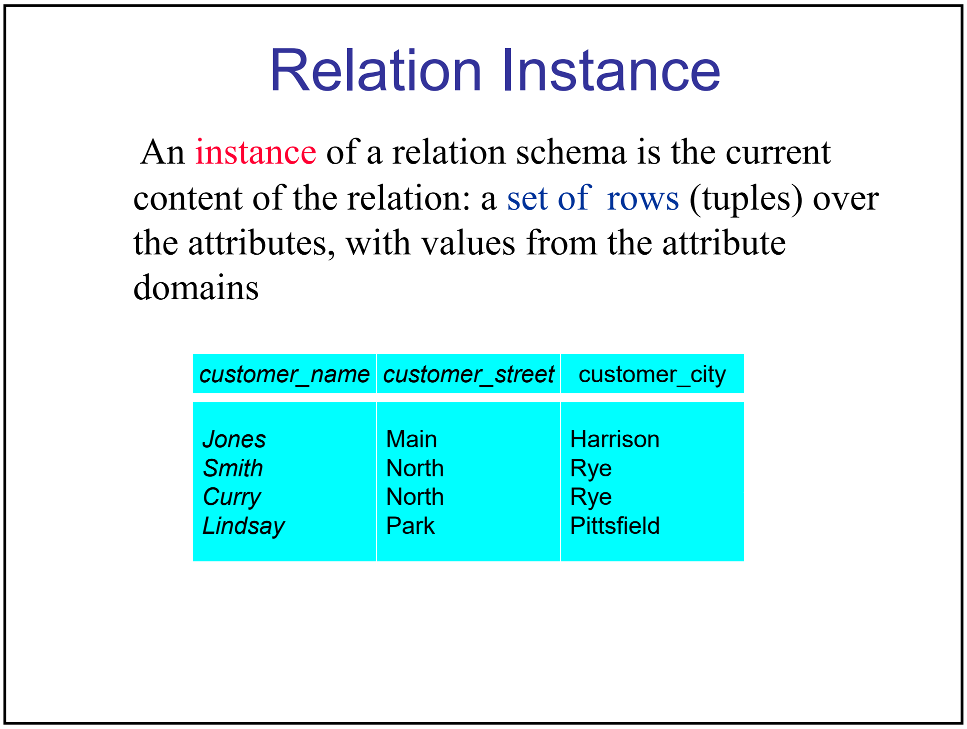
Example

CUSTOMER (Cust-id, Cust-name, Address, Phone#)

integer char strings 7-digits

Attribute Types

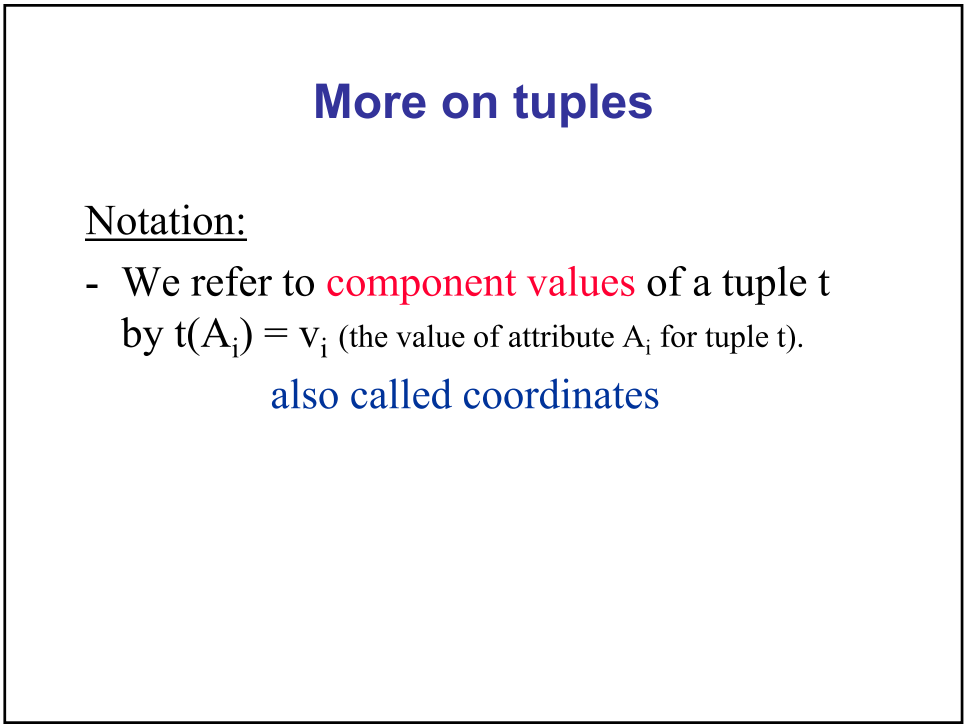
- Each attribute of a relation has a name
- The set of allowed values for each attribute is called the **domain** of the attribute
- Attribute values are (normally) required to be **atomic**; that is, indivisible
- Sometimes, the special value ***null*** is considered a member of every domain



Relation Instance

An instance of a relation schema is the current content of the relation: a set of rows (tuples) over the attributes, with values from the attribute domains

customer_name	*customer_street*	customer_city
Jones	Main	Harrison
Smith	North	Rye
Curry	North	Rye
Lindsay	Park	Pittsfield

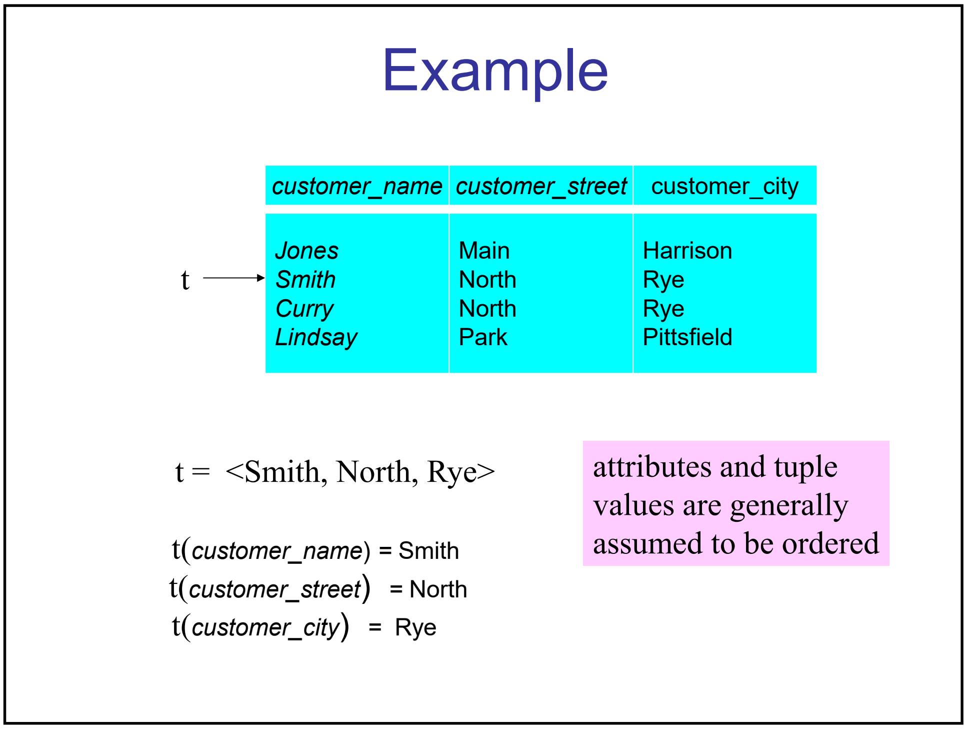


More on tuples

Notation:

- We refer to component values of a tuple t by $t(A_i) = v_i$ (the value of attribute A_i for tuple t).

also called coordinates



Example

	customer_name	*customer_street*	customer_city
	Jones	Main	Harrison
t →	*Smith*	North	Rye
	Curry	North	Rye
	Lindsay	Park	Pittsfield

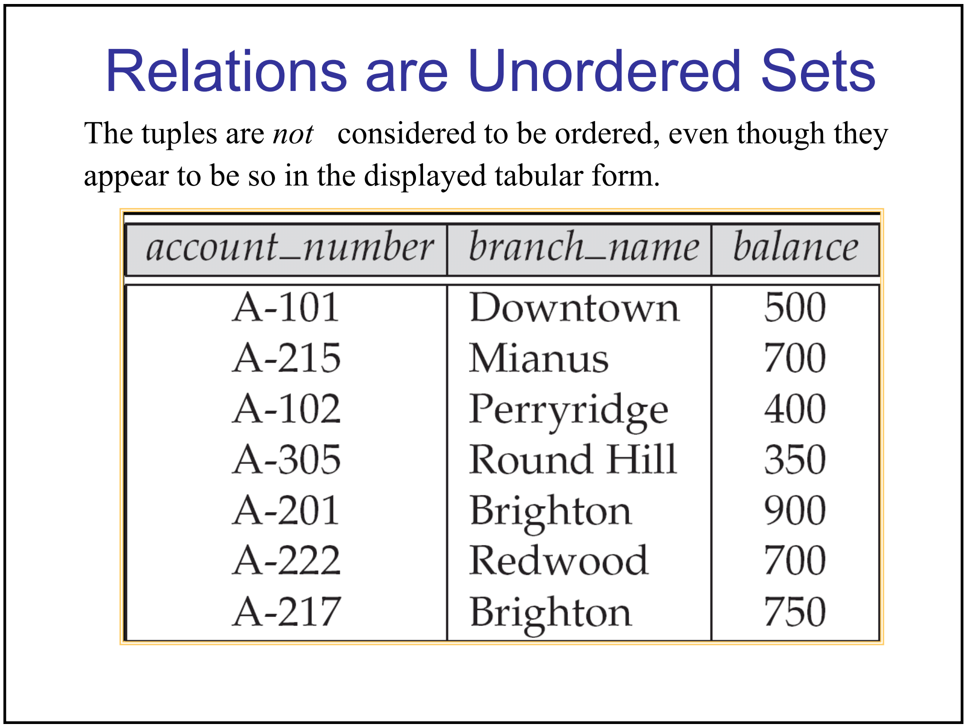
t = <Smith, North, Rye>

t(*customer_name*) = Smith

t(*customer_street*) = North

t(*customer_city*) = Rye

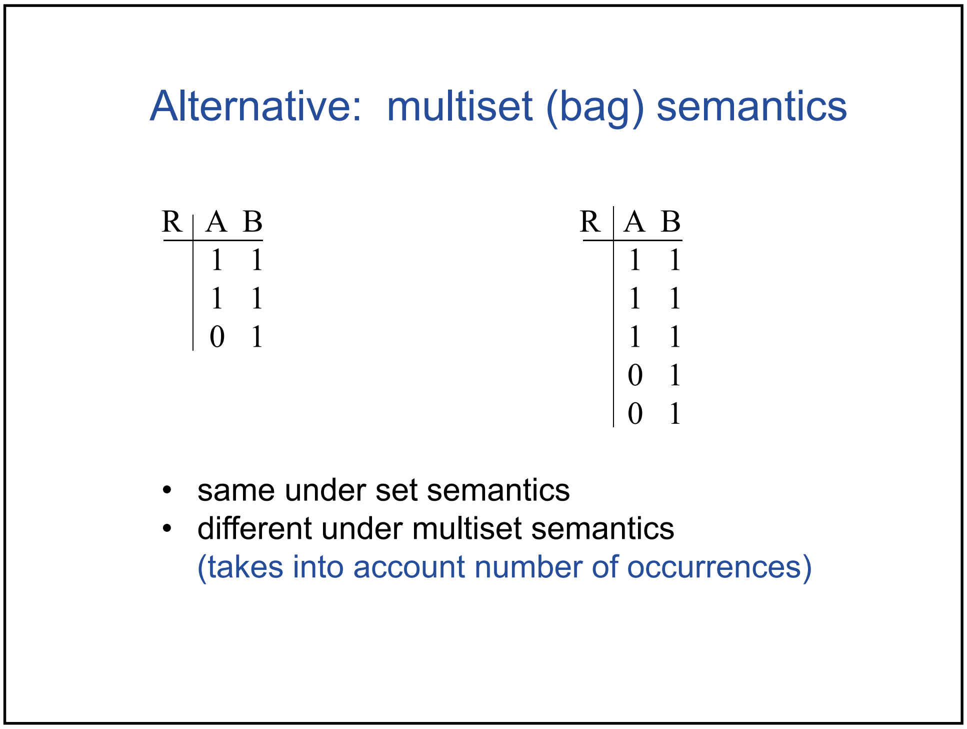
attributes and tuple values are generally assumed to be ordered



Relations are Unordered Sets

The tuples are *not* considered to be ordered, even though they appear to be so in the displayed tabular form.

account_number	*branch_name*	*balance*
A-101	Downtown	500
A-215	Mianus	700
A-102	Perryridge	400
A-305	Round Hill	350
A-201	Brighton	900
A-222	Redwood	700
A-217	Brighton	750

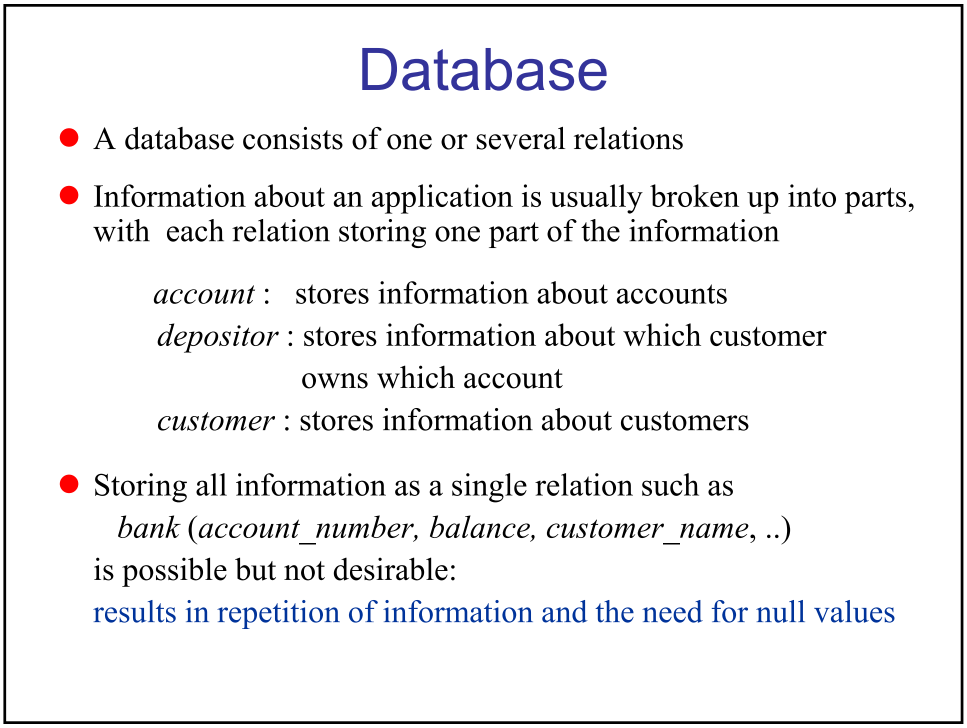


Alternative: multiset (bag) semantics

R	A	B
	1	1
	1	1
	0	1

R	A	B
	1	1
	1	1
	1	1
	0	1
	0	1

- same under set semantics
- different under multiset semantics (takes into account number of occurrences)



Database

- A database consists of one or several relations
- Information about an application is usually broken up into parts, with each relation storing one part of the information

  account : stores information about accounts
  depositor : stores information about which customer owns which account
  customer : stores information about customers

- Storing all information as a single relation such as
  bank (*account_number, balance, customer_name*, ..)
  is possible but not desirable:
  results in repetition of information and the need for null values

Relational Integrity Constraints

- Constraints are *conditions* that must hold on *all* valid relation instances of a database
- Some common types of constraints:
  1. **Key** constraints
  2. **Entity integrity** constraints
  3. **Referential integrity** constraints

Key Constraints

- **Superkey** of R: A set of attributes SK of R such that no two tuples *in any valid relation instance r(R)* will have the same value for SK. That is, for all distinct tuples t1 and t2 in r(R), t1(SK) ≠ t2(SK).
- **Key** of R: A "minimal" superkey; that is, a superkey K such that removal of any attribute from K results in a set of attributes that is not a superkey.

  Example: The CAR relation schema:

  CAR(State, Reg#, SerialNo, Make, Model, Year)

  has two keys Key1 = {State, Reg#}, Key2 = {SerialNo}.

  {SerialNo, Make} is a superkey but *not* a key.
- If a relation has *several* **candidate keys**, one is chosen to be the **primary key**.

Key Constraints

CAR	LicenseNumber	EngineSerialNumber	Make	Model	Year
	Texas ABC-739	A69352	Ford	Mustang	96
	Florida TVP-347	B43696	Oldsmobile	Cutlass	99
	New York MPO-22	X83554	Oldsmobile	Delta	95
	California 432-TFY	C43742	Mercedes	190-D	93
	California RSK-629	Y82935	Toyota	Camry	98
	Texas RSK-629	U028365	Jaguar	XJS	98

The primary key attributes are *underlined*.

EMPLOYEE

FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO

DEPARTMENT

DNAME	DNUMBER	MGRSSN	MGRSTARTDATE

DEPT_LOCATIONS

DNUMBER	DLOCATION

PROJECT

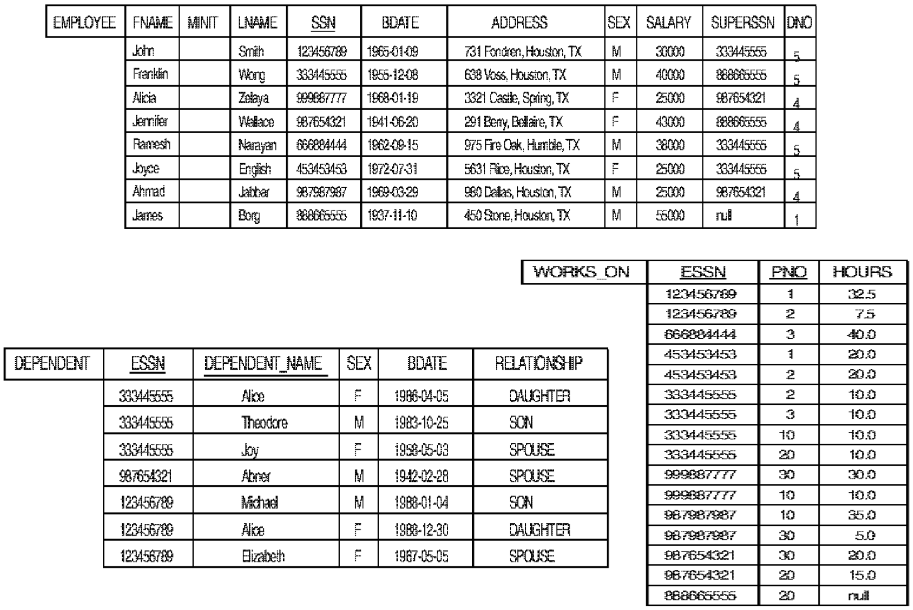
PNAME	PNUMBER	PLOCATION	DNUM

WORKS_ON

ESSN	PNO	HOURS

DEPENDENT

ESSN	DEPENDENT_NAME	SEX	BDATE	RELATIONSHIP



EMPLOYEE	FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO
	John		Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
	Franklin		Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
	Alicia		Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
	Jennifer		Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
	Ramesh		Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
	Joyce		English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
	Ahmad		Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
	James		Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	null	1

WORKS_ON	ESSN	PNO	HOURS
	123456789	1	32.5
	123456789	2	7.5
	666884444	3	40.0
	453453453	1	20.0
	453453453	2	20.0
	333445555	2	10.0
	333445555	3	10.0
	333445555	10	10.0
	333445555	20	10.0
	999887777	30	30.0
	999887777	10	10.0
	987987987	10	35.0
	987987987	30	5.0
	987654321	30	20.0
	987654321	20	15.0
	888665555	20	null

DEPENDENT	ESSN	DEPENDENT_NAME	SEX	BDATE	RELATIONSHIP
	333445555	Alice	F	1986-04-05	DAUGHTER
	333445555	Theodore	M	1983-10-25	SON
	333445555	Joy	F	1958-05-03	SPOUSE
	987654321	Abner	M	1942-02-28	SPOUSE
	123456789	Michael	M	1988-01-04	SON
	123456789	Alice	F	1988-12-30	DAUGHTER
	123456789	Elizabeth	F	1967-05-05	SPOUSE

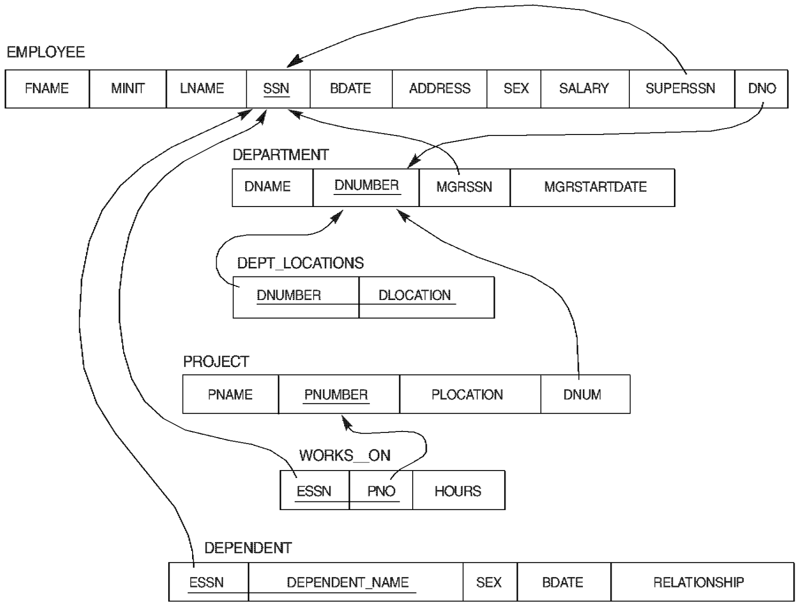
Entity Integrity

- The *primary key attributes* PK of each relation schema R in S cannot have null values in any tuple. This is because PK values are used to *identify* the individual tuples.

t(A) ≠ null for every tuple t in
a valid instance of R, where A is in PK

Note: Other attributes of R may be similarly constrained to disallow null values, even though they are not members of the primary key.

Referential Integrity



EMPLOYEE

FNAME | MINIT | LNAME | SSN | BDATE | ADDRESS | SEX | SALARY | SUPERSSN | DNO

DEPARTMENT

DNAME | DNUMBER | MGRSSN | MGRSTARTDATE

DEPT_LOCATIONS

DNUMBER | DLOCATION

PROJECT

PNAME | PNUMBER | PLOCATION | DNUM

WORKS_ON

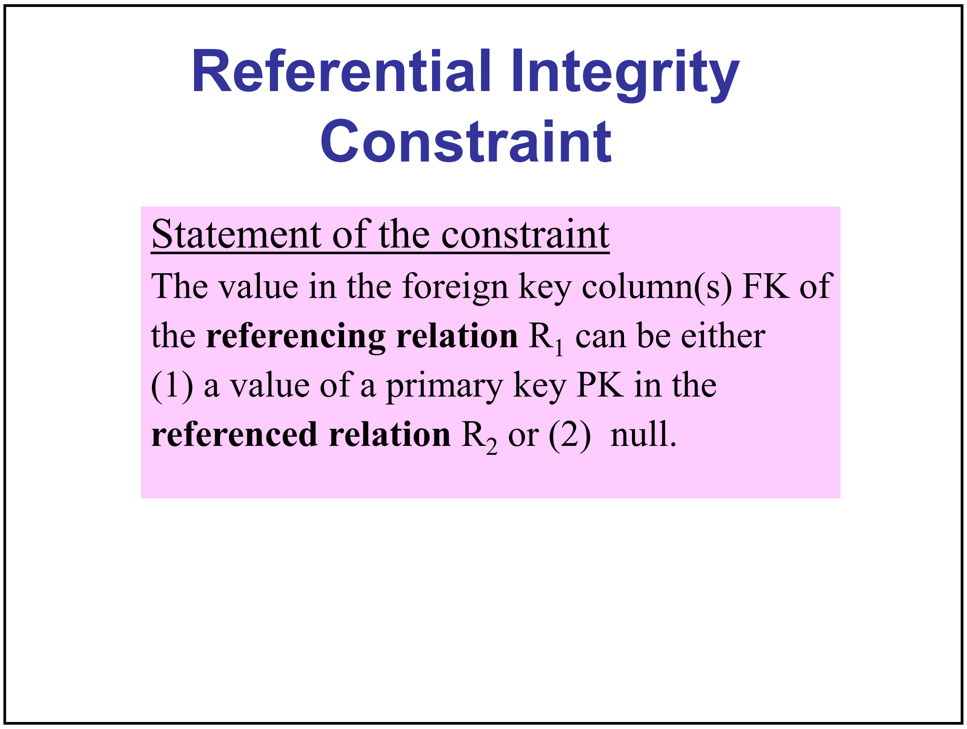
ESSN | PNO | HOURS

DEPENDENT

ESSN | DEPENDENT_NAME | SEX | BDATE | RELATIONSHIP

Referential Integrity

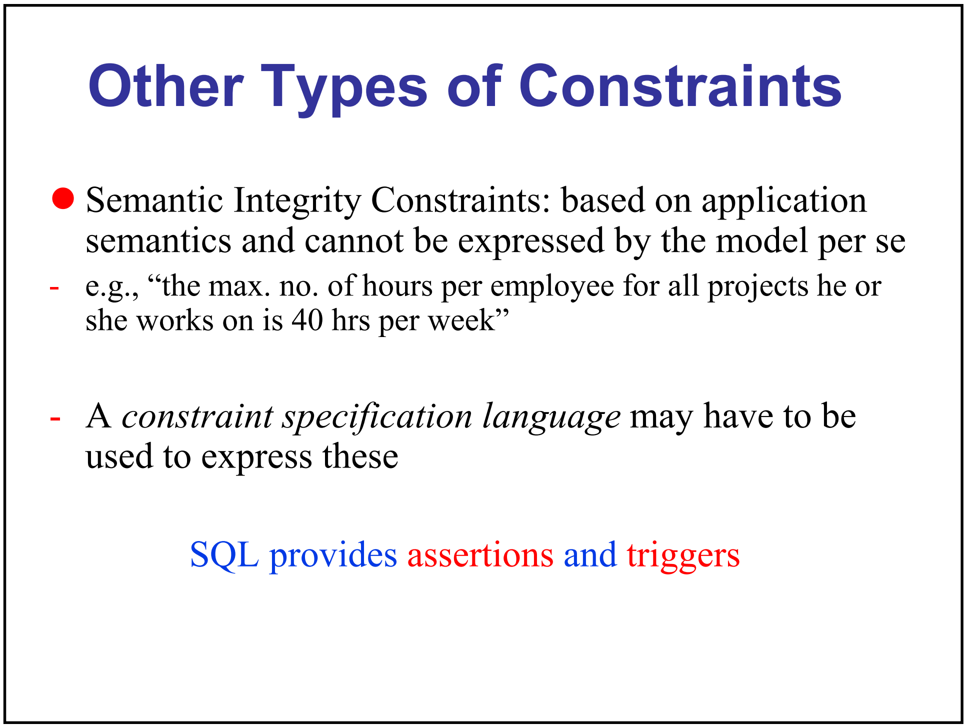
- A constraint involving *two* relations of the database (the previous constraints involve a *single* relation).
- Used to specify a *relationship* among tuples in two relations: the **referencing relation** and the **referenced relation**.
- Tuples in the *referencing relation* R_1 have attributes FK (called **foreign key** attributes) that reference the primary key attributes PK of the *referenced relation* R_2. A tuple t_1 in R_1 is said to **reference** a tuple t_2 in R_2 if $t_1(FK) = t_2(PK)$.
- A referential integrity constraint can be displayed in a relational database schema as a directed arc from R_1.FK to R_2.PK.



Referential Integrity Constraint

Statement of the constraint

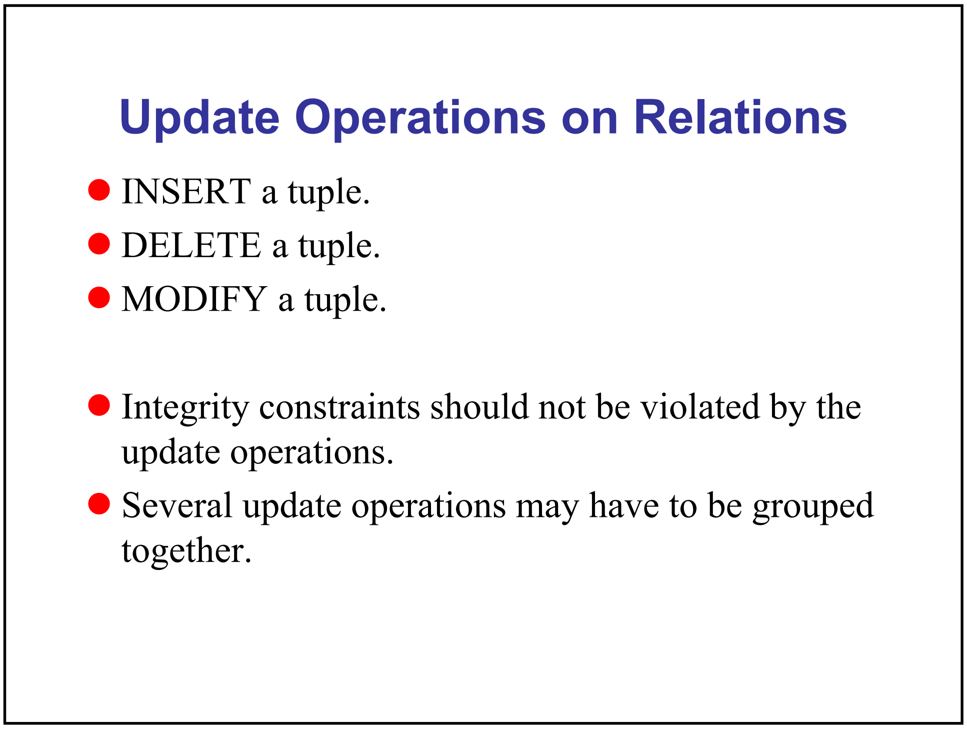
The value in the foreign key column(s) FK of the **referencing relation** R_1 can be either (1) a value of a primary key PK in the **referenced relation** R_2 or (2) null.



Other Types of Constraints

- Semantic Integrity Constraints: based on application semantics and cannot be expressed by the model per se
  - e.g., “the max. no. of hours per employee for all projects he or she works on is 40 hrs per week”
  - A *constraint specification language* may have to be used to express these

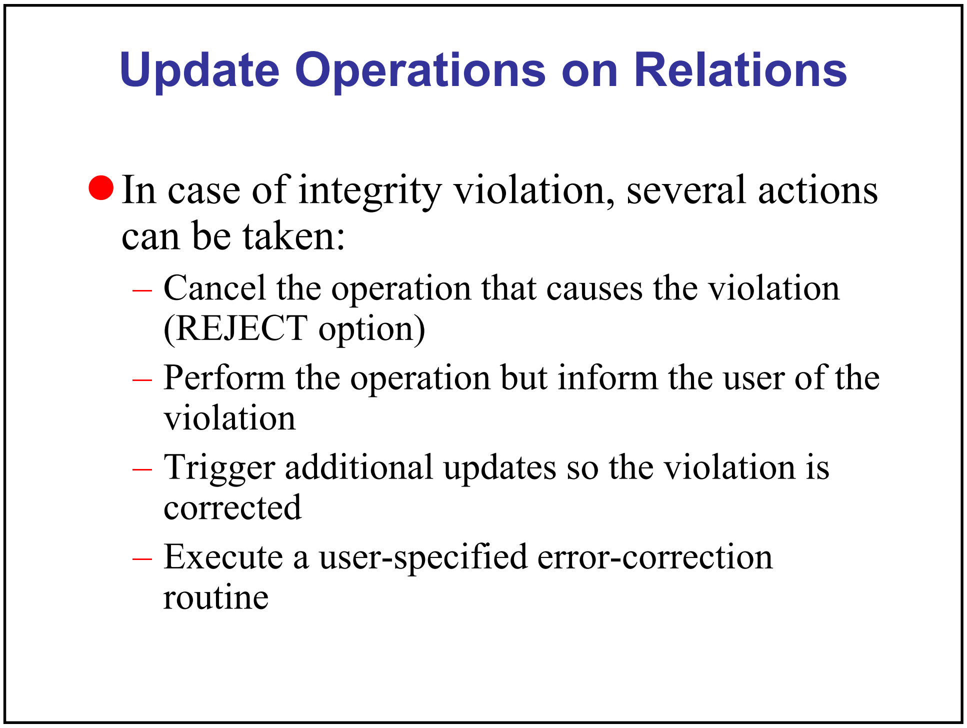
SQL provides assertions and triggers



Update Operations on Relations

- INSERT a tuple.
- DELETE a tuple.
- MODIFY a tuple.

- Integrity constraints should not be violated by the update operations.
- Several update operations may have to be grouped together.



Update Operations on Relations

- In case of integrity violation, several actions can be taken:
  - Cancel the operation that causes the violation (REJECT option)
  - Perform the operation but inform the user of the violation
  - Trigger additional updates so the violation is corrected
  - Execute a user-specified error-correction routine

SQL
"Structured Query Language"

- Standard for relational db systems
- History:

  Developed at IBM in late 70s

  First standard: SQL-86

  Second standard: SQL-92

  Third standard: SQL-99 or SQL3, well over 1000 pages!

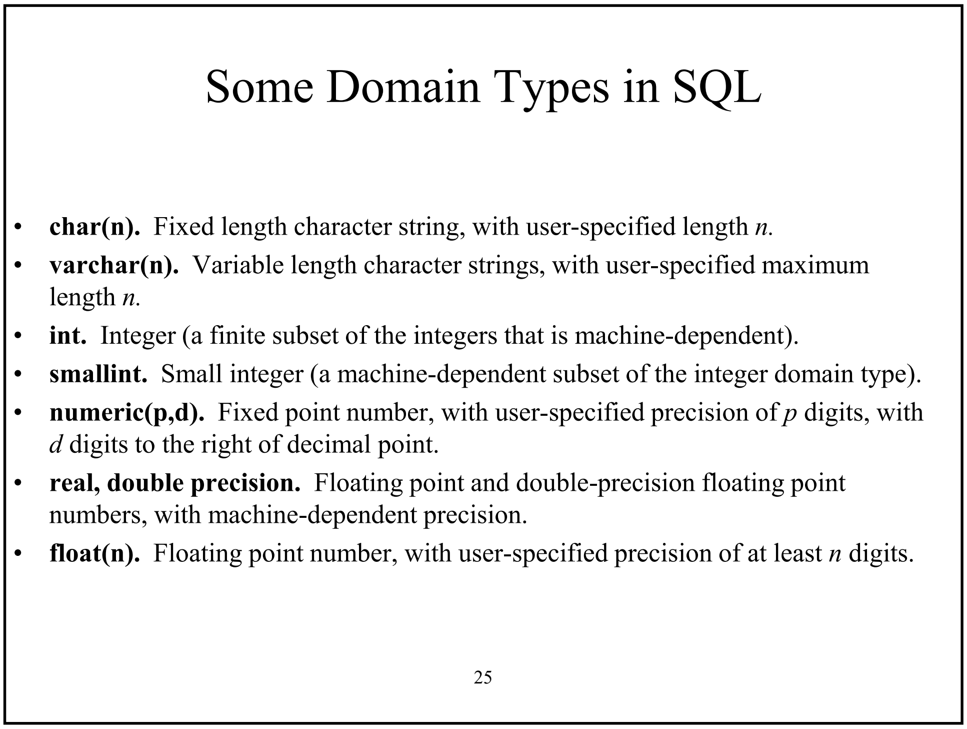
  Many more ….

  "The nice things about standards is that you have so many to choose from" -- Andres S. Tannenbaum

SQL Data Definition Language

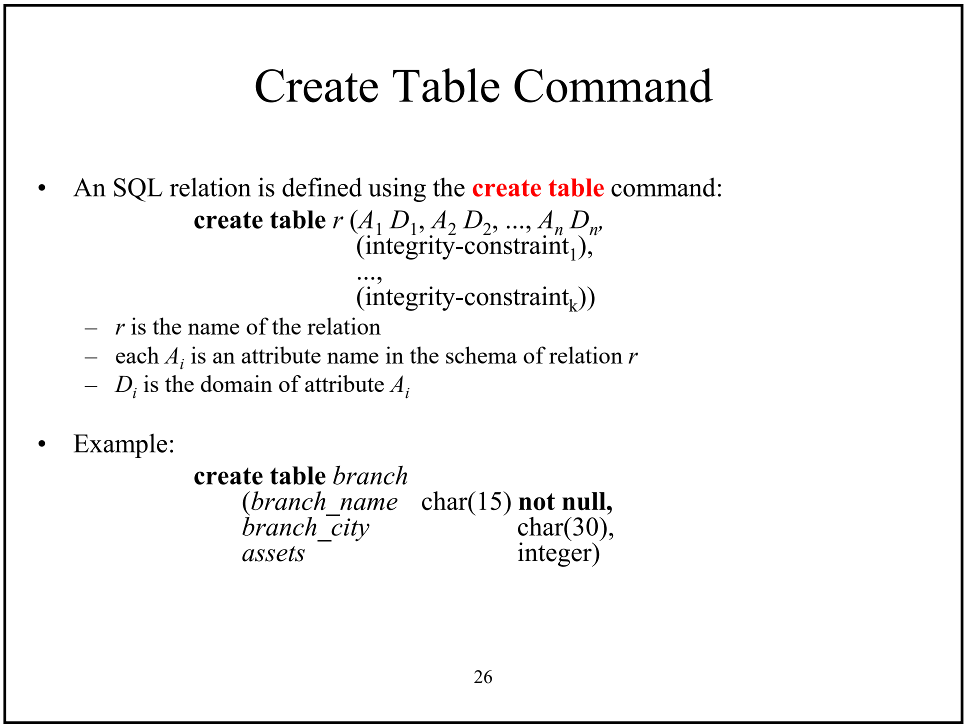
Allows the specification of the database schema

- The name and attributes for each relation.
- The domain of values associated with each attribute.
- Integrity constraints
- The set of indices to be maintained for each relations.
- Security and authorization information for each relation.
- The physical storage structure of each relation on disk.



Some Domain Types in SQL

- **char(n).** Fixed length character string, with user-specified length *n.*
- **varchar(n).** Variable length character strings, with user-specified maximum length *n.*
- **int.** Integer (a finite subset of the integers that is machine-dependent).
- **smallint.** Small integer (a machine-dependent subset of the integer domain type).
- **numeric(p,d).** Fixed point number, with user-specified precision of *p* digits, with *d* digits to the right of decimal point.
- **real, double precision.** Floating point and double-precision floating point numbers, with machine-dependent precision.
- **float(n).** Floating point number, with user-specified precision of at least *n* digits.



Create Table Command

- An SQL relation is defined using the **create table** command:

  create table r (A_1 D_1, A_2 D_2, ..., A_n D_n,
  (integrity-constraint$_1$),
  ...,
  (integrity-constraint$_k$))

  – r is the name of the relation
  – each A_i is an attribute name in the schema of relation r
  – D_i is the domain of attribute A_i

- Example:

  create table *branch*
  (*branch_name* char(15) **not null,**
  branch_city char(30),
  assets integer)

Create Table (cont.)

- Can use the CREATE TABLE command for specifying the primary key attributes, secondary keys, and referential integrity constraints (foreign keys).
- Key attributes can be specified via the PRIMARY KEY and UNIQUE keywords

```
CREATE TABLE   DEPT
(     DNAME                VARCHAR(10)       NOT NULL,
      DNUMBER                        INTEGER             NOT NULL,
      MGRSSN               CHAR(9),
      MGRSTARTDATE         CHAR(9),
      PRIMARY KEY          (DNUMBER),
      UNIQUE               (DNAME),
      FOREIGN KEY          (MGRSSN) REFERENCES EMP  );
```

primary key declaration on an attribute automatically ensures **not null** in SQL-92 onwards, needs to be explicitly stated in SQL-89

The check clause

- **check** (*P*), where *P* is a predicate on attribute values

Declare *branch_name* as the primary key for *branch* and ensure that the values of *assets* are non-negative.

```
create table branch
        (branch_name      char(15),
         branch_city      char(30),
         assets           integer,
         primary key      (branch_name),
         CHECK            (assets >= 0) )
```

Drop Table Command

- Used to remove a relation *and its definition*
- The relation can no longer be used in queries, updates, or any other commands since its description no longer exists
- Example:

  DROP TABLE DEPENDENT;

Alter Table Command

- The **alter table** command is used to add attributes to an existing relation: **alter table** *r* **add** *A D*

  where *A* is the name of the attribute to be added to relation *r* and *D* is the domain of *A*.

  All tuples in the relation are assigned *null* as the default value for the new attribute.
- The **alter table** command can also be used to drop attributes of a relation: **alter table** *r* **drop** *A*

  where *A* is the name of an attribute of relation *r*

  Many databases do not support dropping of attributes

Alter Table (cont.)

- Since new attribute will have NULL values right after the **ALTER** command is executed, the NOT NULL constraint is *not allowed* for such an attribute
- <u>Example:</u>

  ```
  ALTER TABLE  EMPLOYEE
  ADD   JOB   VARCHAR(12);
  ```
- The database users must still enter a value for the new attribute JOB for each EMPLOYEE tuple. This can be done using the UPDATE command.