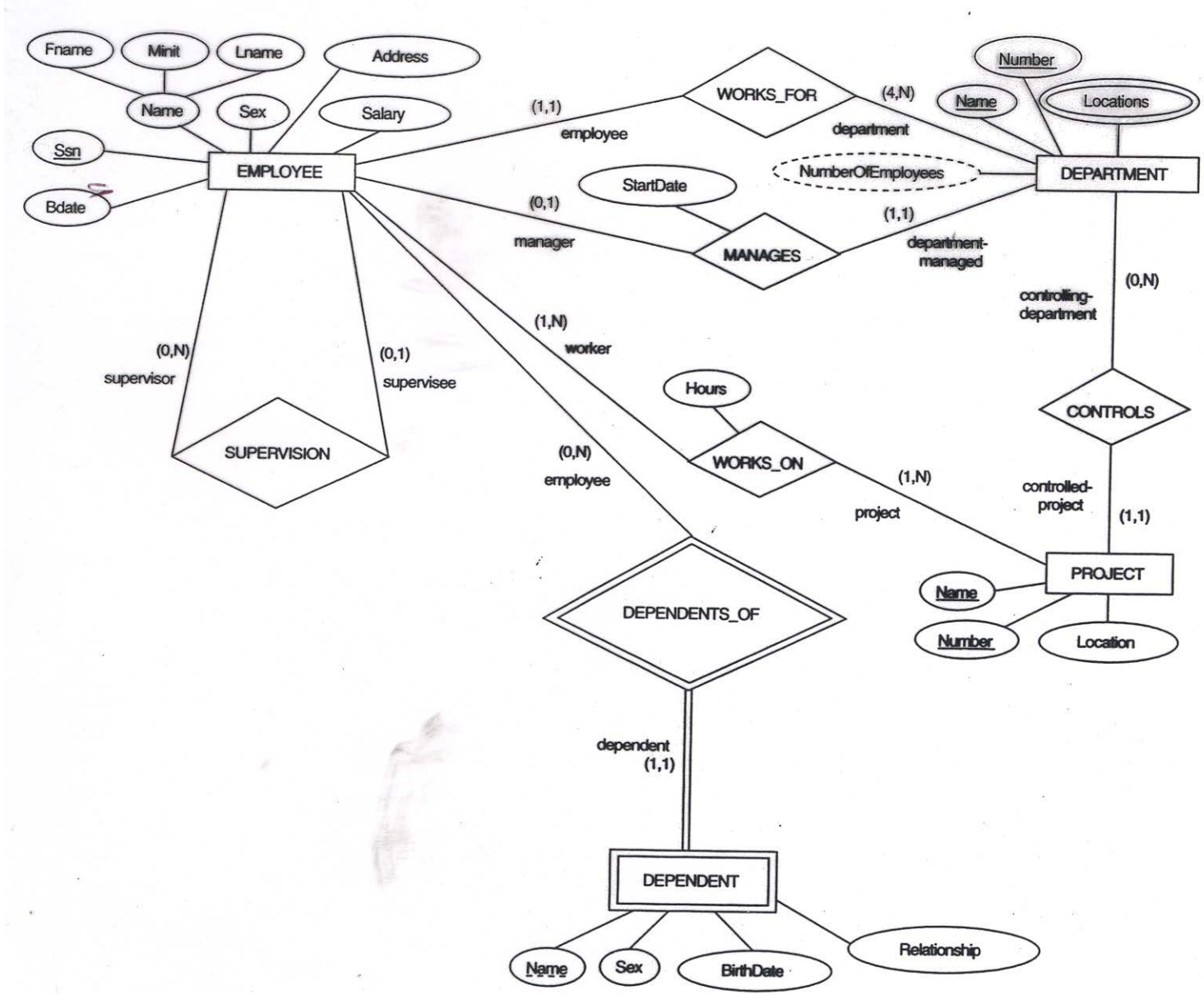
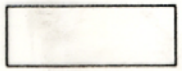
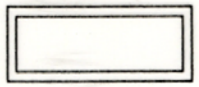
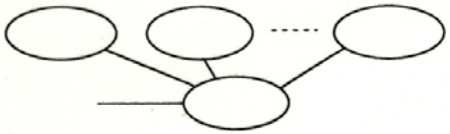
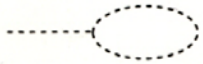
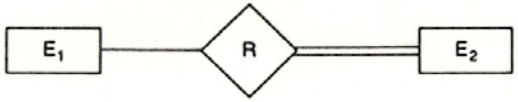
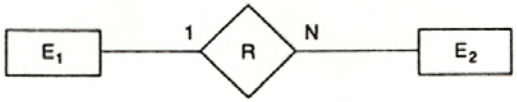
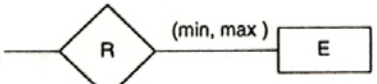
(1) Entity-Relationship Model

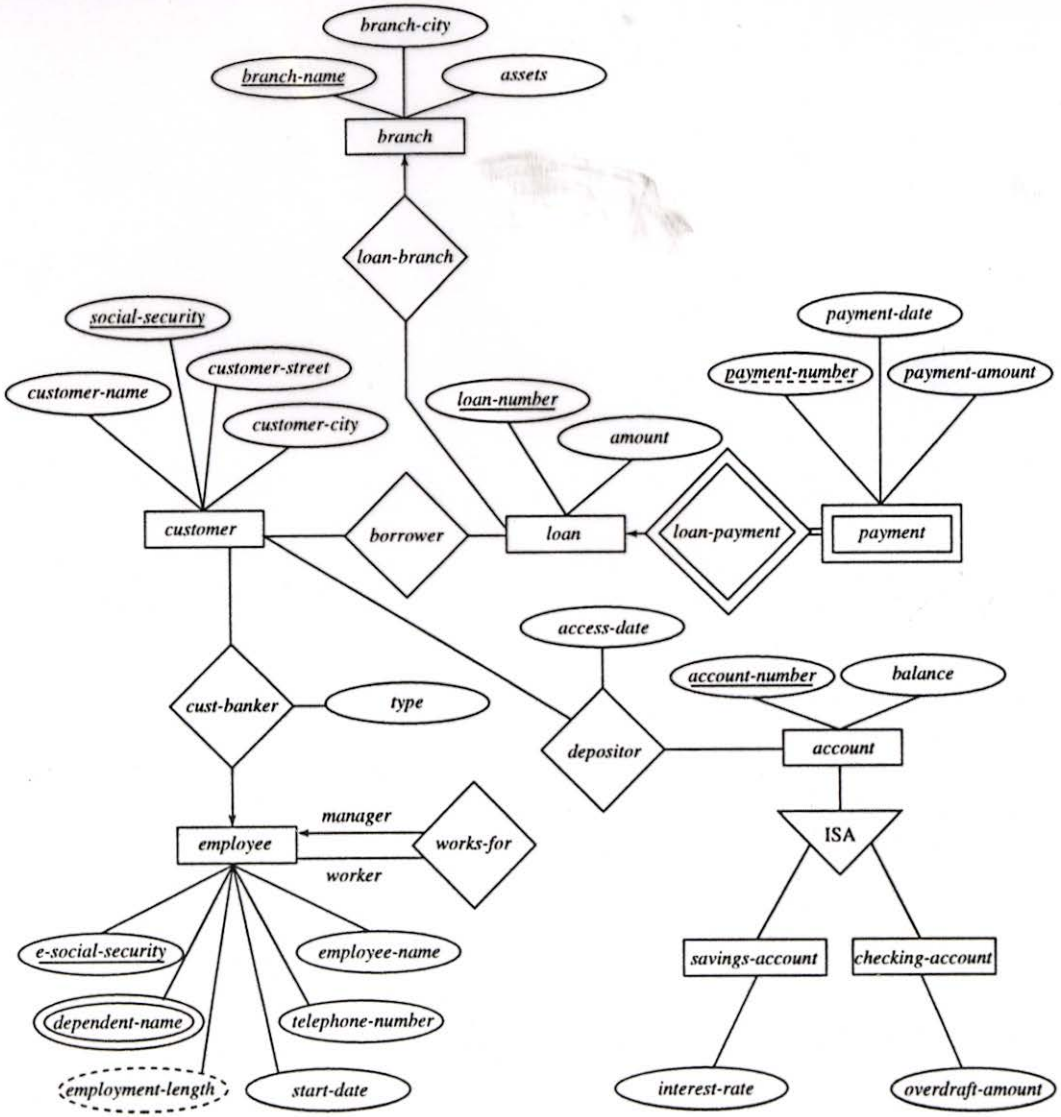
(example and syntax)


Fname
Minit
Lname
Address
Name
Sex
Salary
Ssn
Bdate
EMPLOYEE
WORKS_FOR
(1,1)
employee
(4,N)
department
Number
Name
Locations
DEPARTMENT
NumberOfEmployees
StartDate
MANAGES
(0,1)
manager
(1,1)
department-
managed
(0,N)
controlling-
department
CONTROLS
(1,N)
worker
(0,N)
supervisor
(0,1)
supervisee
SUPERVISION
Hours
WORKS_ON
(0,N)
employee
(1,N)
project
controlled-
project
(1,1)
PROJECT
Name
Number
Location
DEPENDENTS_OF
dependent
(1,1)
DEPENDENT
Name
Sex
BirthDate
Relationship

E-R model Notation

Symbol	Meaning
	ENTITY TYPE
	WEAK ENTITY TYPE
	RELATIONSHIP TYPE
	IDENTIFYING RELATIONSHIP TYPE
	ATTRIBUTE
	KEY ATTRIBUTE
	MULTIVALUED ATTRIBUTE
	COMPOSITE ATTRIBUTE
	DERIVED ATTRIBUTE
	TOTAL PARTICIPATION OF E_2 IN R
	CARDINALITY RATIO 1:N FOR E_1:E_2
	STRUCTURAL CONSTRAINT (min, ma ON PARTICIPATION OF E IN R

E-R Diagram for Banking Enterprise



(2) Process of Database Design

(steps and example)

PROCESS OF DATABASE DESIGN

- **Phase I - Requirement Analysis**
  - Determine information needs
  - Identify functions of the organization
    $\Rightarrow$ *print transcripts, current enrollment*
  - Identify data objects
    $\Rightarrow$ *students, courses, faculty, ...*
  - Identify interactions
    $\Rightarrow$ *enrollment in classes, teaching classes*
- **Phase II - Conceptual Database Design**
- **Phase III - Database Schema Design**

CONCEPTUAL DATABASE DESIGN

1) **What are the Entities?**

- stable data objects
- have subproperties
- involved in (multiple) interactions with other entities

2) **What are the Attributes of Interest?**

- appropriate descriptive information about the entities of interest
- Is there natural substructure to an attribute?
- Are any attributes natural primary keys for an entity?

CONCEPTUAL DATABASE DESIGN (cont)

3) **What are the Relationships?**

- What are the natural interactions among entities?
- Are these relationships representable as attributes?
  - *what are the advantages/disadvantages of doing so?*
- Do the relationships have natural attributes of their own?
- What are the constraints on the relationships?
  - *Cardinality constraints (mapping constraints)*

    1:1 

    N:1 

    1:N 

    N:M 

  - *Participation constraints*

    Total participation 

    Partial participation 

Sample Queries Required to be Handled

- List the name and email address of all Chemistry minors.
- List the phone numbers and rank of all faculty with a full-time appointment in Biology.
- List all courses offered in Chemistry that are for more than 3 credits and taught a faculty person not a member of the Chemistry department.
- List all the department chairs in the Engineering school, along with their department name and department budget.
- List the name, pass-fail status and final grade all students majoring in Art History taking courses in Chemistry in Fall 1997.

(2b) Actually designing a database

We did this interactively in class for the specification in the previous slide, using the E-R model. As a friend for their notes.

(3) Relational Model

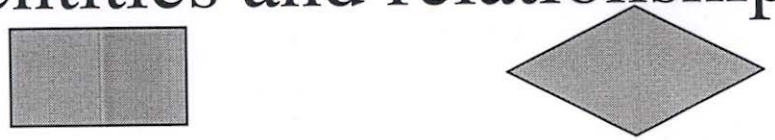
OVERVIEW

- The **Entity-Relationship model** is a *graphical* representation useful for planning and visualizing database design

- The **Relational model** is a *table-based* or *tuple-based* representation that with associated operations and integrity constraints allows formal analysis and direct implementation.

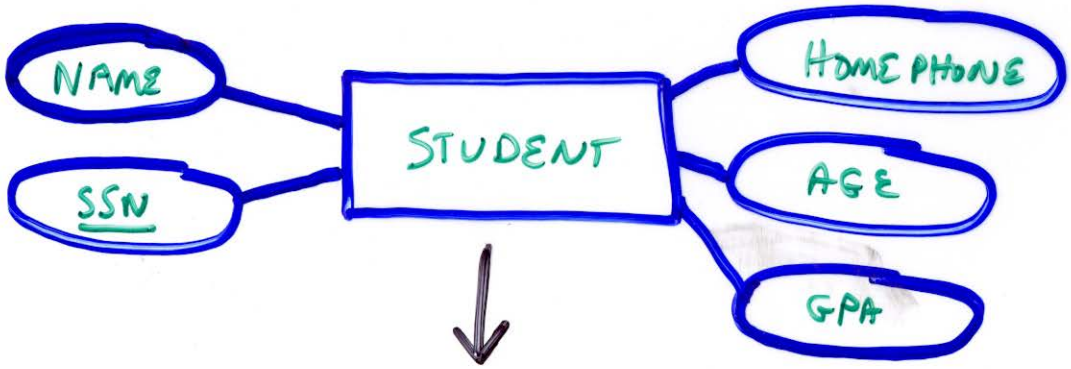
RELATIONAL MODEL

Both entities and relationships



can be represented in a uniform framework as a TABLE or TUPLE-----Generally refered to as a **relation**

Entities and Attributes in the Relational Model



- **Tuple Representation:**
  - Student(NAME, SSN, HOMEPHONE, …, AGE, GPA) ⇐ *Schema*
  - Student(*Ben Bayer, 305-61-2435, 373-1616, 19, 3.21*) ⇐ *Instance*
  - Student(*Kate Ashley, 381-62-1245, 375-4409, 18, 2.89*) ⇐ *Instance*
  - Student(*Barb Benson, 533-69-1238, 839-8361, 19, 3.25*) ⇐ *Instance*
- **Table Representation:**

Relation name

Attributes

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

← SCHEMA (header)

← instance (tuple)

A SCHEMA for a Relation:

Student(NAME, SSN, HOMEPHONE, …, AGE, GPA)

Relation R

Formal Attributes $A_1, \ldots, A_n$

↑ Degree of the relation = # of formal attributes

An INSTANCE of the Relation:

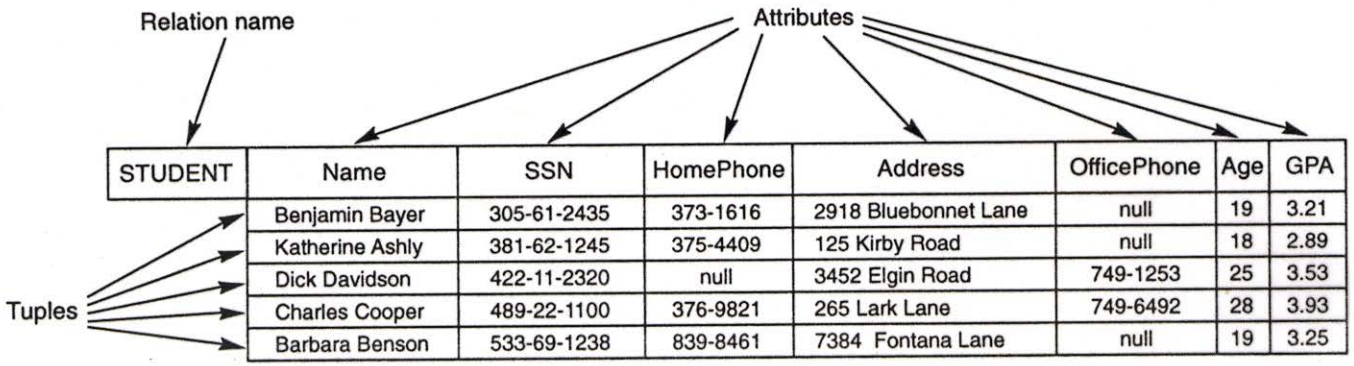
- **Tuple Representation:**

  Student(*Ben Bayer, 305-61-2435, 373-1616, 19, 3.21*)

  Student(*Kate Ashley, 381-62-1245, 375-4409, 18, 2.89*)

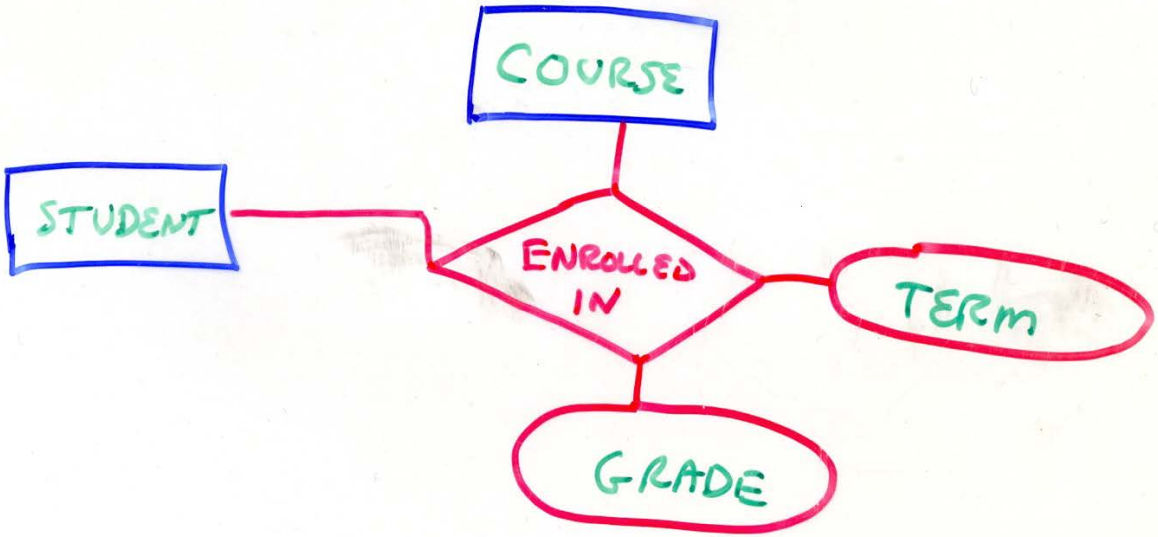
  Student(*Barb Benson, 533-69-1238, 839-8361, 19, 3.25*)

- **Table Representation:**



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

Representing E-R Relationships



PARTICIPATING ENTITIES — ATTRIBUTES OF RELATION

Enrolled_in (STUDENT, COURSE, GRADE, TERM)

→ This is a Pointer to another Entity Relation.

IN Practice, we will use the PRIMARY KEY of STUDENT (=SSN) to represent this Pointer.

CAPTURING N:M RELATIONSHIPS

Student:

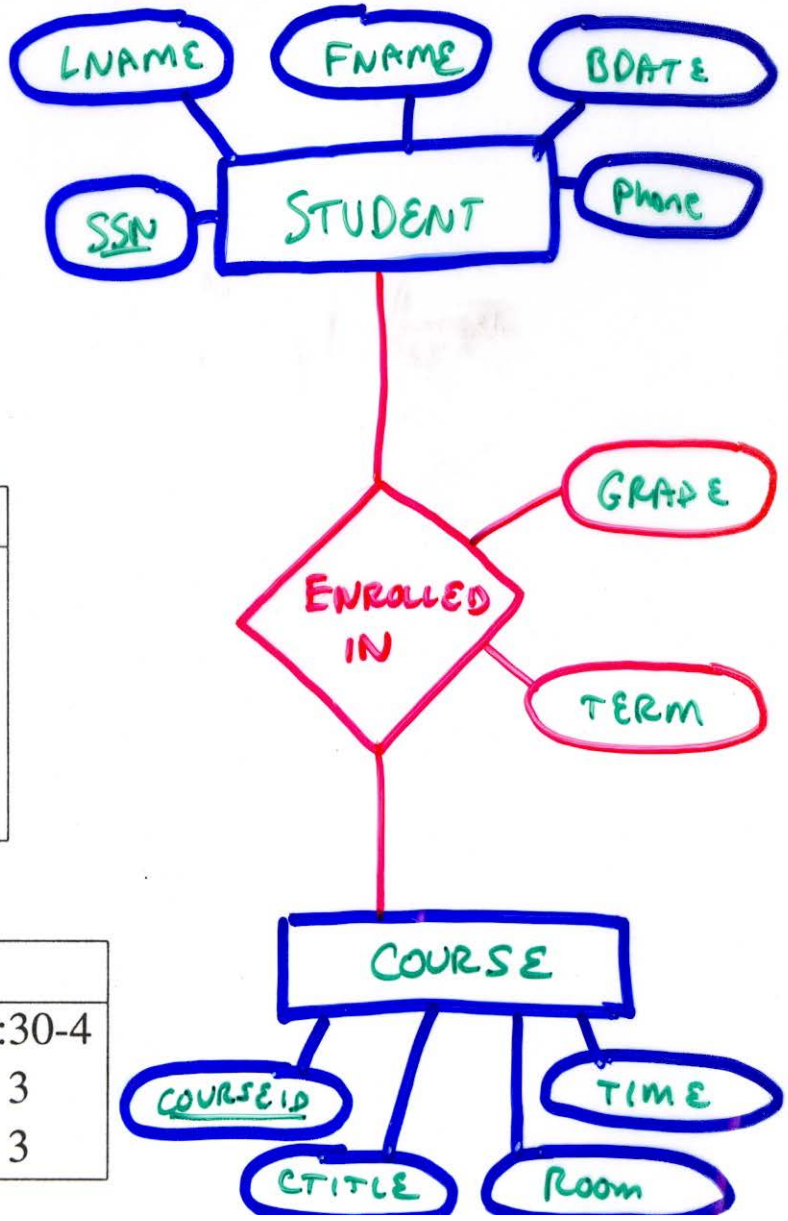
SSN	LNAME	FNAME	BDATE	PHONE
485-12-3398	Jones	Steven	05-24-74	516-5416
339-48-2167	Bayer	Eric	12-28-66	516-5560
280-22-9944	Ashley	Kate	01-17-75	516-8867
128-21-2176	Benson	Barb	02-02-76	516-5372

Enrolled_In:

STUDENT ID	COURSE ID	Grade	Term
485-12-3398	600.465	B+	Fall 96
339-48-2167	600.465	C-	Fall 96
280-22-9944	600.334	A-	Fall 95
128-21-2176	600.315	A	Fall 95
128-21-2176	600.334	B+	Fall 96

Course:

COURSE ID	COURSE TITLE	ROOM	TIME
600.315	Database Systems	Shaffer 3	ThF 2:30-4
600.334	Computer Architecture	Shaffer 303	MTW 3
600.465	Artificial Intelligence	NEB 225	MTW 3



CAPTURING N:1 RELATIONSHIPS (Option 1)

Faculty:

SSN	LNAME	FNAME	OFFICE	PHONE
485-12-3398	Salzberg	Steven	NEB 324B	x5416
280-22-9944	Masson	Gerald	NEB 224	x8867
128-21-2176	Yarowsky	David	NEB 324	x5372
884-37-2881	Jelinek	Fred	Barton 320	x7765

N

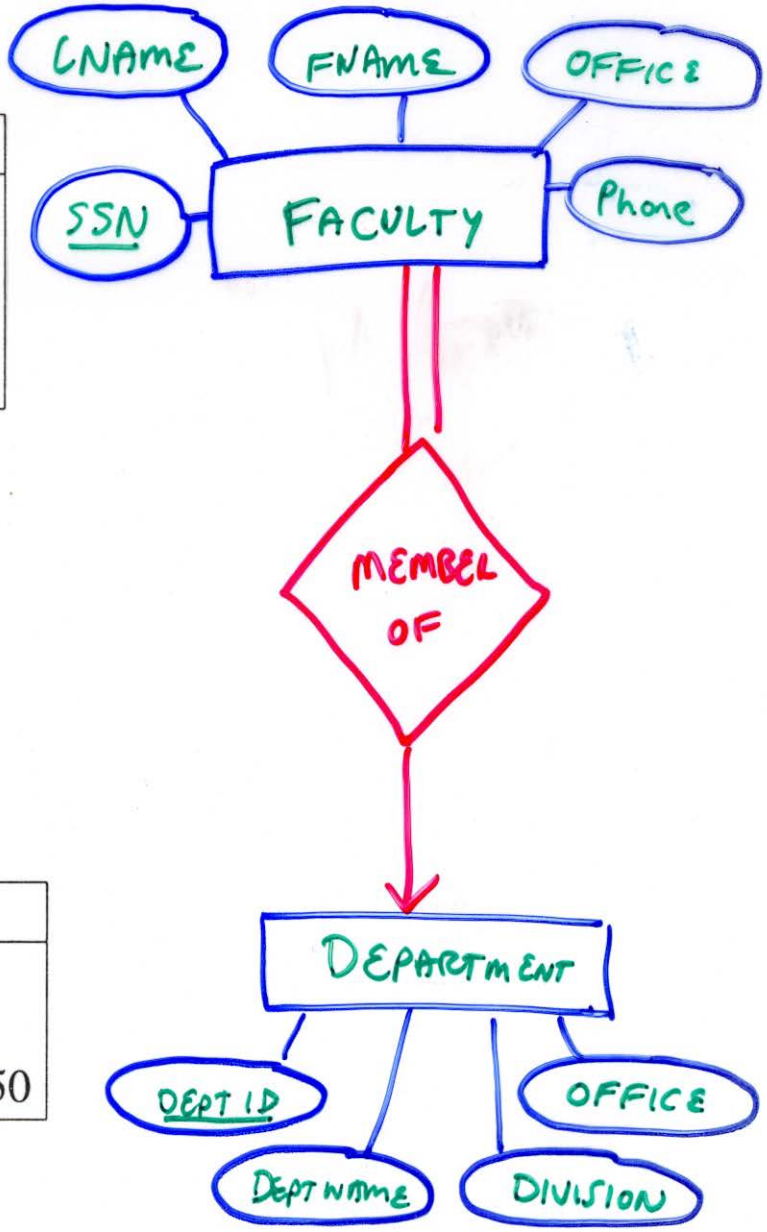
Member_Of:

INSTRUCTOR	DEPARTMENT
485-12-3398	600
280-22-9944	600
128-21-2176	600
884-37-2881	520

1

Department:

DEPT ID	DEPARTMENT NAME	DIVISION	OFFICE
600	Computer Science	ENG	NEB 224
520	Electrical Engineering	ENG	Barton 10
050	Cognitive Science	AS	Krieger 350



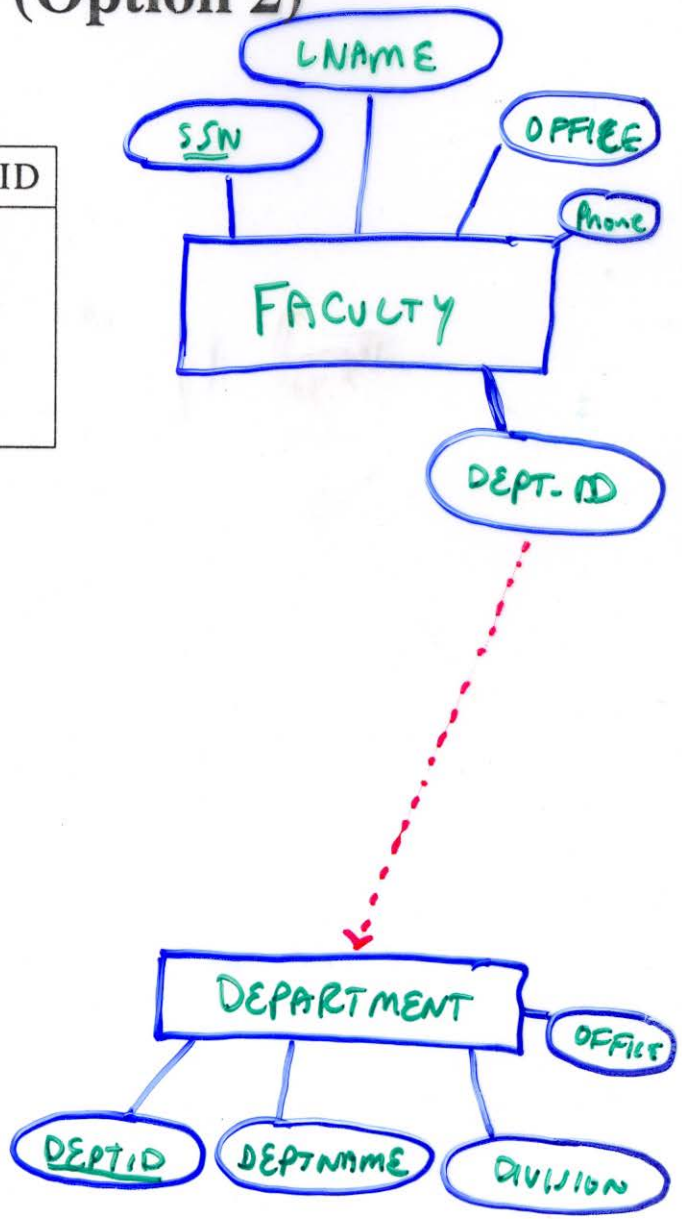
CAPTURING N:1 RELATIONSHIPS (Option 2)

Faculty:

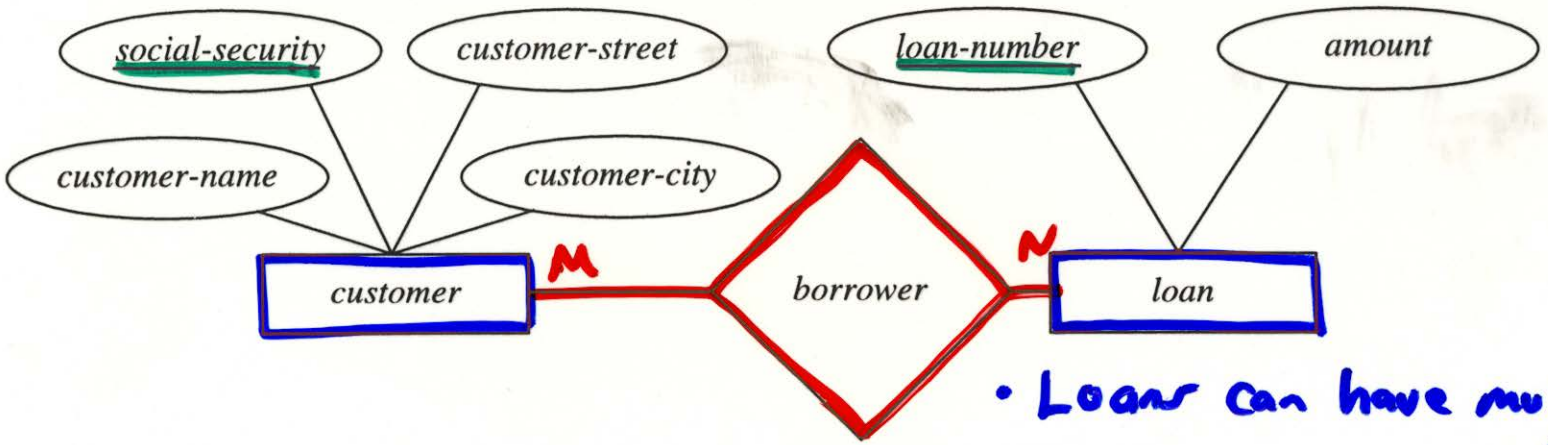
SSN	LNAME	FNAME	OFFICE	PHONE	DEPT_ID
485-12-3398	Salzberg	Steven	NEB 324B	x5416	600
280-22-9944	Masson	Gerald	NEB 224	x8867	600
128-21-2176	Yarowsky	David	NEB 324	x5372	600
884-37-2881	Jelinek	Fred	Barton 320	x7765	520

Department:

DEPT ID	DEPARTMENT NAME	DIVISION	OFFI CE
600	Computer Science	ENG	NEB 224
520	Electrical Engineering	ENG	Barton 10
050	Cognitive Science	AS	Krieger 350



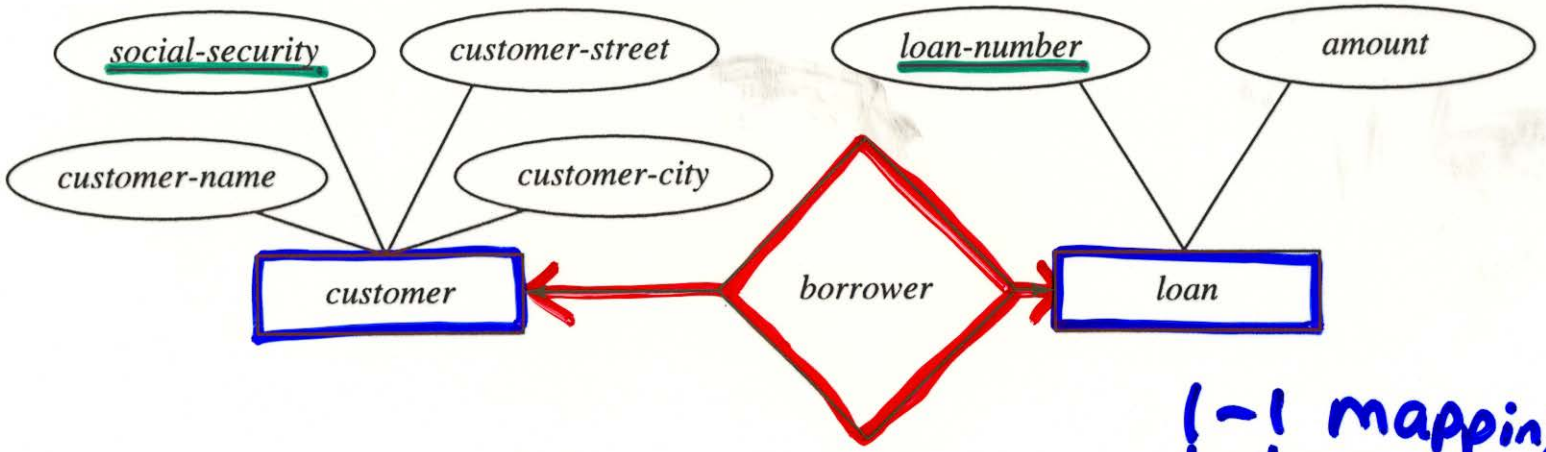
Many-To-Many Relationship



- Loans can have multiple Customers
- Customers can have multiple loans

- A customer is associated with several (possibly 0) loans via borrower
- A loan is associated with several (possibly 0) customers via borrower

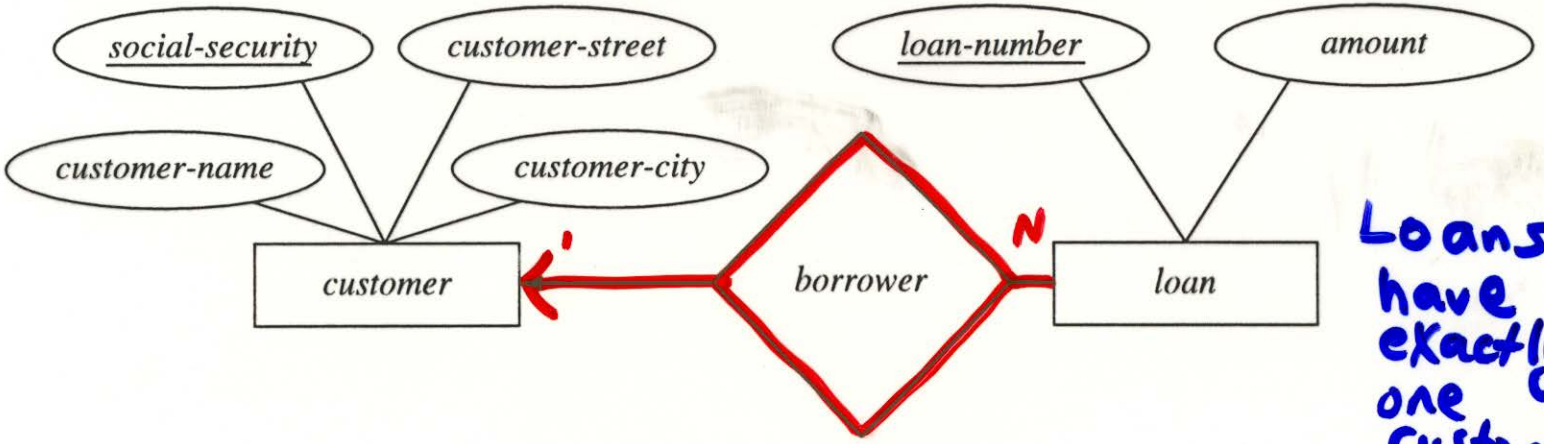
One-To-One Relationship



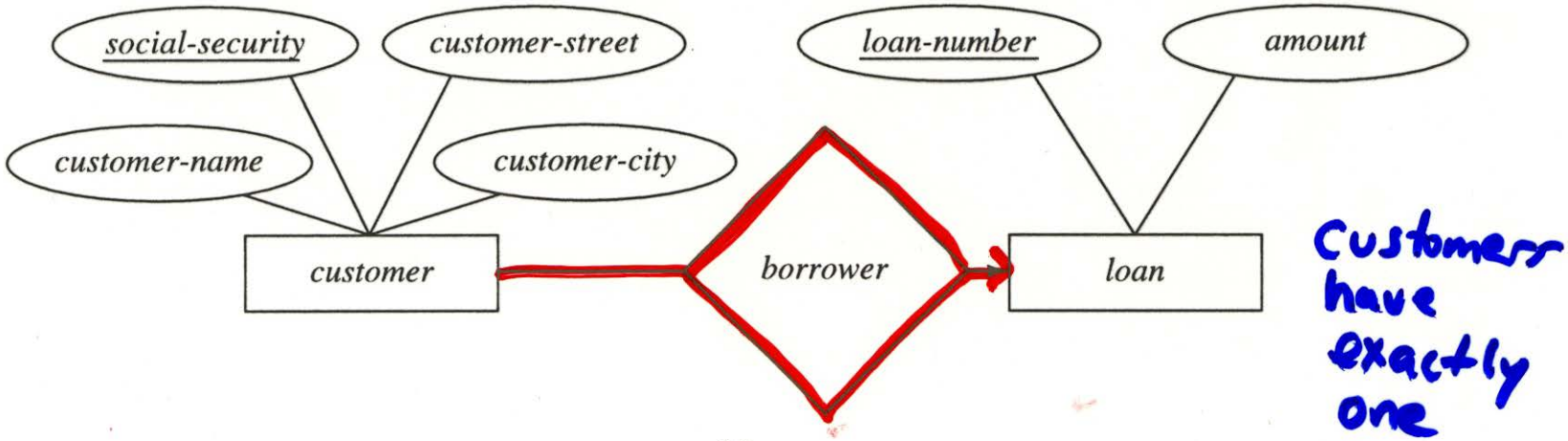
1-1 mapping between loans and Customers

- A customer is associated with at most one loan via the relationship *borrower*
- A loan is associated with at most one customer via *borrower*

One-To-Many and Many-to-One Relationships



(a)

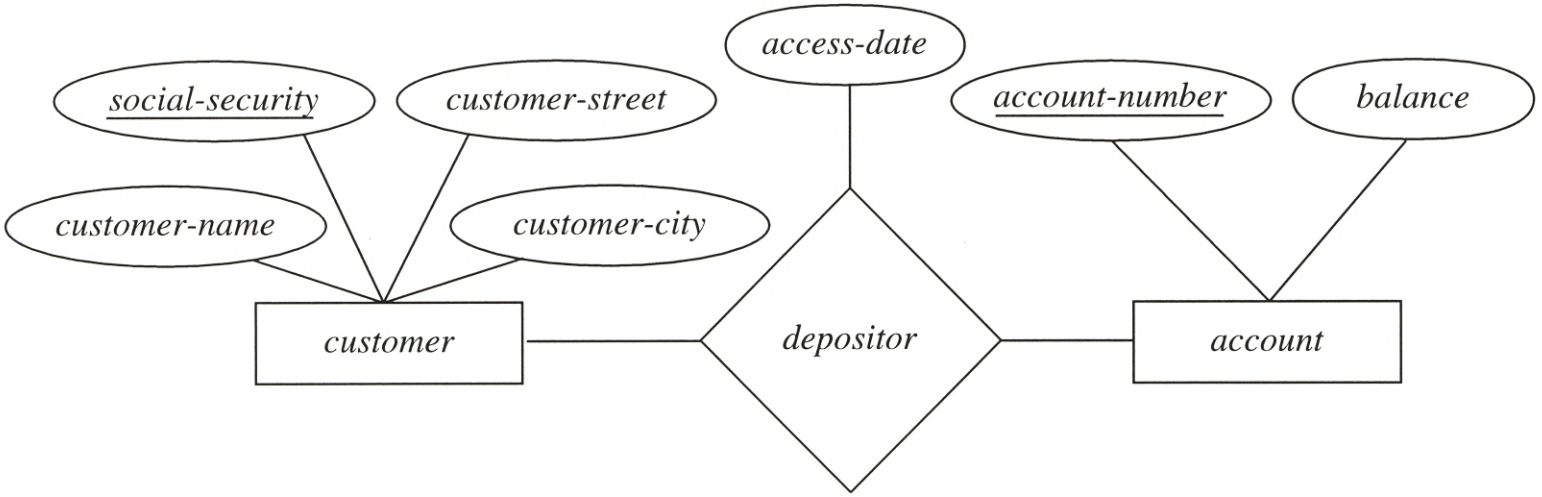


(b)

Relationship Sets (Cont.)

- An *attribute* can also be a property of a relationship set.

  For instance, the *depositor* relationship set between entity sets *customer* and *account* may have the attribute *access-date*



DATABASE SCHEMES

- A **Database Scheme** is the set of all relations / relational schema in the database universe.

- For example:

  DBS1 = { Student(..,..,..,..), Faculty(..,..,..,..), Enrolled_in(..,..,..), ... }

DOMAINS OF ATTRIBUTES

- Dom(SSN) = { *set of 10-digit numbers* }
- Dom(SEX) = { *M, F* }

- **A relation r**(R) is a subset of the cartesian product of the attributes defining the relation

$$r(R) \subseteq Dom(A_1) \times Dom(A_2) \times \ldots\ldots Dom(A_n)$$

n = degree of the relation

$\Rightarrow$ Set of tuples that are valid in the real world

KEYS IN THE RELATIONAL MODEL

- Super Keys (*subset of keys that uniquely labels an entity*)

  Student(SSN, JCARDNUM, NAME, SEX, BDATE, PHONE,)

  Student(SSN, JCARDNUM, NAME, SEX, BDATE, PHONE,)

- Candidate Keys (*minimal superkeys*)

  Student(SSN, JCARDNUM, NAME, SEX, BDATE, PHONE,)

  Student(SSN, JCARDNUM, NAME, SEX, BDATE, PHONE,)

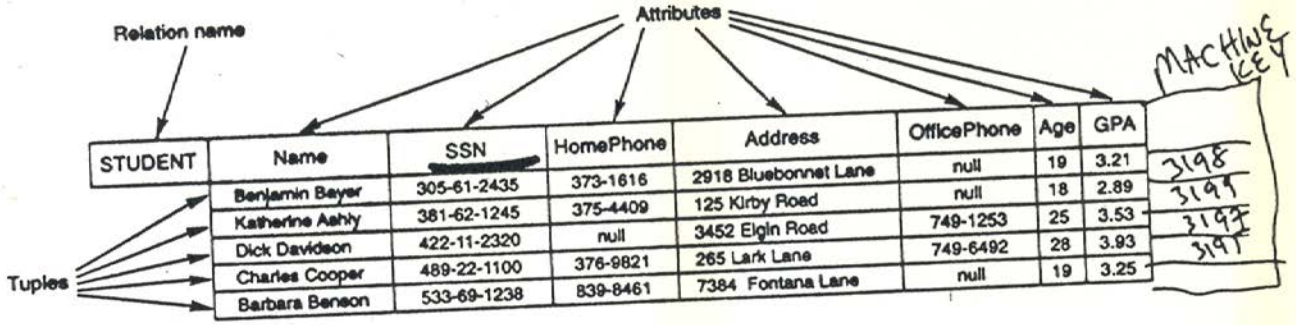
- Primary Key (*arbitrary member of the candidate keys*)

  Student(SSN, JCARDNUM, NAME, SEX, BDATE, PHONE,)

$\Rightarrow$ Same roles and notation as in the ER-model

Candidate keys $\subseteq$ Super keys

Primary Key $\in$ Candidate keys


Relation name
Attributes
Tuples
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
MACHINE KEY
3198
3199
3197
3197

PRIMARY KEY CHOICE

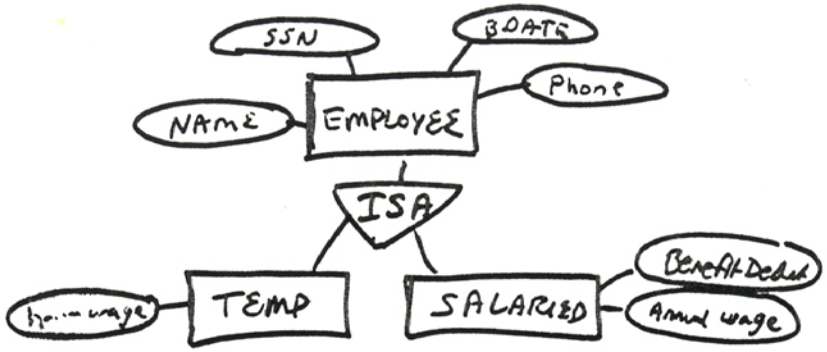
1. **Naturally occurring keys:**

   such as government issued ID numbers (SSN, Driver's Lisc Number)

2. **Machine assigned keys:**

   Arbitrary unique identifier numbers specific to the database

REPRESENTING SPECIALIZATION AND INHERITANCE IN THE RELATIONAL MODEL



EMPLOYEE

SSN	NAME	BDATE	PHONE
485 31 9118	J. SMITH	3-26-53	x5311
316 43 8821	D. JONES	4-28-66	x6331

Primary Entity

SALARIED (foreign key)

ESSN	AnnlWage	BenefitDedct
485 31 9118	63,000	6%

TEMP (foreign key)

ESSN	hrwage	overtime
316 43 8021	13.45	20.00

Specializations

(4) Relational Model Examples

A very old relational database (for historical comparison) and a new design we will use several times in class

1896 Ledger Book – an early relational database

2. Worked for Hora Talbot

Aug	6	G B Talbot and team 1 day	$3	00
Aug	6	Dick Jones 1 day	1	00
Aug	6	Elbert Talbot 1 day	1	00
Aug	7	G B Talbot and team 1 day	3	00
Aug	7	Dick Jones 1 day	1	00
Aug	7	Elbert Talbot 1 day	1	00
Aug	9	G B Talbot and team ½ day in afternoon	1	50
Aug	9	Elbert ½ day in after noon		50
Aug	9	Adah ½ day in after noon		50
Aug	10	G B and ½ day in fore noon and 3 hours in the)	2	25
Aug	10	Elbert ½ day in fore noon 3 hours (after noon		75
Aug	10	Adah 3 hour in th after noon		25
Aug	12	G. B ½ day in fore Con 2 hours in afternoon	2	00
Aug	12	Dick ½ day in fore noon 2 hours in afternoon		66⅔
Aug	12	Elbert ½ day in fore noon 2 hours in afternoon		66⅔
Aug	13	G. B and team 1 day	3	00
Aug	13	Dick Jones 1 day	1	00
Aug	13	Elbert Talbot 1 day	1	00
Aug	13	Adah Talbot ½ day in the after noon		50
Aug	14	G. B. and team 1 day	3	00
Aug	14	Dick Jones 1 day,	1	00
Aug	14	Elbert Talbot 1 day	1	00
Aug	14	Adah Talbot ½ day in after noon		50
Aug	16	G. B. and team 1 day	3	00
Aug	16	Dick Jone 1 day	1	00

FIGURE 1-9. *G. B. Talbot's ledger book*

The "Address" relation – Talbot's ledger book

Addresses for Dora's Help

Bert Sargeant, Canmer Retreat House, Hill St, Berkeley
Pat Lavay, Rose Hill Rfd 3, N. Edmeston
Dick Jones, Cayuga Hotel, N. Edmeston
* Jack Talbot, Papa King Rooming, 127 Main, N. Edmeston
Andrew Dye, Rose Hill for Men, Rfd 3, N. Edmeston
Hayes and Palmer Wallbom, ~~Fort Lake~~ Rose Hill
* Albert Talbot, Weitbracht Rooming, 320 Geneva, Keene
Richard Nash and brothers, Weitbracht Rooming.
? Peter Lawson, Canmer Retreat House, Hill St, Berkeley
Jed Hopkins, Matts Long Bunk House, 3 Mile Rd, Keene
Helen Brandt, ~~Nath Hamlin, Nath Edmeston~~
William Ewing, Canmer Retreat House, Hill St, Berkeley

George Oscar, Rose Hill, c/o Pat Lavay
Donald Rollo, Matts Long Bunk House, 3 Mile Rd, Keene
Gerhardt Kentgen, Papa King Rooming, 127 Main, Edmeston
Edythe Gannoe, Bells Dairy Farm, Keene
Wilfred Lovell ?
Roland Brandt, Matts Long Bunk House, 3 Mile Road, Keene
Daniella Lawson (with Peter at Canmer)
George B. McCormick and Lilly ('Lily 2') with Wallboms
Effie Butler, c/o Golden Rodmen's, Keene
~~Dick Jones Co~~
Andrew Schlater, Rfd 1, Roydon

FIGURE 1-10. *Addresses of workers in Talbot's ledger book*

Data in Talbot's Ledger in Relational Format

The WORKER Table

NAME	AGE	LODGING
Adah Talbot	23	Papa King
Bart Sarjeant	22	Cranmer
Dick Jones	18	Rose Hill
Elbert Talbot	43	Weitbrocht
Helen Brandt	15	
Jed Hopkins	33	Matts
John Pearson	27	Rose Hill
Victoria Lynn	32	Mullers
Wilfred Lowell	67	

The WORKER SKILL Table

NAME	SKILL	ABILITY
Adah Talbot	Work	Good
Dick Jones	Smithy	Excellent
Elbert Talbot	Discus	Slow
Helen Brandt	Combine Driver	Very Fast
John Pearson	Combine Driver	
John Pearson	Woodcutter	Good
John Pearson	Smithy	Average
Victoria Lynn	Smithy	Precise
Wilfred Lowell	Work	Average
Wilfred Lowell	Discus	Average

The SKILL Table

SKILL	DESCRIPTION
Combine Driver	Harness, Drive, Groom Horses, Adjust Blades
Discus	Harness, Drive, Groom Horses, Blade Depth
Grave Digger	Mark and Cut Sod, Dig, Shore, Fill, Resod
Smithy	Stack for Fire, Run Bellows, Cut, Shoe Horses
Woodcutter	Mark and Fell Trees, Split, Stack, Haul
Work	General Unskilled Labor

The LODGING Table

LODGING	LONGNAME	MANAGER	ADDRESS
Cranmer	Cranmer Retreat House	Thom Cranmer	Hill St, Berkeley
Matts	Matts Long Bunk House	Roland Brandt	3 Mile Rd, Keene
Mullers	Mullers Coed Lodging	Ken Muller	120 Main, Edmeston
Papa King	Papa King Rooming	William King	127 Main, Edmeston
Rose Hill	Rose Hill For Men	John Peletier	Rfd 3, N. Edmeston
Weitbrocht	Weitbrocht Rooming	Eunice Benson	320 Geneva, Keene

FIGURE 2-8. *Information in Talbot's tables*

Formal Relational Structure of Talbot's Ledger

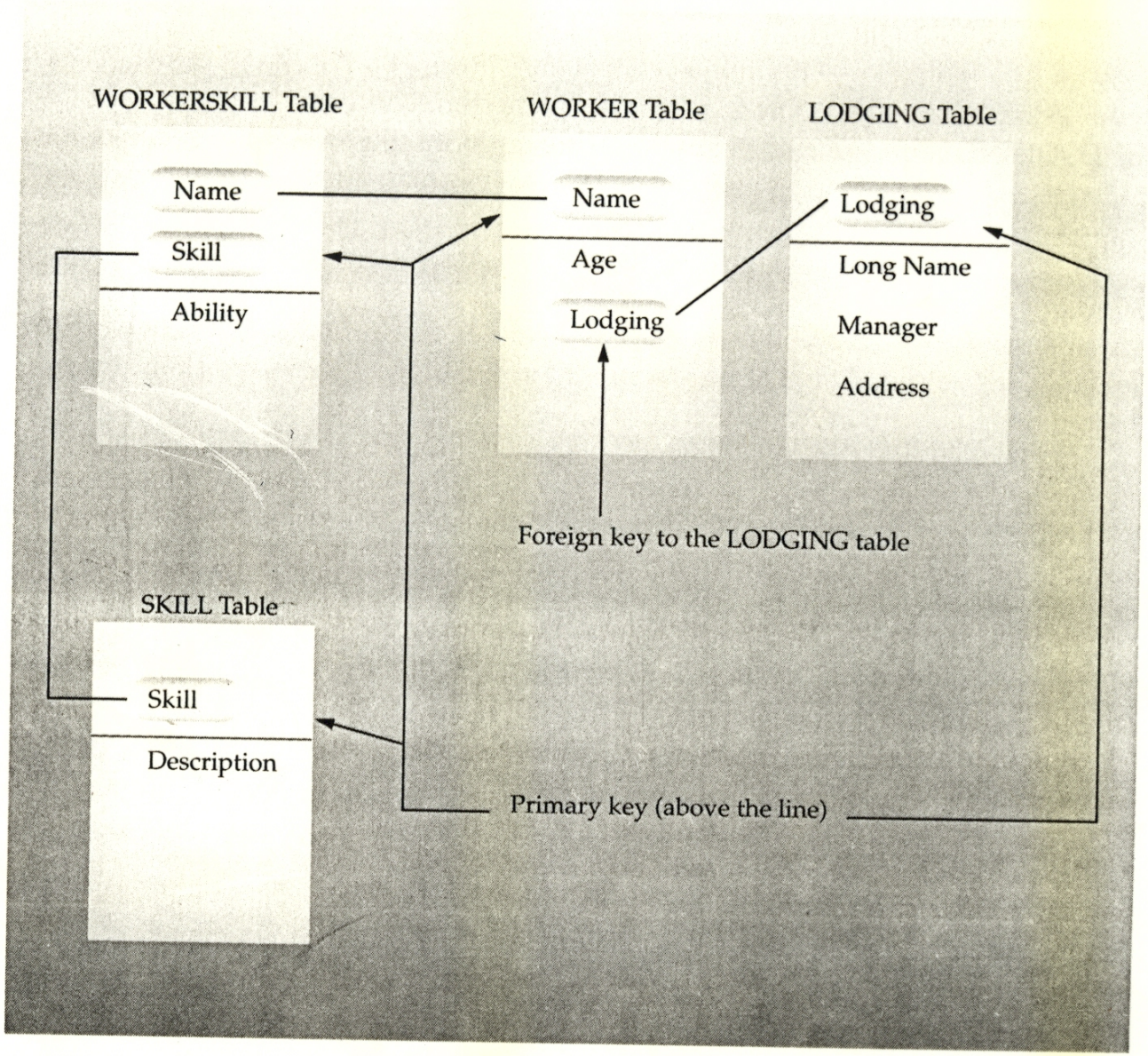


FIGURE 2-7. *Relationships between the worker tables*

EMPLOYEE	FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO
	John	B	Smith	123456789	09-JAN-55	731 Fondren, Houston, TX	M	30000	333445555	5
	Franklin	T	Wong	333445555	08-DEC-45	638 Voss, Houston, TX	M	40000	888665555	5
	Alicia	J	Zelaya	999887777	19-JUL-58	3321 Castle, Spring, TX	F	25000	987654321	4
	Jennifer	S	Wallace	987654321	20-JUN-31	291 Berry, Bellaire, TX	F	43000	888665555	4
	Ramesh	K	Narayan	666884444	15-SEP-52	975 Fire Oak, Humble, TX	M	38000	333445555	5
	Joyce	A	English	453453453	31-JUL-62	5631 Rice, Houston, TX	F	25000	333445555	5
	Ahmad	V	Jabbar	987987987	29-MAR-59	980 Dallas, Houston, TX	M	25000	987654321	4
	James	E	Borg	888665555	10-NOV-27	450 Stone, Houston, TX	M	55000	null	1

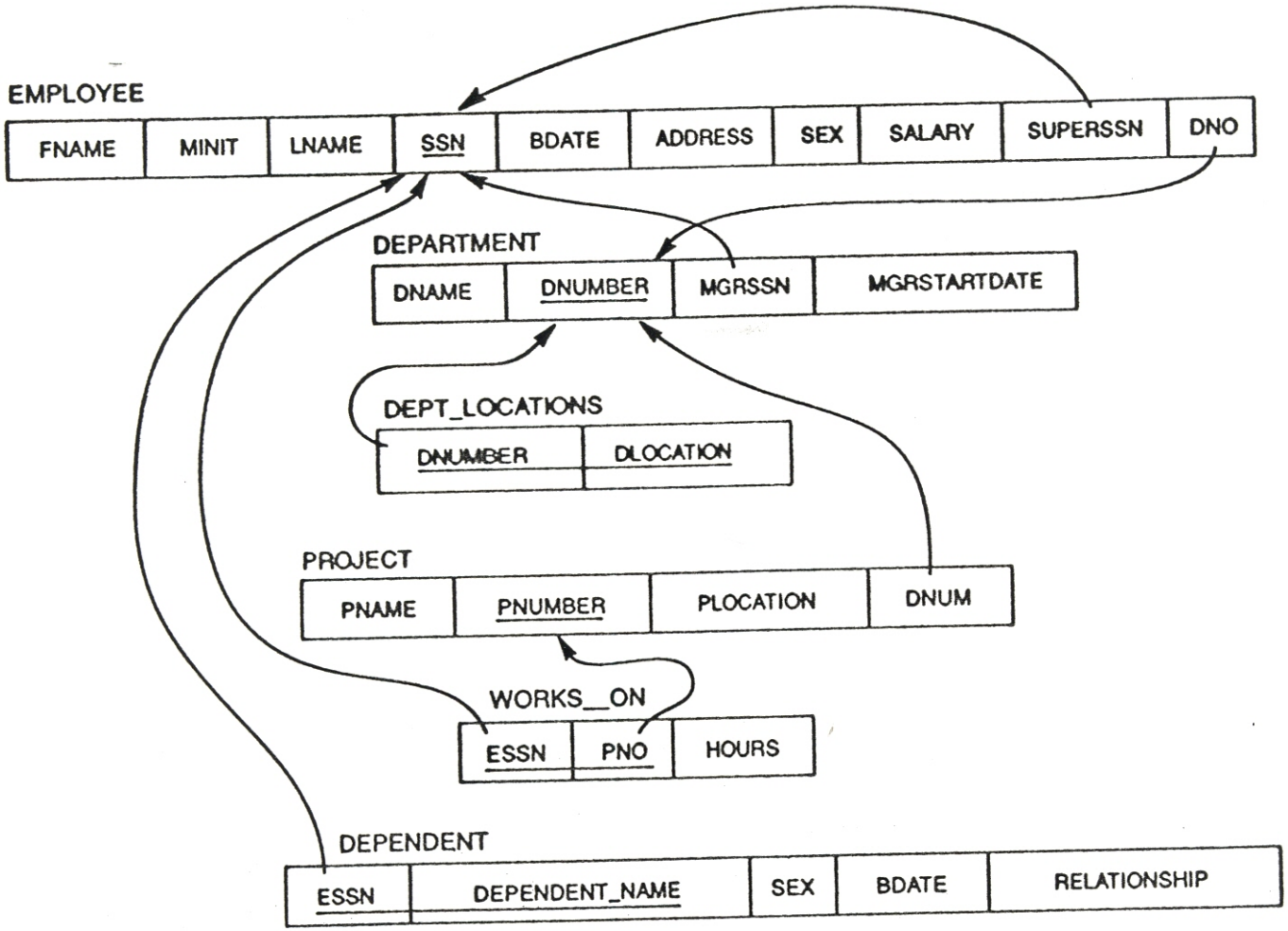
DEPT_LOCATIONS	DNUMBER	DLOCATION
	1	Houston
	4	Stafford
	5	Bellaire
	5	Sugarland
	5	Houston

DEPARTMENT	DNAME	DNUMBER	MGRSSN	MGRSTARTDATE
	Research	5	333445555	22-MAY-78
	Administration	4	987654321	01-JAN-85
	Headquarters	1	888665555	19-JUN-71

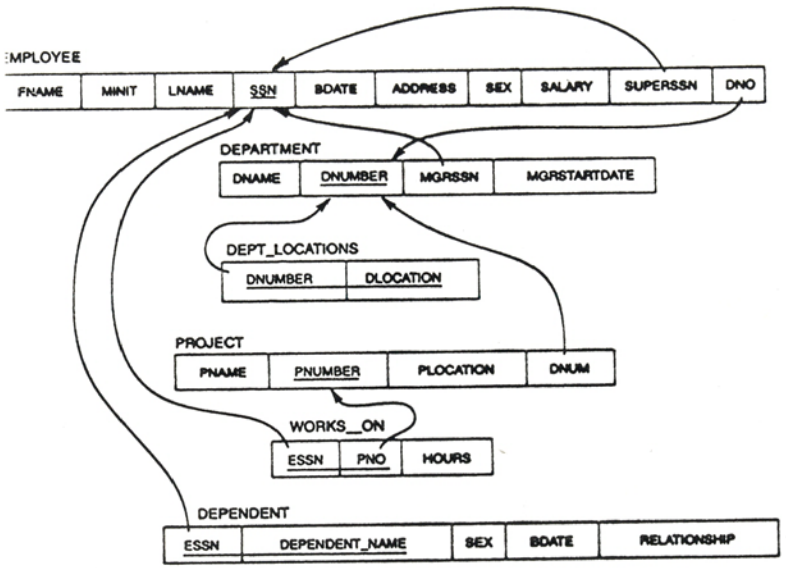
WORKS_ON	ESSN	PNO	HOURS
	123456789	1	32.5
	123456789	2	7.5
	666884444	3	40.0
	453453453	1	20.0
	453453453	2	20.0
	333445555	2	10.0
	333445555	3	10.0
	333445555	10	10.0
	333445555	20	10.0
	999887777	30	30.0
	999887777	10	10.0
	987987987	10	35.0
	987987987	30	5.0
	987654321	30	20.0
	987654321	20	15.0
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

PROJECT	PNAME	PNUMBER	PLOCATION	DNUM
	ProductX	1	Bellaire	5
	ProductY	2	Sugarland	5
	ProductZ	3	Houston	5
	Computerization	10	Stafford	4
	Reorganization	20	Houston	1
	Newbenefits	30	Stafford	4

DEPENDENT	ESSN	DEPENDENT_NAME	SEX	BDATE	RELATIONSHIP
	333445555	Alice	F	05-APR-76	DAUGHTER
	333445555	Theodore	M	25-OCT-73	SON
	333445555	Joy	F	03-MAY-48	SPOUSE
	987654321	Abner	M	29-FEB-32	SPOUSE
	123456789	Michael	M	01-JAN-78	SON
	123456789	Alice	F	31-DEC-78	DAUGHTER
	123456789	Elizabeth	F	05-MAY-57	SPOUSE


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

SQL Data Definition Language



(a)

```
CREATE TABLE EMPLOYEE
        ( FNAME             VARCHAR(15)         NOT NULL ,
          MINIT             CHAR ,
          LNAME             VARCHAR(15)         NOT NULL ,
          SSN               CHAR(9)             NOT NULL ,
          BDATE             DATE ,
          ADDRESS           VARCHAR(30) ,
          SEX               CHAR ,
          SALARY            DECIMAL(10,2) ,
          SUPERSSN          CHAR(9) ,
          DNO               INT                 NOT NULL ,
        PRIMARY KEY (SSN) ,
        FOREIGN KEY (SUPERSSN) REFERENCES EMPLOYEE(SSN) ,
        FOREIGN KEY (DNO) REFERENCES DEPARTMENT(DNUMBER) ) ;
CREATE TABLE DEPARTMENT
        ( DNAME             VARCHAR(15)         NOT NULL ,
          DNUMBER           INT                 NOT NULL ,
          MGRSSN            CHAR(9)             NOT NULL ,
          MGRSTARTDATE      DATE ,
        PRIMARY KEY (DNUMBER) ,
        UNIQUE (DNAME) ,
        FOREIGN KEY (MGRSSN) REFERENCES EMPLOYEE(SSN) ) ;
CREATE TABLE DEPT_LOCATIONS
        ( DNUMBER           INT                 NOT NULL ,
          DLOCATION         VARCHAR(15)         NOT NULL ,
        PRIMARY KEY (DNUMBER, DLOCATION) ,
        FOREIGN KEY (DNUMBER) REFERENCES DEPARTMENT(DNUMBER) ) ;
CREATE TABLE PROJECT
        ( PNAME             VARCHAR(15)         NOT NULL ,
          PNUMBER           INT                 NOT NULL ,
          PLOCATION         VARCHAR(15) ,
          DNUM              INT                 NOT NULL ,
        PRIMARY KEY (PNUMBER) ,
        UNIQUE (PNAME) ,
        FOREIGN KEY (DNUM) REFERENCES DEPARTMENT(DNUMBER) ) ;
CREATE TABLE WORKS_ON
        ( ESSN              CHAR(9)             NOT NULL ,
          PNO               INT                 NOT NULL ,
          HOURS             DECIMAL(3,1)        NOT NULL ,
        PRIMARY KEY (ESSN, PNO) ,
        FOREIGN KEY (ESSN) REFERENCES EMPLOYEE(SSN) ,
        FOREIGN KEY (PNO) REFERENCES PROJECT(PNUMBER) ) ;
CREATE TABLE DEPENDENT
        ( ESSN              CHAR(9)             NOT NULL ,
          DEPENDENT_NAME    VARCHAR(15)         NOT NULL ,
          SEX               CHAR ,
          BDATE             DATE ,
          RELATIONSHIP      VARCHAR(8) ,
        PRIMARY KEY (ESSN, DEPENDENT_NAME) ,
        FOREIGN KEY (ESSN) REFERENCES EMPLOYEE(SSN) ) ;
```

(a)

```
CREATE TABLE EMPLOYEE
        ( FNAME          VARCHAR(15)      NOT NULL ,
          MINIT          CHAR ,
          LNAME          VARCHAR(15)      NOT NULL ,
          SSN            CHAR(9)          NOT NULL ,
          BDATE          DATE
          ADDRESS        VARCHAR(30) ,
          SEX            CHAR ,
          SALARY         DECIMAL(10,2) ,
          SUPERSSN       CHAR(9) ,
          DNO            INT              NOT NULL ,
    PRIMARY KEY (SSN) ,
    FOREIGN KEY (SUPERSSN) REFERENCES EMPLOYEE(SSN) ,
    FOREIGN KEY (DNO) REFERENCES DEPARTMENT(DNUMBER) ) ;

CREATE TABLE DEPARTMENT
        ( DNAME          VARCHAR(15)      NOT NULL ,
          DNUMBER        INT              NOT NULL ,
          MGRSSN         CHAR(9)          NOT NULL ,
          MGRSTARTDATE   DATE ,
        PRIMARY KEY (DNUMBER) ,
        UNIQUE (DNAME) ,
        FOREIGN KEY (MGRSSN) REFERENCES EMPLOYEE(SSN) ) ;

CREATE TABLE DEPT_LOCATIONS
        ( DNUMBER        INT              NOT NULL ,
          DLOCATION      VARCHAR(15)      NOT NULL ,
        PRIMARY KEY (DNUMBER, DLOCATION) ,
        FOREIGN KEY (DNUMBER) REFERENCES DEPARTMENT(DNUMBER) ) ;

CREATE TABLE PROJECT
        ( PNAME          VARCHAR(15)      NOT NULL ,
          PNUMBER        INT              NOT NULL ,
          PLOCATION      VARCHAR(15) ,
          DNUM           INT              NOT NULL ,
        PRIMARY KEY (PNUMBER) ,
        UNIQUE (PNAME) ,
        FOREIGN KEY (DNUM) REFERENCES DEPARTMENT(DNUMBER) ) ;

CREATE TABLE WORKS_ON
        ( ESSN           CHAR(9)          NOT NULL ,
          PNO            INT              NOT NULL ,
          HOURS          DECIMAL(3,1)     NOT NULL ,
        PRIMARY KEY (ESSN, PNO) ,
        FOREIGN KEY (ESSN) REFERENCES EMPLOYEE(SSN) ,
        FOREIGN KEY (PNO) REFERENCES PROJECT(PNUMBER) ) ;
```

Potential join attributes