732A54
Big Data Analytics
6hp

http://www.ida.liu.se/~732A54

Relational databases

Literature

- Elmasri, Navathe, Fundamentals of Database Systems, 7th edition, Addison Wesley, 2016. Chapters 3-6 and 9; section 7.1.

Database methods

1. Representation and storage of data

Databases

- One (of many) way(s) to store data in electronic form

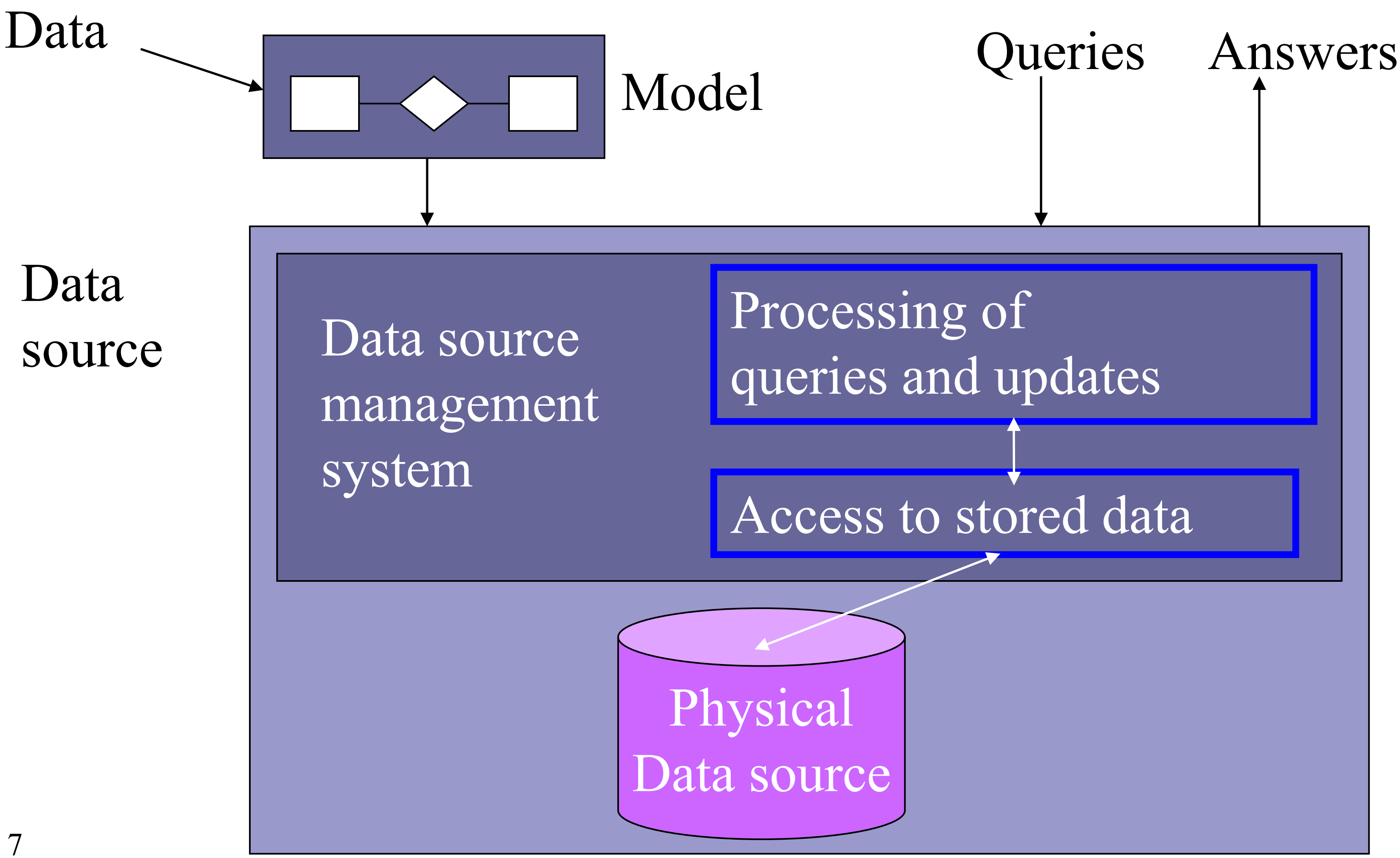
- Used in every-day life: bank, reservation of hotel or journey, library search, shops

Databases

- Database management system (DBMS): a collection of programs that supports a user to create and maintain a database

- database system = database + DBMS

Data Sources



Persons

- Data source administrator
- Data source designer
- ’end user’
- application programmer

- DBMS designer
- tool developer
- operator, maintenance

Issues - this course

- What information is stored?
- How is the information stored?

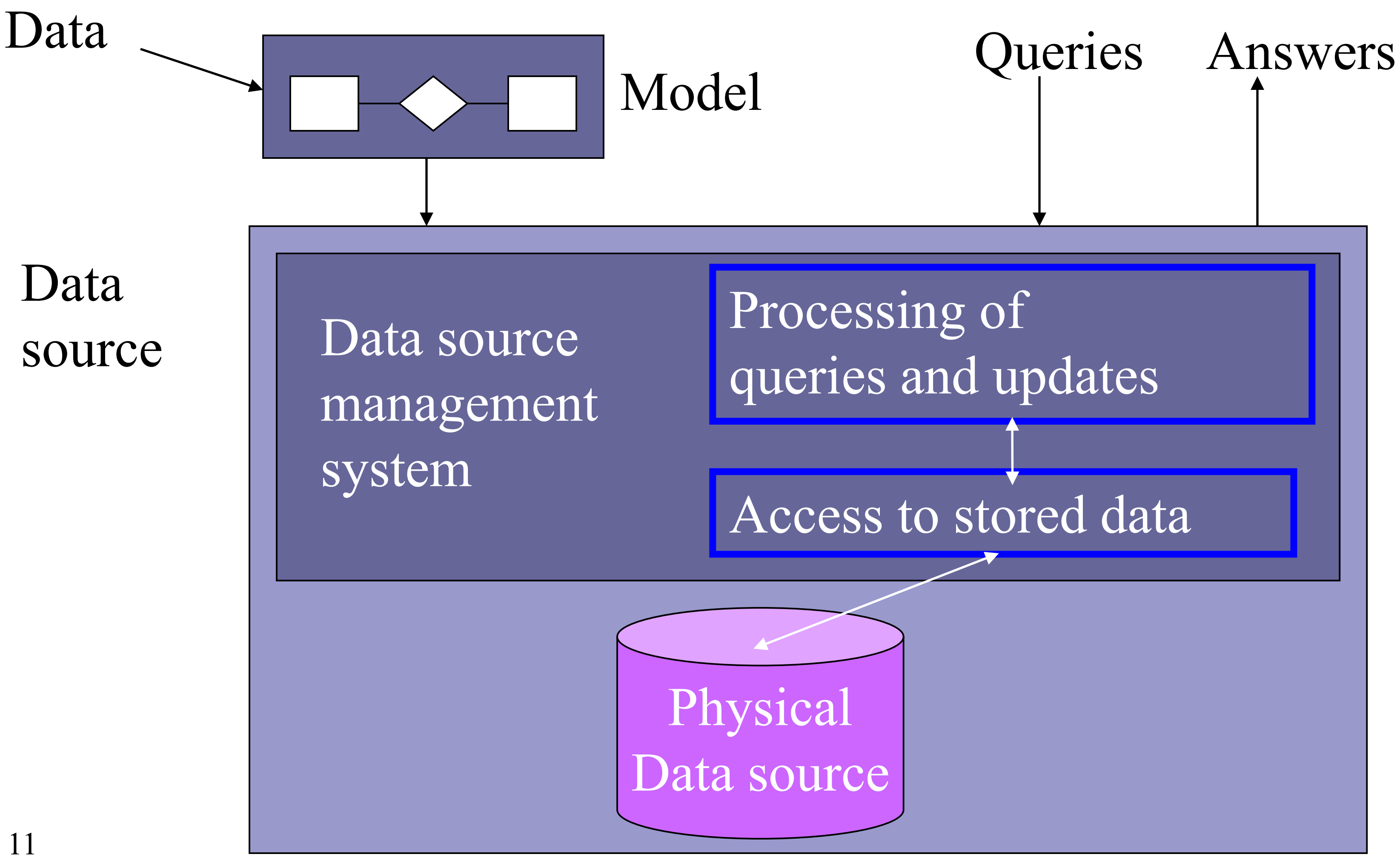
  (high level and low level)
- How is the information accessed?

  (user level and system level)

Other issues

- How to optimize performance of a data source?
- How to recover a data source after crash?
- How to access information from multiple data sources?
- How to allow multiple users to access a data source?

Data Sources



Which information is stored?

- Model of reality
  - Entity-Relationship model (ER)
  - Unified Modeling Language (UML)

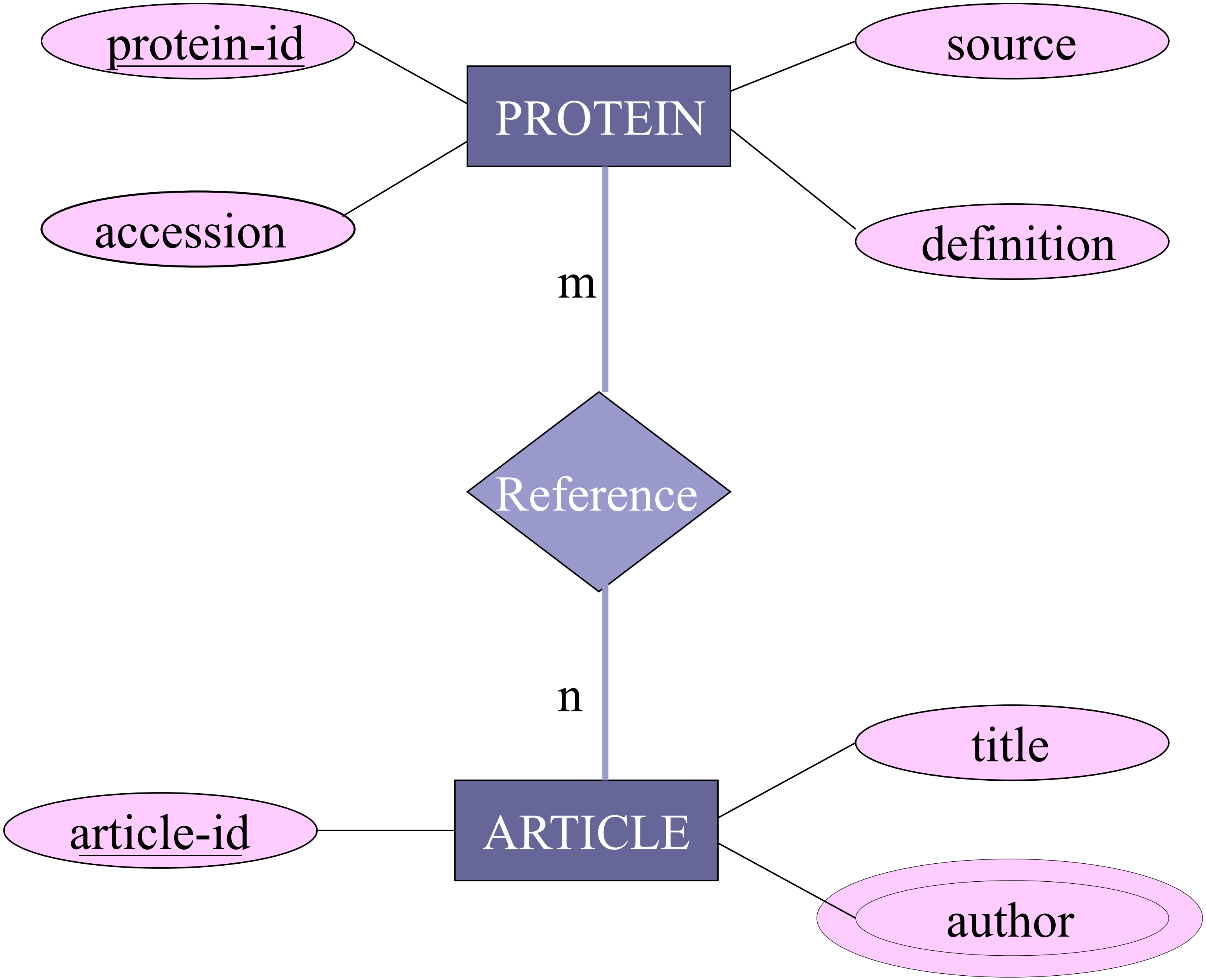
ER/EER diagram

- structured way to model data, independent of type of data source
- notions:

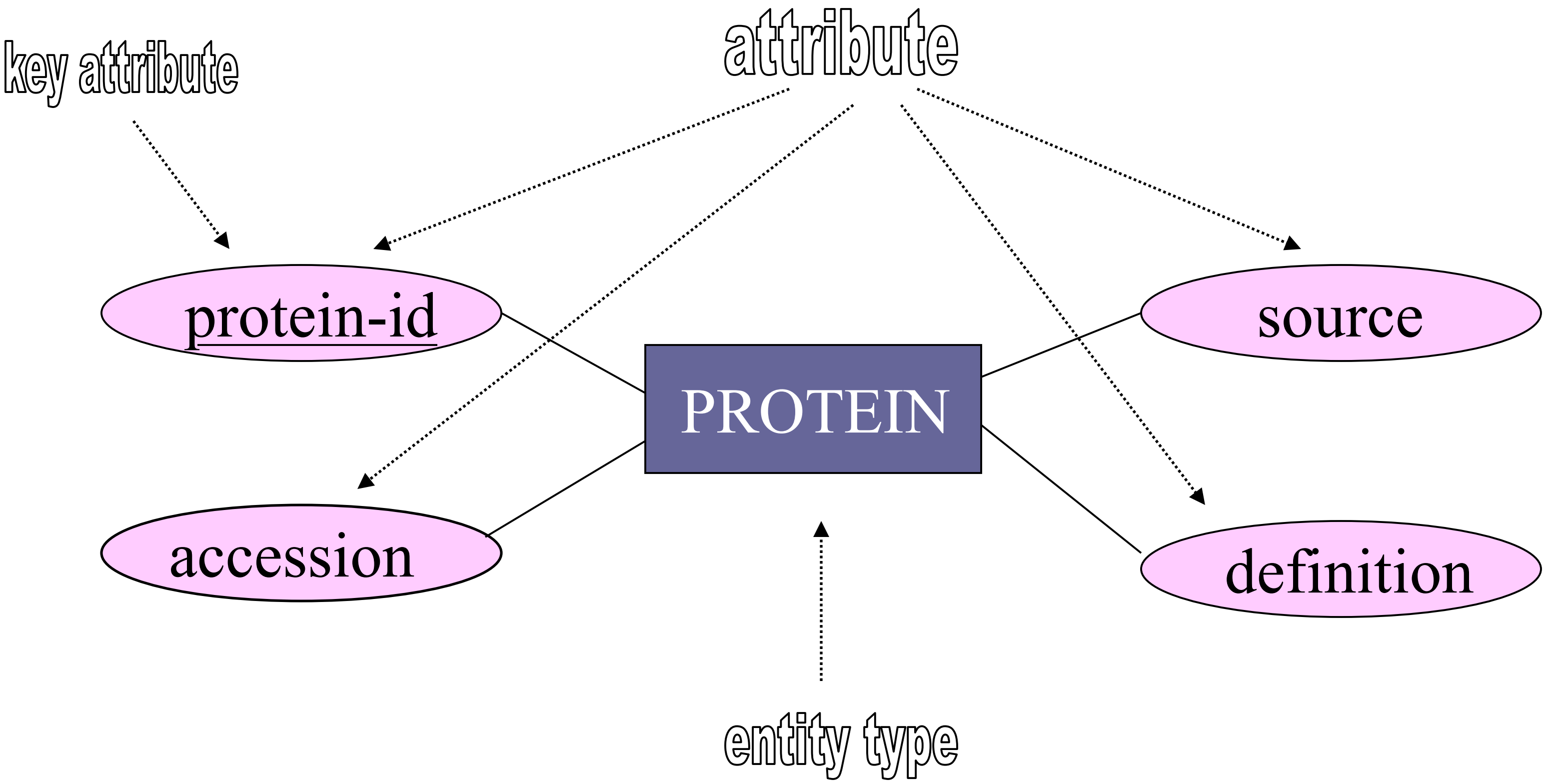
  - entities and entity types
  - attributes
  - key attributes
  - relationships and cardinality constraints
  - sub-types (EER)

DEFINITION	Homo sapiens adrenergic, beta-1-, receptor
ACCESSION	NM_000684
SOURCE ORGANISM	human
REFERENCE	1
AUTHORS	Frielle, Collins, Daniel, Caron, Lefkowitz, Kobilka
TITLE	Cloning of the cDNA for the human beta 1-adrenergic receptor
REFERENCE	2
AUTHORS	Frielle, Kobilka, Lefkowitz, Caron
TITLE	Human beta 1- and beta 2-adrenergic receptors: structurally and functionally related receptors derived from distinct genes

Entity-relationship

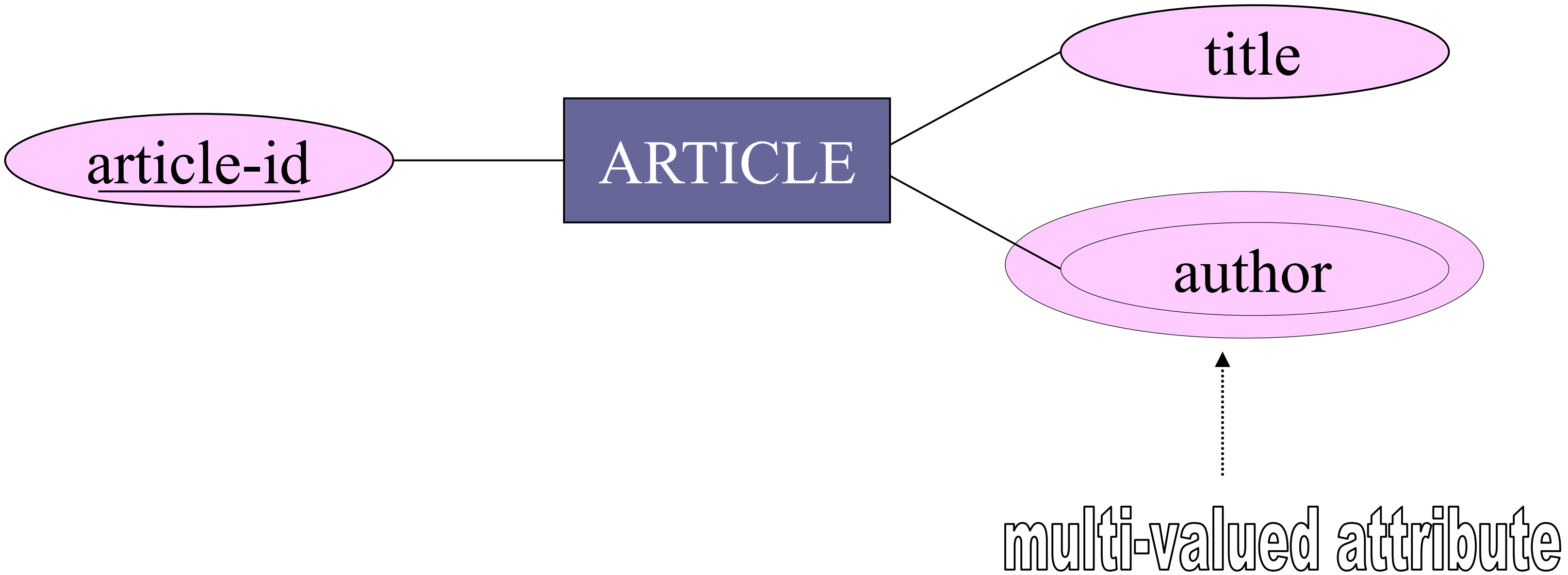


Entity-relationship

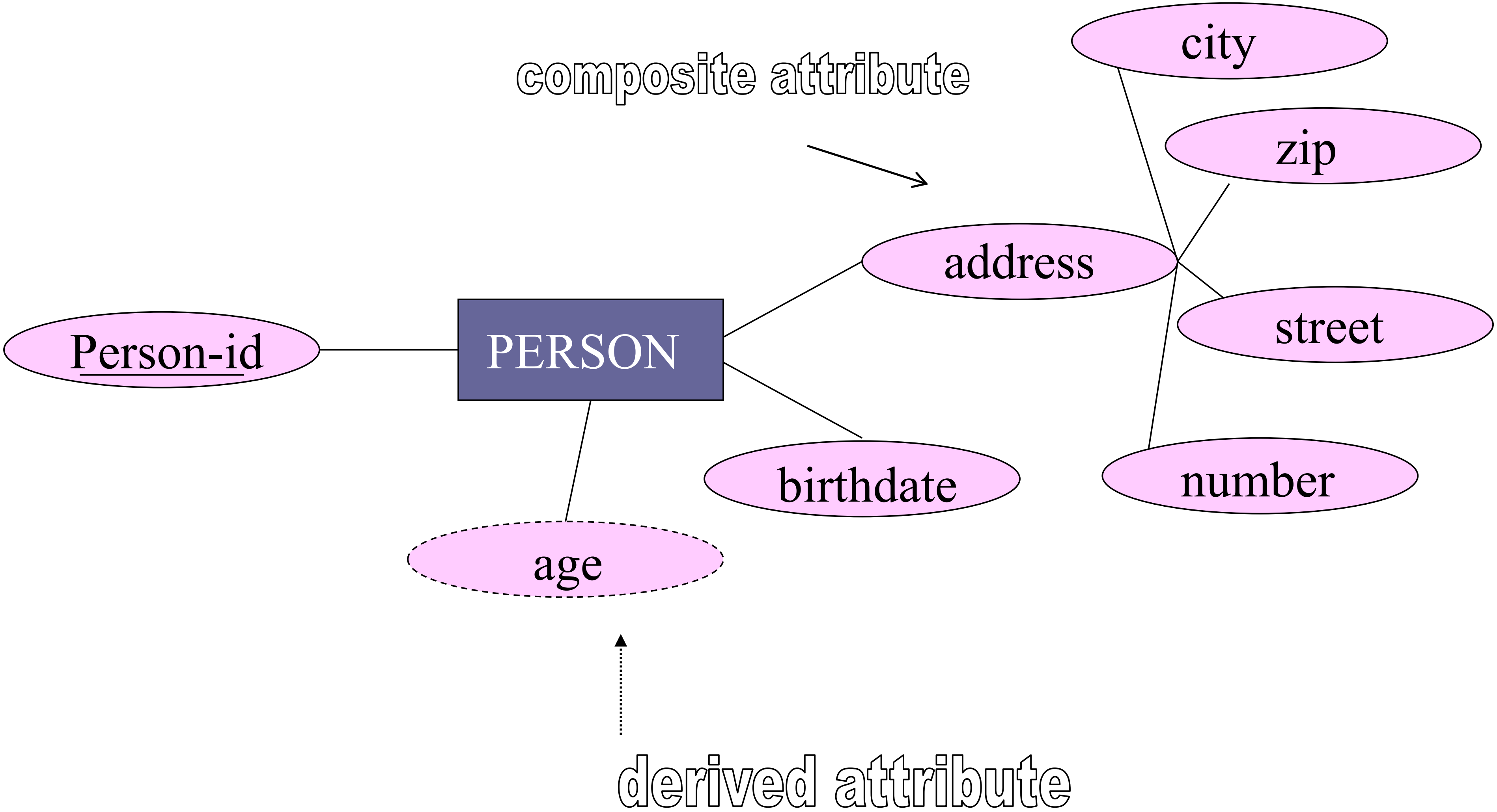


Weak entity type: type without key attribute

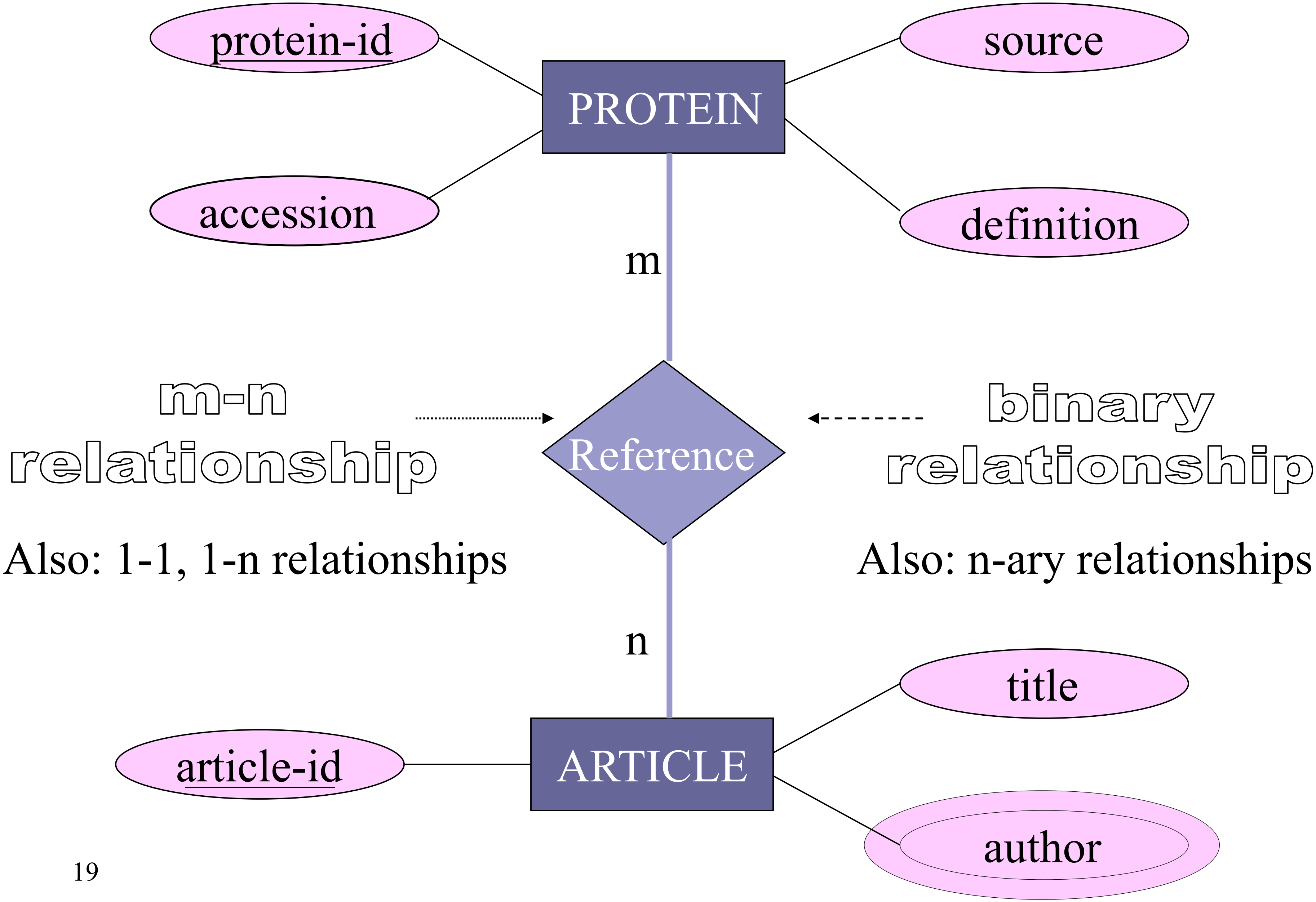
Entity-relationship



Entity-relationship



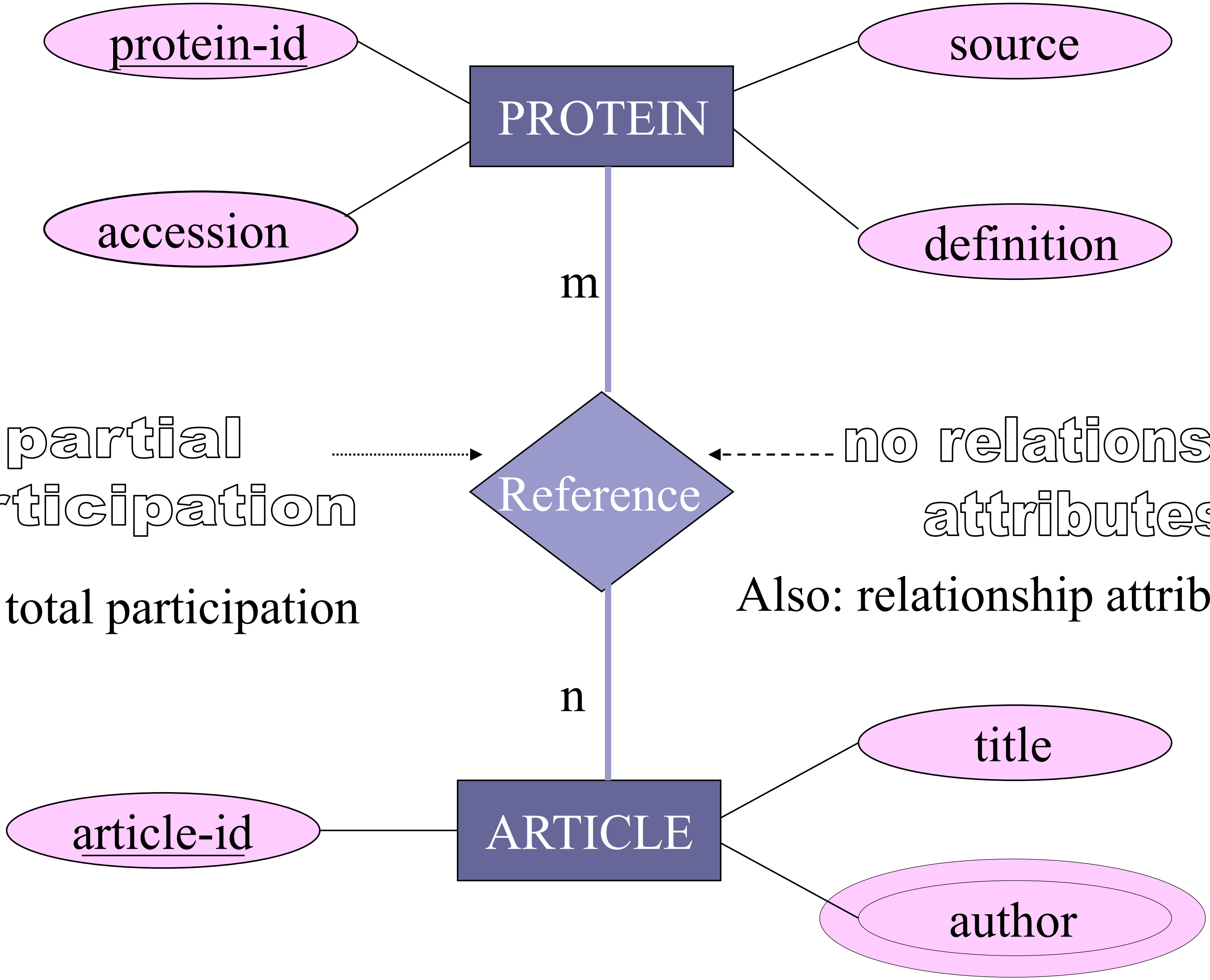
Entity-relationship



Also: 1-1, 1-n relationships

Also: n-ary relationships

Entity-relationship



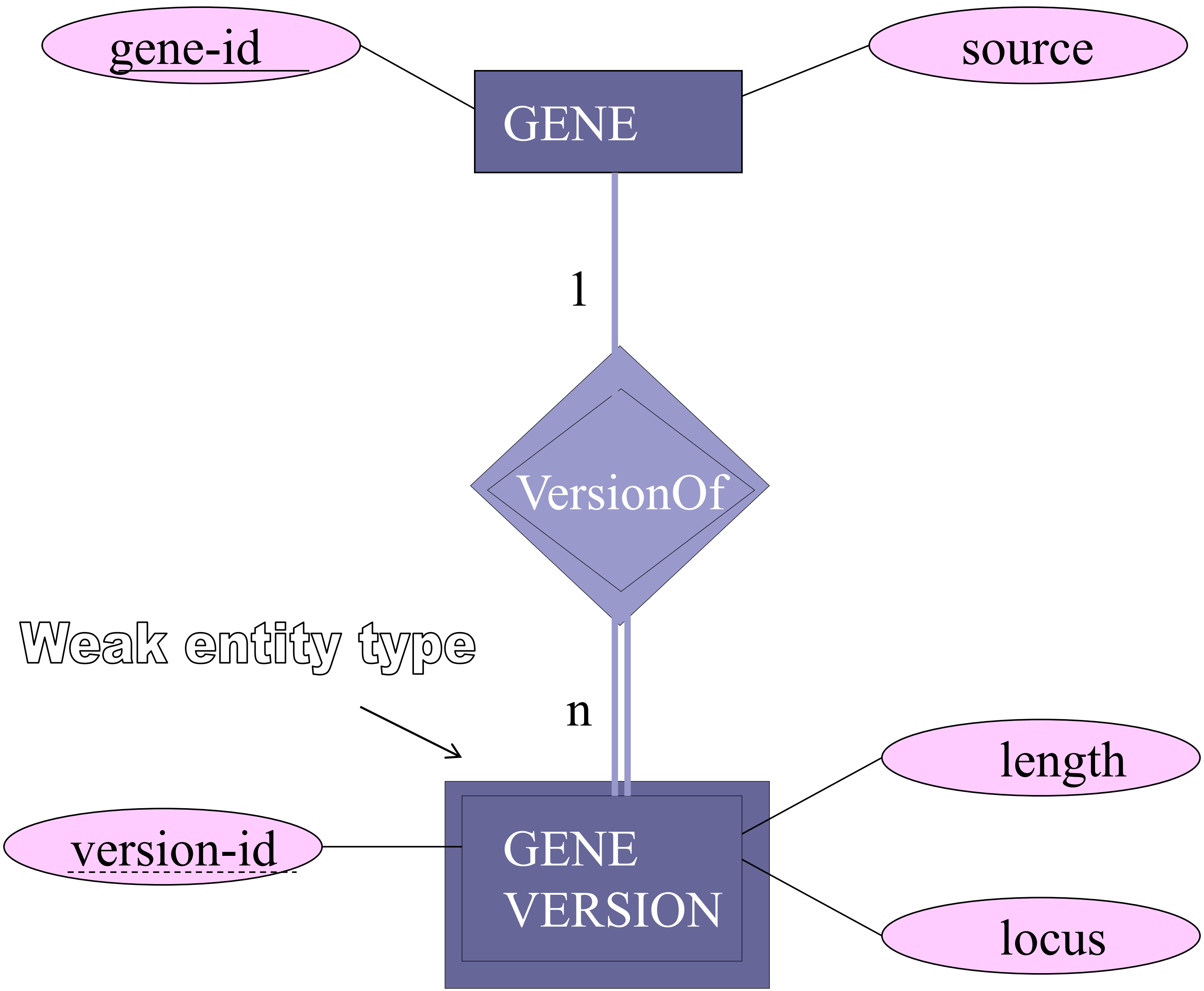
partial participation

no relationship attributes

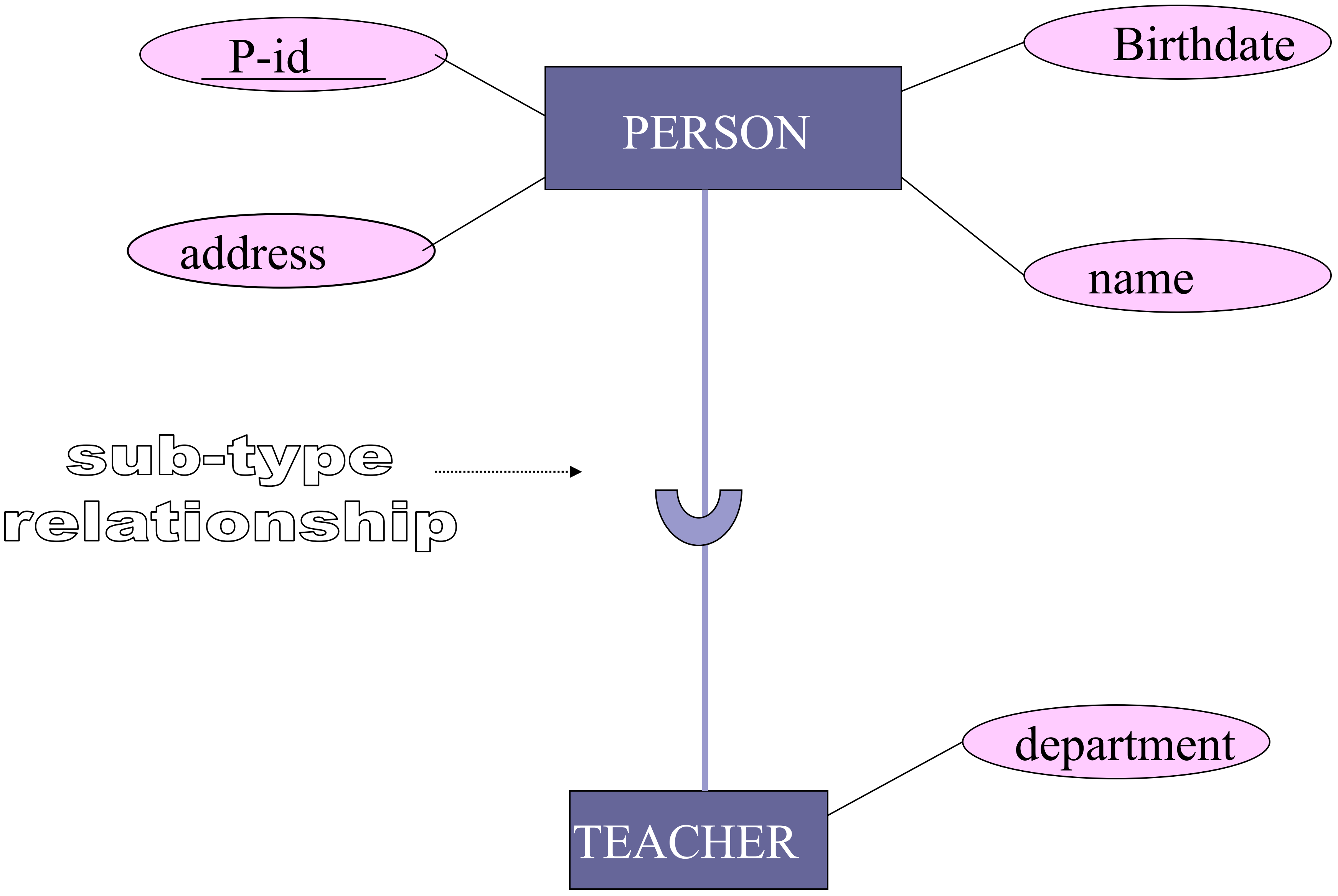
Also: total participation

Also: relationship attributes

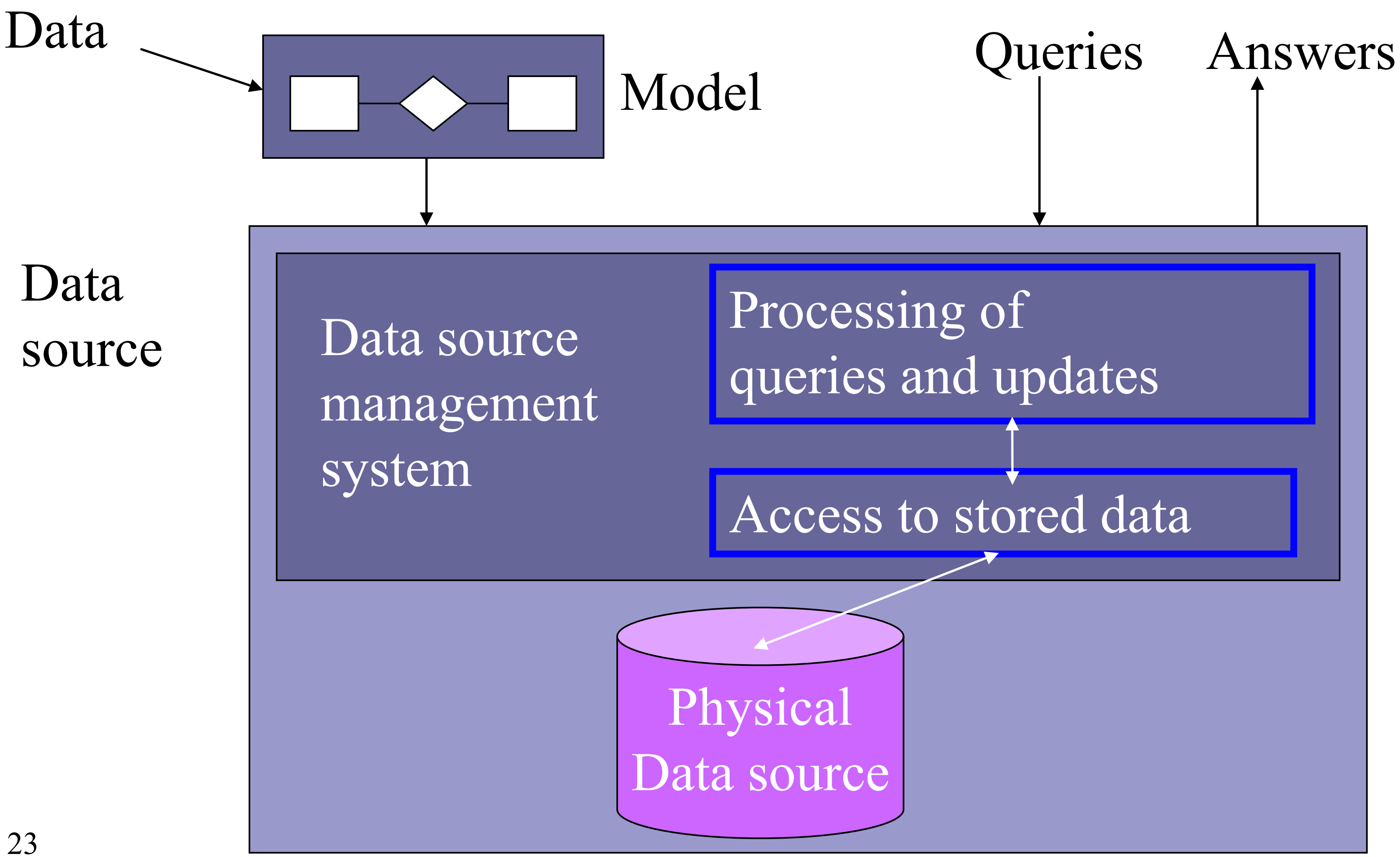
Entity-relationship



Enhanced Entity-relationship

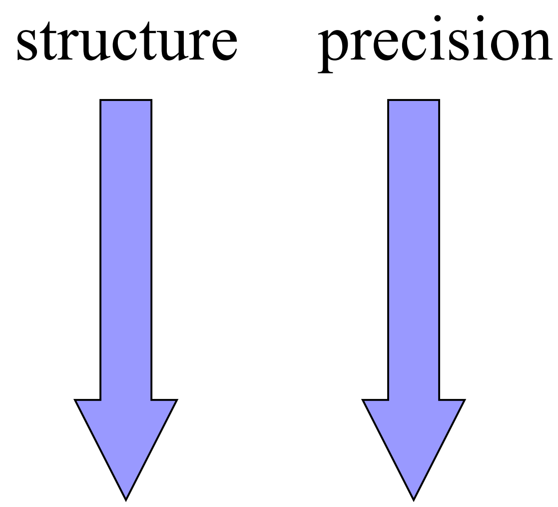


Data Sources



How is information stored? (high level)
How is information accessed? (user level)

- Text (IR)
- Semi-structured data
- Data models (DB)
- Rules + Facts (KB)



Databases

- Relational databases:

  - model: tables + relational algebra

  - query language (SQL)

- Object-oriented, extended-relational, NoSQL databases

Relational Databases

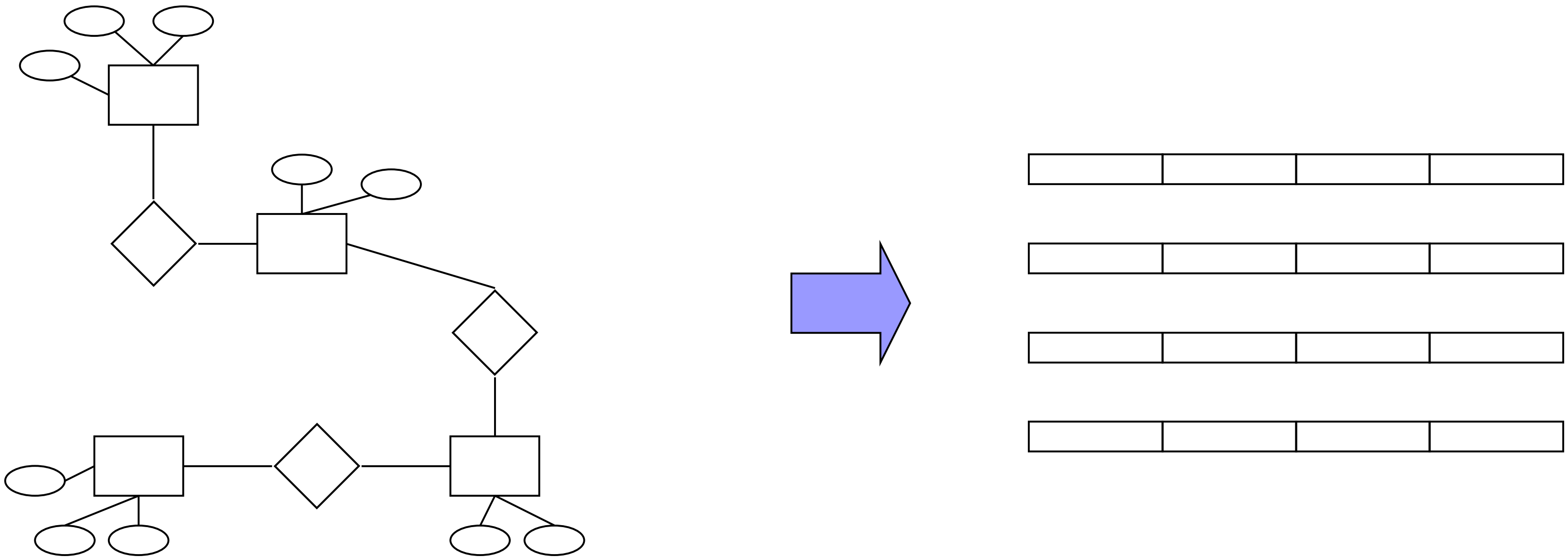
- Tables = relations (~ entity type)

  - row = tuple (~ entity)

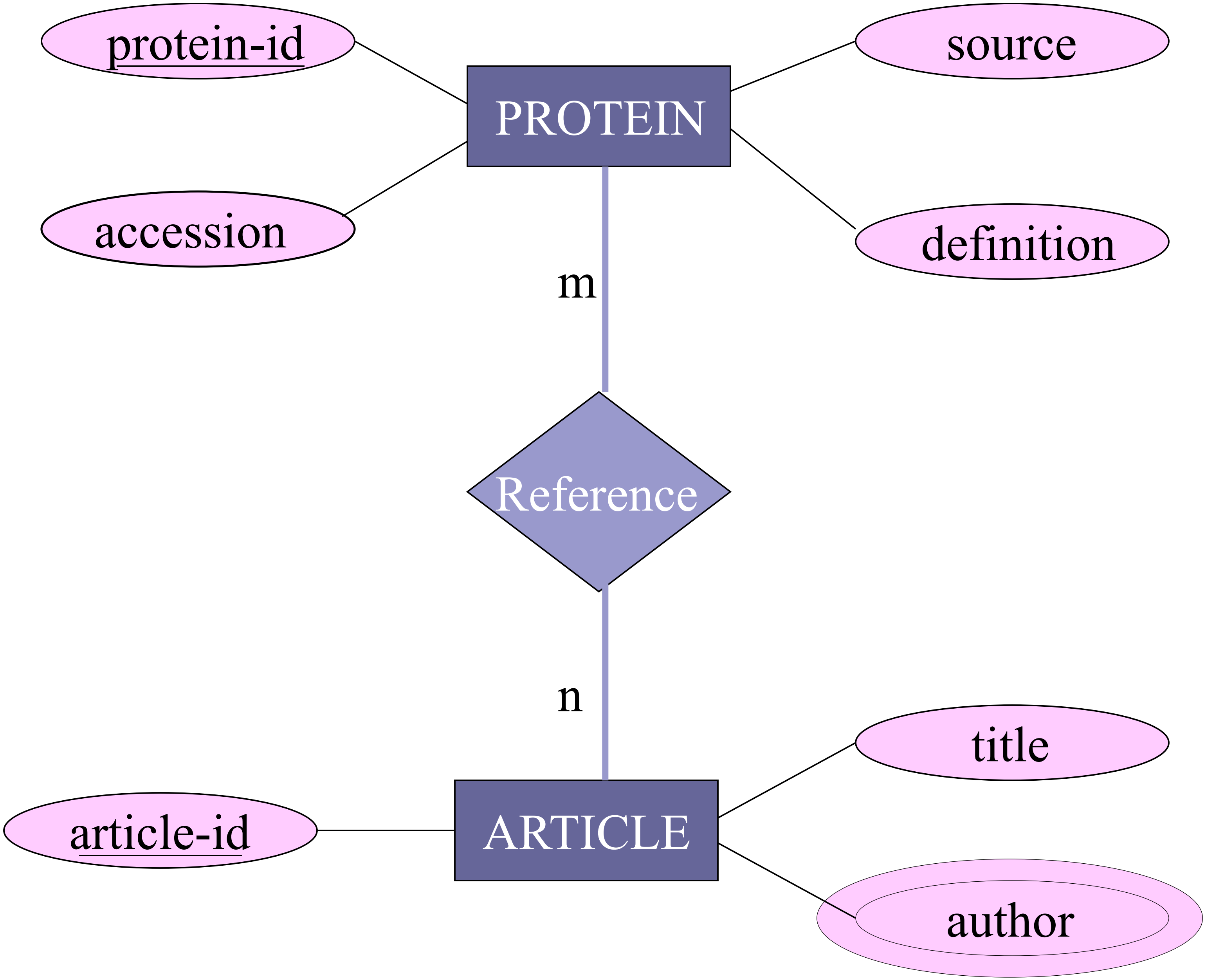
  - column = attribute (~ attribute)

- primary keys
- foreign keys

ER/EER to database schema



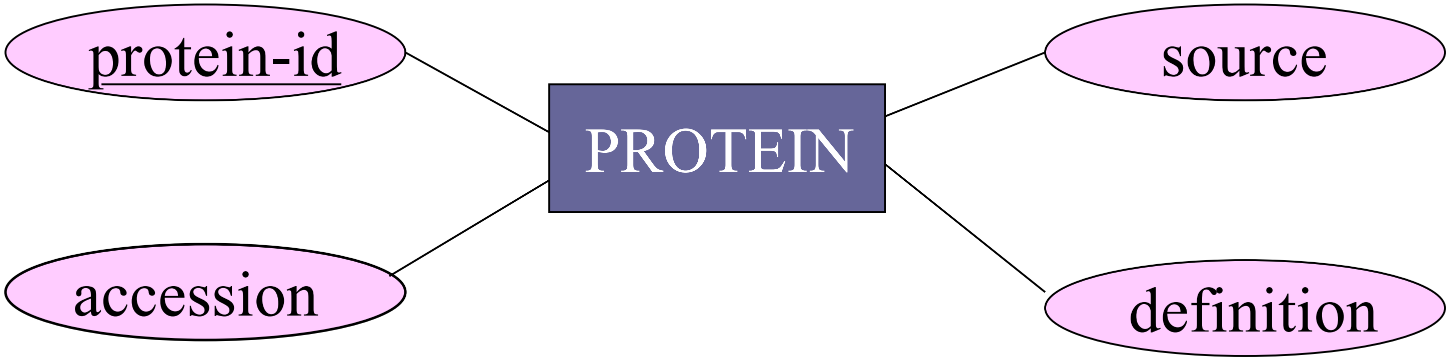
Entity-relationship



ER/EER to database schema

Step 1

For each (strong) entity E create a table R with the same simple attributes as the entity.



PROTEIN (PROTEIN-ID, ACCESSION, SOURCE, DEFINITION)

Author is multi-valued attribute.

ARTICLE-TITLE (<u>ARTICLE-ID,</u> TITLE)

GENE (GENE-ID, SOURCE)

ER/EER to database schema

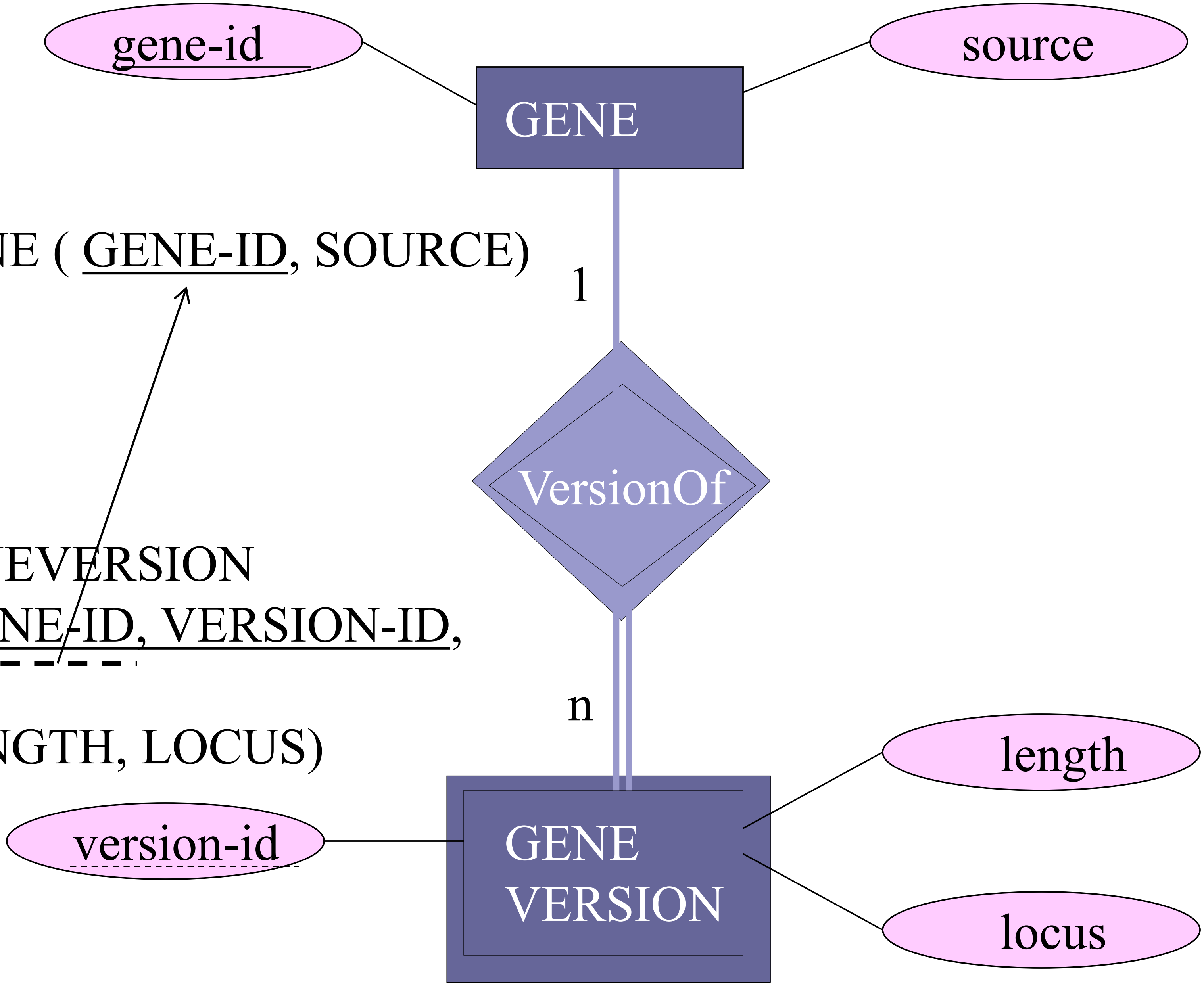
Step 2

For each weak entity W med owner entity E, create a table R with the same simple attributes as W and add the primary key attributes from the relation that corresponds to E.

GENE (<u>GENE-ID</u>, SOURCE)

GENEVERSION
(<u>GENE-ID, VERSION-ID</u>,

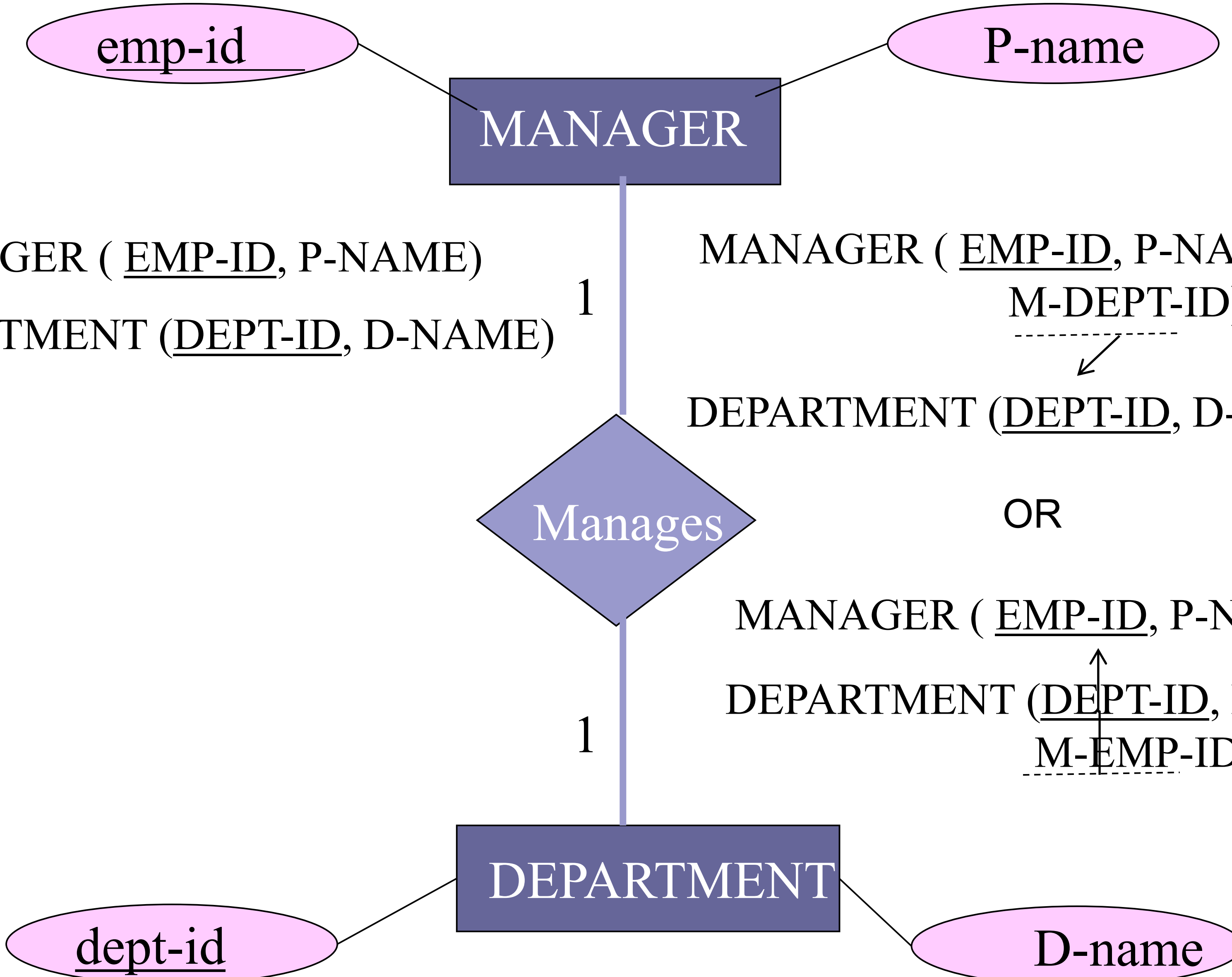
LENGTH, LOCUS)



ER/EER to database schema

Step 3

For each binary 1:1 relationship between S and T, add the primary key of the table corresponding to one of S or T as a foreign key to the table corresponding to the other.



MANAGER (EMP-ID, P-NAME)

DEPARTMENT (DEPT-ID, D-NAME)

MANAGER (EMP-ID, P-NAME, M-DEPT-ID)

DEPARTMENT (DEPT-ID, D-NAME)

OR

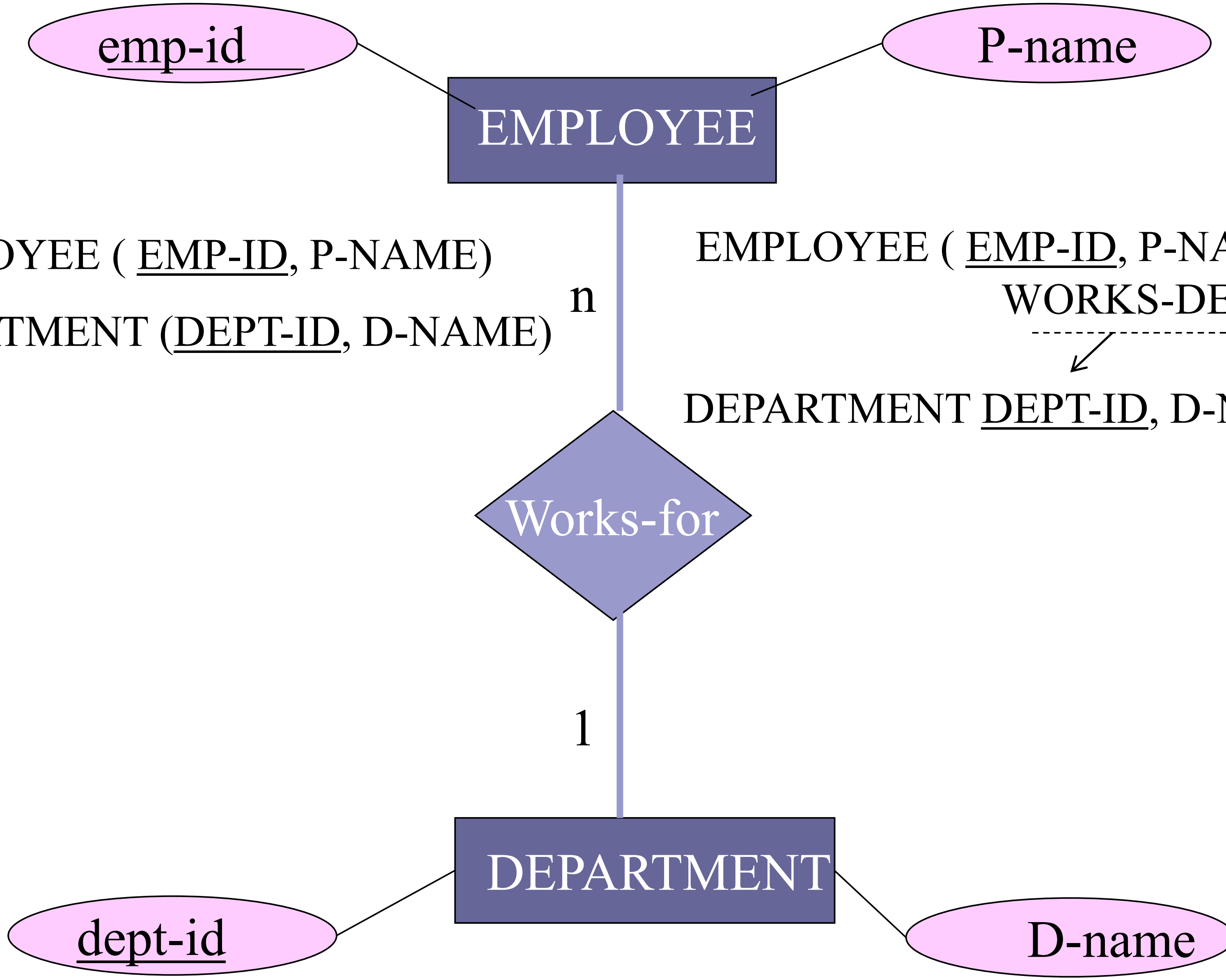
MANAGER (EMP-ID, P-NAME)

DEPARTMENT (DEPT-ID, D-NAME, M-EMP-ID)

ER/EER to database schema

Step 4

For each binary 1: n relationship between S and T (every S is related to many T, every T is related to one S), add the primary key of the table corresponding to S as a foreign key to the table corresponding to T.



EMPLOYEE (<u>EMP-ID</u>, P-NAME)

DEPARTMENT (<u>DEPT-ID</u>, D-NAME)

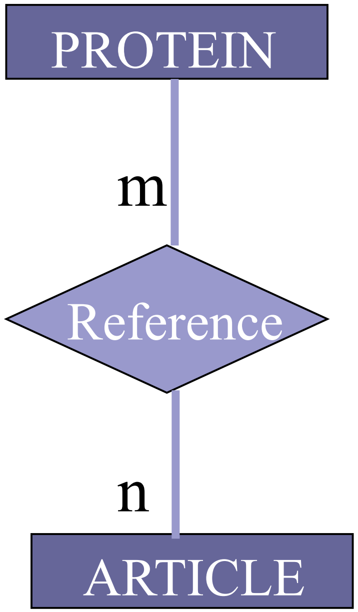
EMPLOYEE (<u>EMP-ID</u>, P-NAME, WORKS-DEPT-ID)

DEPARTMENT <u>DEPT-ID</u>, D-NAME)

ER/EER to database schema

Step 5

For each binary m : n relationship between S and T create a table R with the primary keys of the tables corresponding to S and T as foreign keys. If the relationship has attributes, then add these to R.



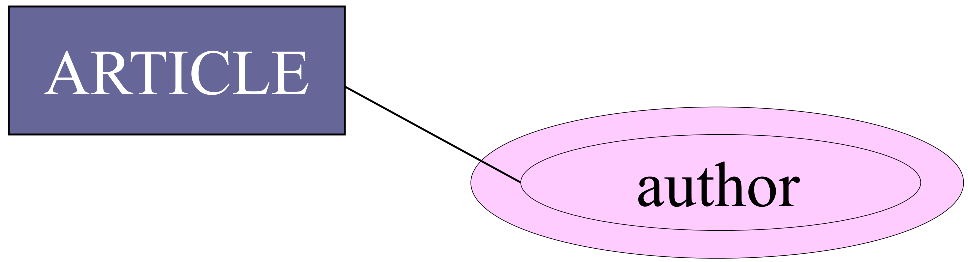
REFERENCE (PROTEIN-ID, ARTICLE-ID)

PROTEIN (PROTEIN-ID) ARTICLE (ARTICLE-ID)

ER/EER to database schema

Step 6

For every multi-valued attribute A in R, create a new table that contains an attribute corresponding to A and the primary key of R as foreign key.



ARTICLE-AUTHOR (ARTICLE-ID, AUTHOR)

ARTICLE (ARTICLE-ID)

Relational databases

PROTEIN

PROTEIN-ID	ACCESSION	DEFINITION	SOURCE
1	NM_000684	Homo sapiens adrenergic, beta-1-, receptor	human

REFERENCE

PROTEIN-ID	ARTICLE-ID
1	1
1	2

ARTICLE-AUTHOR

ARTICLE-ID	AUTHOR
1	Frielle
1	Collins
1	Daniel
1	Caron
1	Lefkowitz
1	Kobilka
2	Frielle
2	Kobilka
2	Lefkowitz
2	Caron

ARTICLE-TITLE

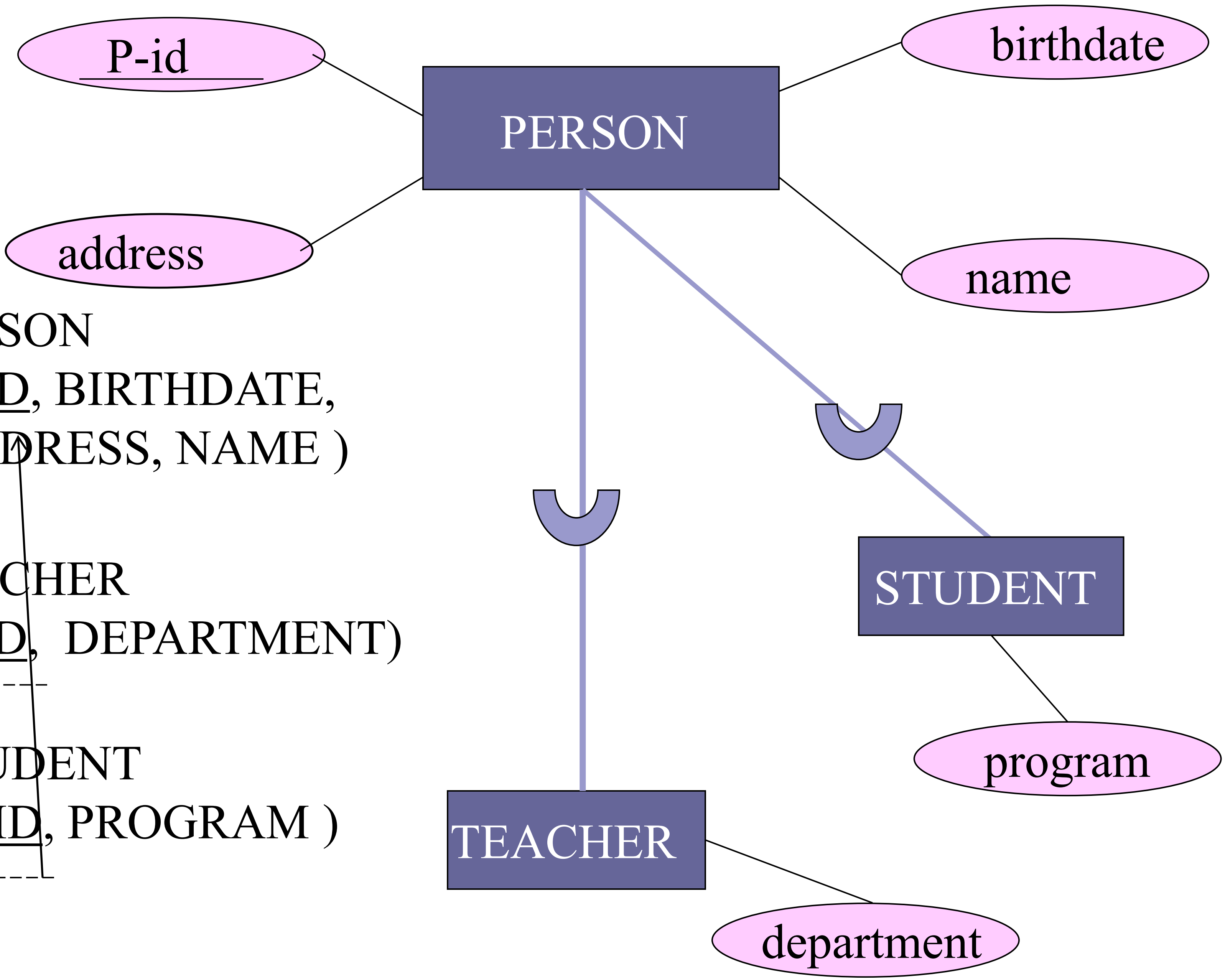
ARTICLE-ID	TITLE
1	Cloning of the cDNA for the human beta 1-adrenergic receptor
2	Human beta 1- and beta 2-adrenergic receptors: structurally and functionally related receptors derived from distinct genes

EER to database schema

Sub-type relationship

Assume type C has subtypes S_i

option 1: Create a relation R for C with all attributes in C. Then create relation R_i for each S_i with all attributes from S_i and the primary key from R.



PERSON
(<u>P-ID</u>, BIRTHDATE,
ADDRESS, NAME)

TEACHER
(<u>P-ID</u>, DEPARTMENT)

STUDENT
(<u>P-ID</u>, PROGRAM)

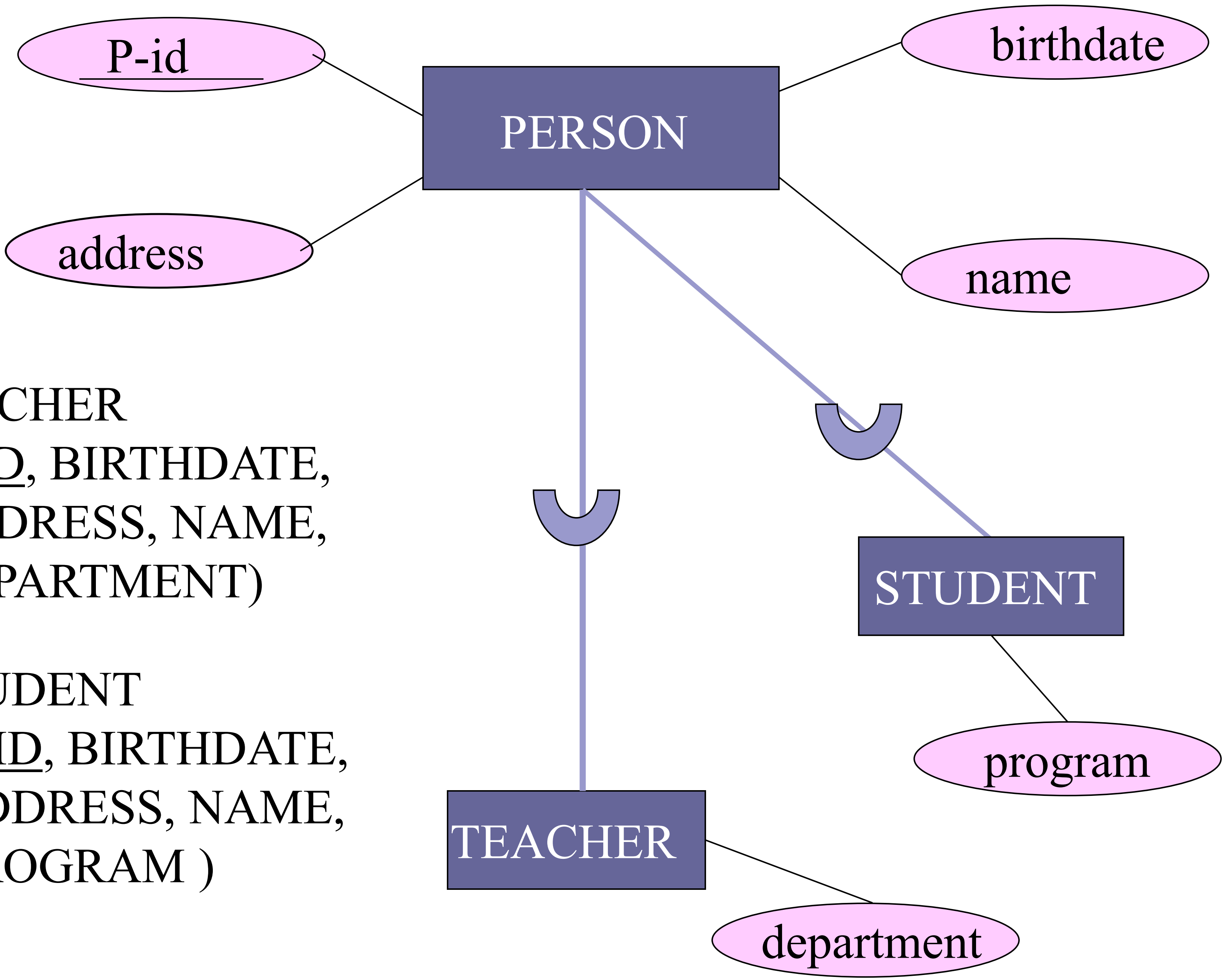
EER to database schema

Sub-type relationship

Assume type C has subtypes Si

option 2: Create a relation Ri for each Si with as attributes all attributes from Si and from C.

Only works if every C belongs to a Si.



TEACHER
(P-ID, BIRTHDATE,
ADDRESS, NAME,
DEPARTMENT)

STUDENT
(P-ID, BIRTHDATE,
ADDRESS, NAME,
PROGRAM)

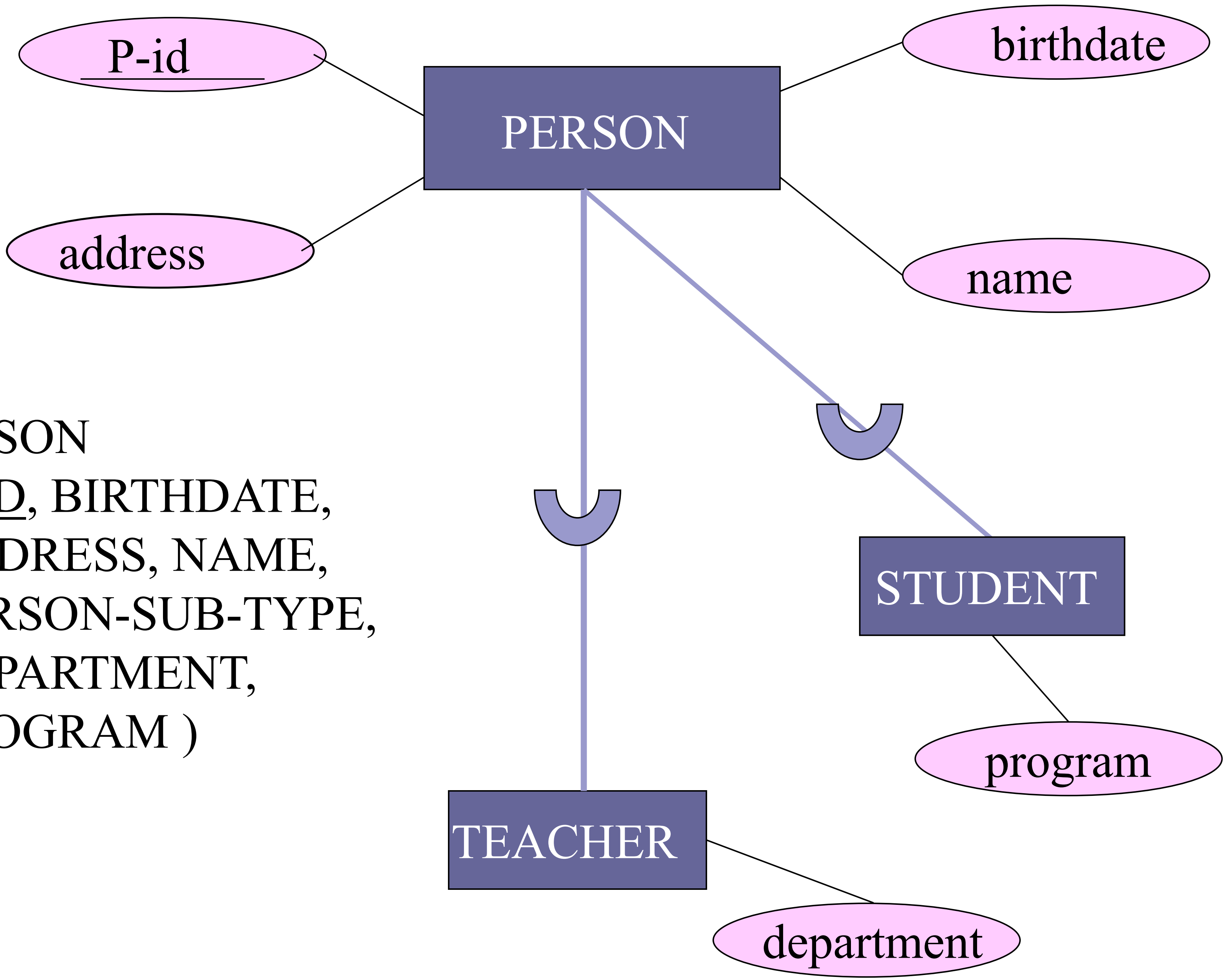
EER to database schema

Sub-type relationship

Assume type C has subtypes S_i

option 3: Create a relation R with all attributes from C and all attributes from the S_i. Add an attribute to discriminate between the subtypes.

Only works for disjoint subtypes.



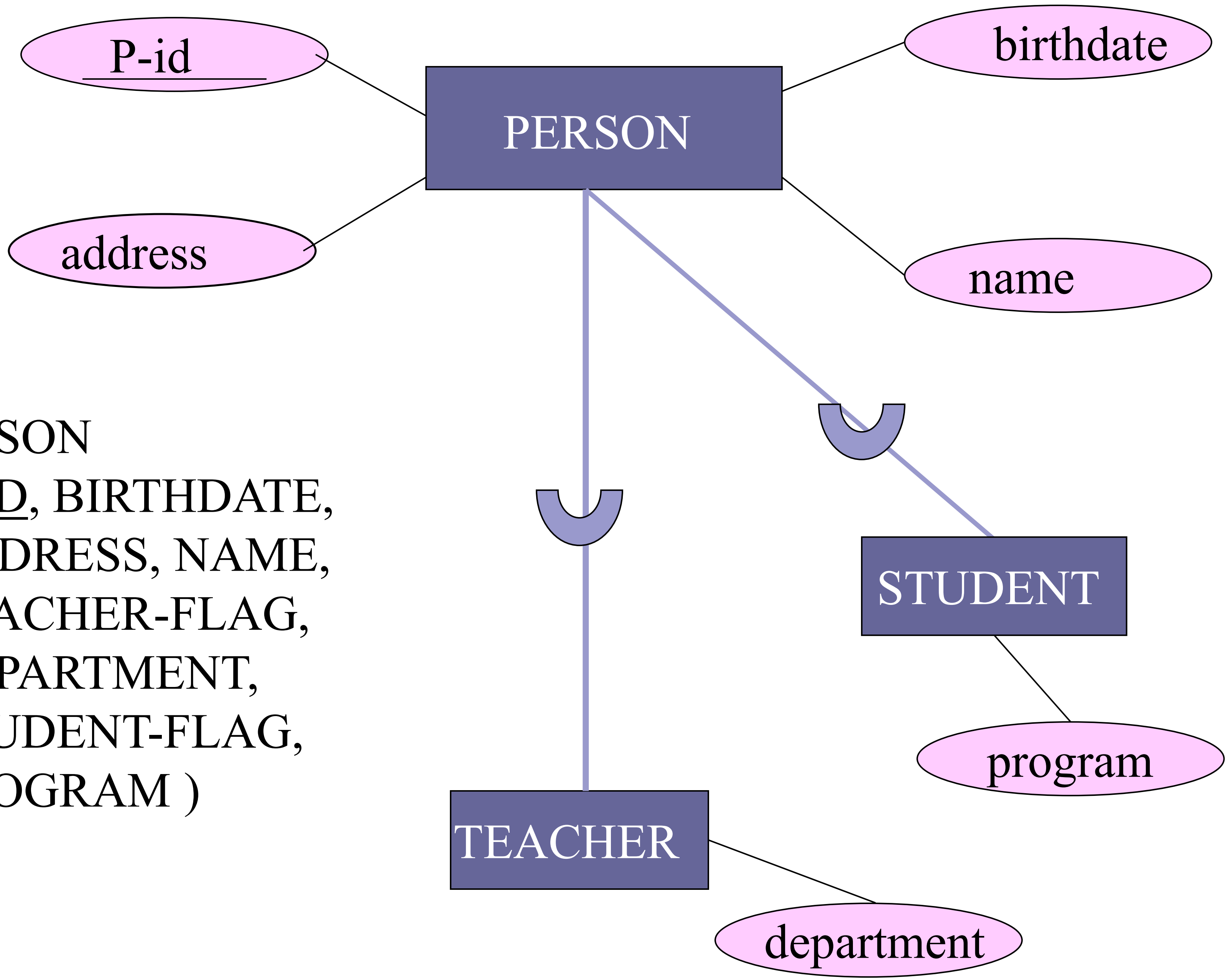
PERSON
(<u>P-ID</u>, BIRTHDATE,
ADDRESS, NAME,
PERSON-SUB-TYPE,
DEPARTMENT,
PROGRAM)

EER to database schema

Sub-type relationship

Assume type C has subtypes S_i

option 4: Create a relation R with all attributes from C and all attributes from the S_i. Add a flag attribute F_i to R for each S_i.



PERSON
(P-ID, BIRTHDATE,
ADDRESS, NAME,
TEACHER-FLAG,
DEPARTMENT,
STUDENT-FLAG,
PROGRAM)

SQL

select source
from protein
where accession = 'NM_000684';

PROTEIN

PROTEIN-ID	ACCESSION	DEFINITION	SOURCE
1	NM_000684	Homo sapiens adrenergic, beta-1-, receptor	human

SQL

select title
from protein, article-title, reference
where protein.accession = 'NM_000684'
  and protein.protein-id
    = reference.protein-id
  and reference.article-id
    = article-title.article-id;

REFERENCE

PROTEIN-ID	ARTICLE-ID
1	1
1	2

PROTEIN

PROTEIN-ID	ACCESSION	DEFINITION	SOURCE
1	NM_000684	Homo sapiens adrenergic, beta-1-, receptor	human

ARTICLE-TITLE

ARTICLE-ID	TITLE
1	Cloning of the …
2	Human beta 1- …

Database methods

2. Querying relational databases using SQL

SQL

- Developed by IBM Research as interface to System R. (197*, SEQUEL)
- QL, DDL and DML (queries, data definition, updates, views)
- used in many database systems
- table = relation, tuple = row, attribute = column

- EMPLOYEE (FNAME, MINIT, LNAME, SSN, BDATE, ADDRESS, SEX, SALARY, SUPERSSN, DNO)
- DEPT-LOCATIONS (DNUMBER, DLOCATION)
- DEPARTMENT (DNAME, DNUMBER, MGRSSN, MGRSTARTDATE)

- WORKS-ON (ESSN, PNO, HOURS)
- PROJECT (PNAME, PNUMBER, PLOCATION, DNUM)
- DEPENDENT (ESSN,DEPENDENT-NAME, SEX, BDATE, RELATIONSHIP)

SQL syntax

SELECT *attribute-list*

FROM *table-list*

WHERE *condition*;

- attribute-list: attributes that are required
- table-list: tables that are needed to process the query
- condition: expression with logical operators (and, or , not) and equality and inequality operators; identifies the tuples that should be retrieved

- Q1: List SSN for all employees.

SELECT SSN
FROM EMPLOYEE;

SSN
123456789
333445555
999887777
987654321
666884444
453453453
987987987
888665555

- Q2: List birth date and address for all employees whose name is `John B. Smith'.

SELECT BDATE, ADDRESS
FROM EMPLOYEE
WHERE FNAME = ‘John’
    AND MINIT = ‘B’
    AND LNAME = ‘Smith’;

BDATE	ADDRESS
1965-01-09	731 Fondren, Houston, TX

- Q3: List all information about the employees of department 5.

SELECT FNAME, MINIT, LNAME,SSN, BDATE, ADDRESS, SEX, SALARY, SUPERSSN, DNO

FROM EMPLOYEE

WHERE DNO = 5;

SELECT *
FROM EMPLOYEE
WHERE DNO = 5;

- Q4: List name and address for all employees that work at the research department.

```
SELECT FNAME, LNAME, ADDRESS
FROM EMPLOYEE, DEPARTMENT
WHERE DNAME = 'Research'
    AND DNUMBER = DNO;
```

```
SELECT *
FROM EMPLOYEE, DEPARTMENT
WHERE DNAME = 'Research'
      AND DNUMBER = DNO;
```

FNAME	….	DNO	DNAME	DNUMBER	…	MGRSTARTDATE
John	….	5	Research	5	…	1988-05-22
Franklin	….	5	Research	5	…	1988-05-22
Ramesh	….	5	Research	5	…	1988-05-22
Joyce	….	5	Research	5	…	1988-05-22

- Q5: List project number, department number and the name and address of the director of the department for all projects that are located in Stafford.

SELECT PNUMBER, DNUM, LNAME, ADDRESS

FROM PROJECT, DEPARTMENT, EMPLOYEE

WHERE PLOCATION = `Stafford'

AND DNUMBER = DNUM

AND SSN = MGRSSN;

```
SELECT PROJECT. PNUMBER,
  PROJECT.DNUM,
  EMPLOYEE.LNAME,
  EMPLOYEE.ADDRESS
FROM PROJECT, DEPARTMENT,
  EMPLOYEE
WHERE PROJECT.PLOCATION =
  `Stafford'
    AND DEPARTMENT.DNUMBER =
  PROJECT.DNUM
    AND EMPLOYEE.SSN =
  DEPARTMENT.MGRSSN;
```

- Q6: List first and last name for all employees together with first and last names of their bosses.

SELECT E.FNAME, E.LNAME, S.FNAME, S.LNAME

FROM EMPLOYEE E, EMPLOYEE S

WHERE E.SUPERSSN = S.SSN;

- SQL considers a table as a multi-set (bag), i.e. tuples can occur more than once in a table.
- Why?

\- Removing duplicates is expensive.

\- User may want information about duplicates.

\- Aggregation operators.

- Q7: List all salaries.

SELECT SALARY
FROM EMPLOYEE;

SELECT ALL SALARY
FROM EMPLOYEE;

- Q8: List all salaries without duplicates.

SELECT DISTINCT SALARY

FROM EMPLOYEE;

- Q9: List all project numbers for projects in which an employee with name Smith works or where the leader of the department to which the project belongs is called Smith.

(**SELECT DISTINCT** PNUMBER

FROM PROJECT, DEPARTMENT, EMPLOYEE

WHERE DNUM = DNUMBER **AND**

MGRSSN = SSN **AND** LNAME = ‘Smith’)

UNION

(**SELECT DISTINCT** PNUMBER

FROM PROJECT, WORKS-ON, EMPLOYEE

WHERE PNO = PNUMBER **AND**

ESSN = SSN **AND** LNAME = ‘Smith’);

- Q10: List all employees that live in Houston.

SELECT FNAME, LNAME

FROM EMPLOYEE

WHERE ADDRESS **LIKE** ‘%Houston%’;

- Q11: List names for all employees that are born in the 1950's.

SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE BDATE **LIKE** '_ _ 5%';

- Q12: List names and salaries for all employees that work with ProductX in case they would receive a raise of 10%.

SELECT FNAME, LNAME, 1.1 * SALARY

FROM EMPLOYEE, WORKS-ON, PROJECT

WHERE SSN = ESSN

AND PNO = PNUMBER

AND PNAME = `PRODUCTX';

- Q13: List all employees in department 5 with a salary between 30,000$ and 40,000$.

```
SELECT *
FROM EMPLOYEE
WHERE DNO = 5  AND
(SALARY BETWEEN 30000 AND
   40000);
```

- Q14: List all employees and the projects they work with sorted with respect to department and within the department sorted alphabetically with respect to last name and then first name.

SELECT DNAME, LNAME, FNAME, PNAME

FROM DEPARTMENT, EMPLOYEE, PROJECT, WORKS-ON

WHERE PNO = PNUMBER **AND** SSN = ESSN **AND** DNO = DNUMBER

ORDER BY DNAME, LNAME, FNAME;

SELECT DNAME, LNAME, FNAME, PNAME

FROM DEPARTMENT, EMPLOYEE, PROJECT, WORKS-ON

WHERE PNO = PNUMBER **AND** SSN = ESSN **AND** DNO = DNUMBER

ORDER BY DNAME **DESC**, LNAME **ASC**, FNAME **ASC**;

- Q15: List SSN for all employees that work with the same project at the same times as the person with SSN '123456789' (John Smith).

SELECT ESSN

FROM WORKS-ON

WHERE (PNO, HOURS) **IN**

(**SELECT** PNO, HOURS

FROM WORKS-ON

WHERE ESSN = '123456789');

```
SELECT E.ESSN
FROM WORKS-ON E, WORKS-ON JS
WHERE JS.ESSN = '123456789'
   AND E.PNO = JS.PNO
   AND E.HOURS = JS.HOURS;
```

- Q16: List all employees whose salary is higher than the salaries of the employees who work at department 5.

SELECT LNAME, FNAME

FROM EMPLOYEE

WHERE SALARY > **ALL**

(**SELECT** SALARY

FROM EMPLOYEE

WHERE DNO = 5);

- Q17: List all employees whose salary is higher than the salary of some employee who works at department 5.

```
SELECT LNAME, FNAME
FROM EMPLOYEE
WHERE SALARY > SOME
(SELECT SALARY
FROM EMPLOYEE
WHERE DNO = 5);
```

- Q18: List all employees that do not have a relative at the company.

```
SELECT LNAME, FNAME
FROM EMPLOYEE
WHERE NOT EXISTS
(SELECT *
FROM DEPENDENT
WHERE SSN = ESSN);
```

- Q19: List all department managers that have at least one relative at the company.

SELECT LNAME, FNAME

FROM EMPLOYEE

WHERE EXISTS

(**SELECT** *

FROM DEPARTMENT

WHERE SSN = MGRSSN)

AND EXISTS

(**SELECT** *

FROM DEPENDENT

WHERE SSN = ESSN);

- Q20: List SSN for all employees that work with project 1, 2 or 3.

SELECT DISTINCT ESSN

FROM WORKS-ON

WHERE PNO **IN** (1, 2, 3);

- Q21: List all employees that do not have a boss.

```
SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE SUPERSSN IS NULL;
```

- Q22: List the sum, the highest, lowest and average of the salaries of the employees of the research department.

```
SELECT SUM(SALARY),
  MAX(SALARY), MIN(SALARY),
  AVG(SALARY)
FROM EMPLOYEE, DEPARTMENT
WHERE DNAME = 'Research'
  AND DNO = DNUMBER;
```

- Q23: List the number of employees.

SELECT COUNT(*)
FROM EMPLOYEE;

- Q24: List for each department the department number, the number of employees and the average salary.

```
SELECT DNO, COUNT(*),
  AVG(SALARY)
FROM EMPLOYEE
GROUP BY DNO;
```

DNO	COUNT(*)	AVG_SALARY
5	4	33250
4	3	31000
1	1	55000

- Q25: List for each project the project number, project name and the number of employees that work with the project.

SELECT PNUMBER, PNAME, **COUNT**(*)

FROM PROJECT, WORKS-ON

WHERE PNUMBER = PNO

GROUP BY PNUMBER, PNAME;

- Q26: List for each project with at least 2 employees the project number, project name and number of employees that work with the project.

SELECT PNUMBER, PNAME, **COUNT**(*)

FROM PROJECT, WORKS-ON

WHERE PNUMBER = PNO

GROUP BY PNUMBER, PNAME

HAVING COUNT(*) > 1;

Creating new tables

CREATE TABLE DEPTS-INFO

(DEPT-NUMBER integer **primary key**,

DEPT-NAME varchar(15),

NO-OF-EMPLOYEES integer,

TOTAL-SAL integer,

foreign key (DEPT-NUMBER) **references** DEPARTMENT(DNUMBER));

```
INSERT INTO DEPTS-INFO
( DEPT-NUMBER, DEPT-NAME,
NO-OF-EMPLOYEES, TOTAL-SAL)
SELECT DNUMBER, DNAME,
   COUNT (*), SUM(SALARY)
FROM DEPARTMENT, EMPLOYEE
WHERE DNUMBER = DNO
GROUP BY DNUMBER, DNAME;
```