Chapter 2:
Entity-Relationship Model

Jan - 2015

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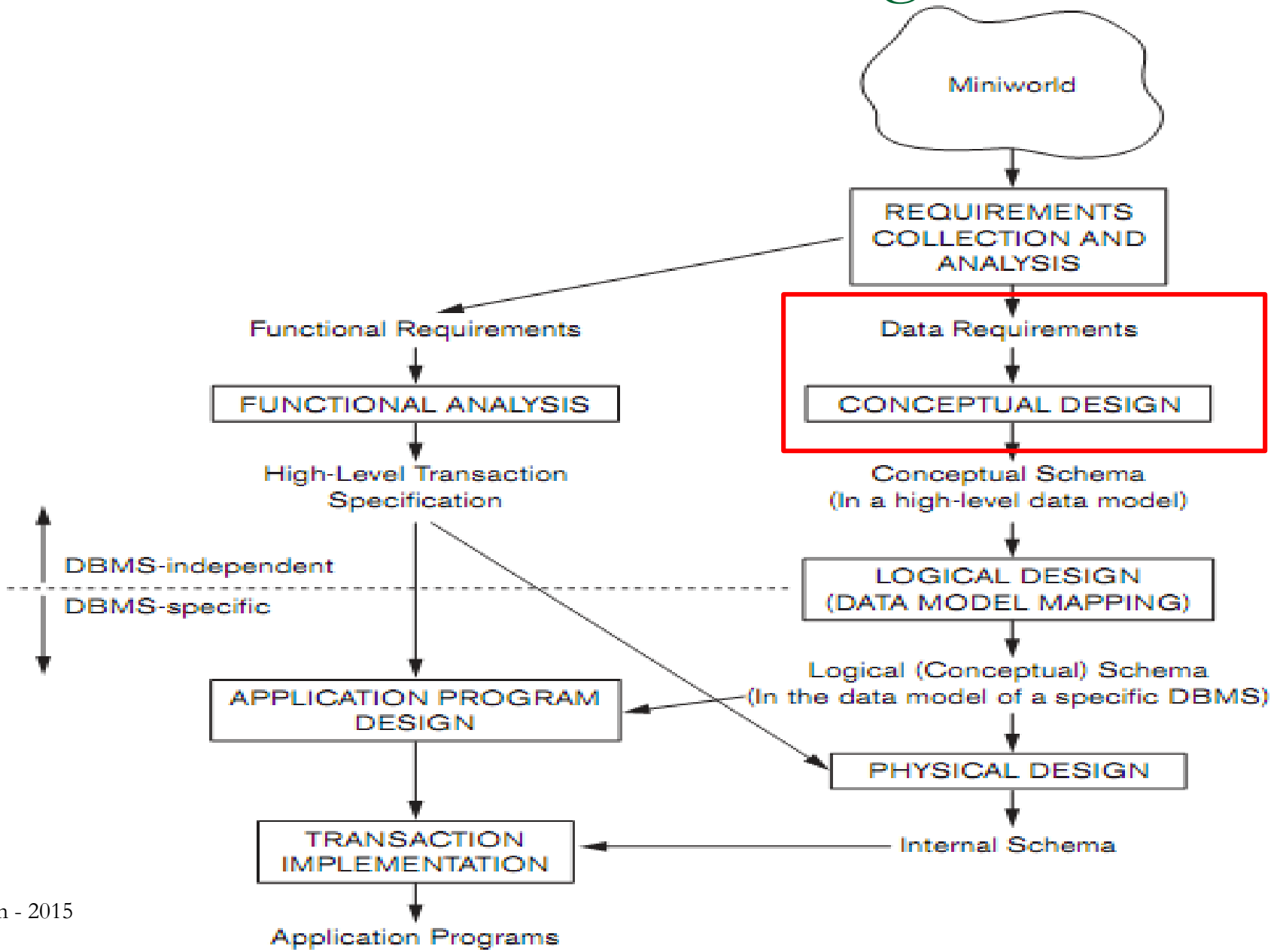
Overview of Database Design Process

- Two main activities:
  - Database design
  - Applications design
- Focus in this chapter on database design
  - To design the conceptual schema for a database application
- Applications design focuses on the programs and interfaces that access the database
  - Generally considered part of software engineering

Overview of Database Design Process



Overview of Database Design Process

- **Requirements collection and analysis**
  - Database designers interview prospective database users to understand and document data requirements
  - Result:
    - Data requirements
    - Functional requirements

Overview of Database Design Process

- **Conceptual design**
  - Create a conceptual schema for the database.
    - Description of data requirements
    - Uses the concepts provided by the high-level data model
    - Includes detailed descriptions of the entity types, relationships, and constraints
    - Independent of storage and implementation details.

Overview of Database Design Process

- **Logical design or data model mapping**
  - Result is a database schema in implementation data model of DBMS
- **Physical design phase**
  - Internal storage structures, file organizations, indexes, access paths, and physical design parameters for the database files specified

Contents

What is ER Model?

- **Entity-Relationship (ER) model**
  - Popular high-level conceptual data model
  - A logical organisation of data within a database system
- **ER diagrams:**
  - Diagrammatic notation associated with the ER model

Why use ER data modelling?

- User requirements can be specified formally & unambiguously
- The conceptual data model is independent of any particular DBMS
- It does not involve any physical or implemental details
- It can be easily understood by ordinary users.
- It provides an effective bridge between user requirements and logical database design and implementation

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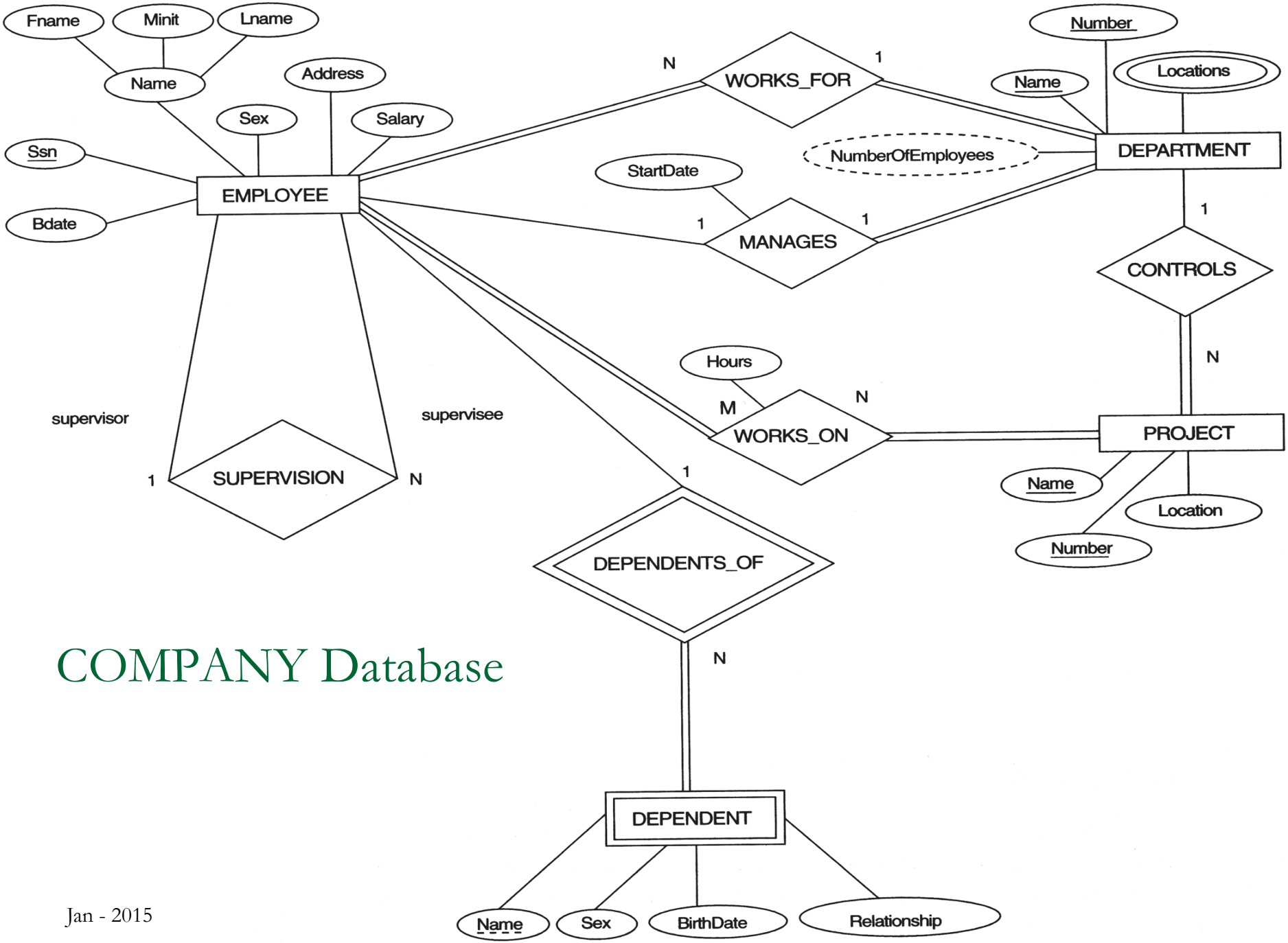
A Sample Database Application

- The **COMPANY** database: keeps track of **employees, departments, and projects.**
- The company is organized into DEPARTMENTs. Each department has a unique name, a unique number, and a particular employee who *manages* the department. We keep track of the start date when that employee began managing the department. A department may have several locations.
- A department controls a number of PROJECTs, each of which has a unique name, a unique number, and a single location.

A Sample Database Application

- We store EMPLOYEE's name, Social Security number, address, salary, sex, and birth date. *An employee is assigned to one department, but may work on several projects*, which are not necessarily controlled by the same department. We keep track of the current number of hours per week that an employee works on each project. We also keep track of the direct supervisor of each employee.
- We want to keep track of the DEPENDENTs of each employee, including first name, sex, birth date, and relationship to the employee.



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ER Model Concepts

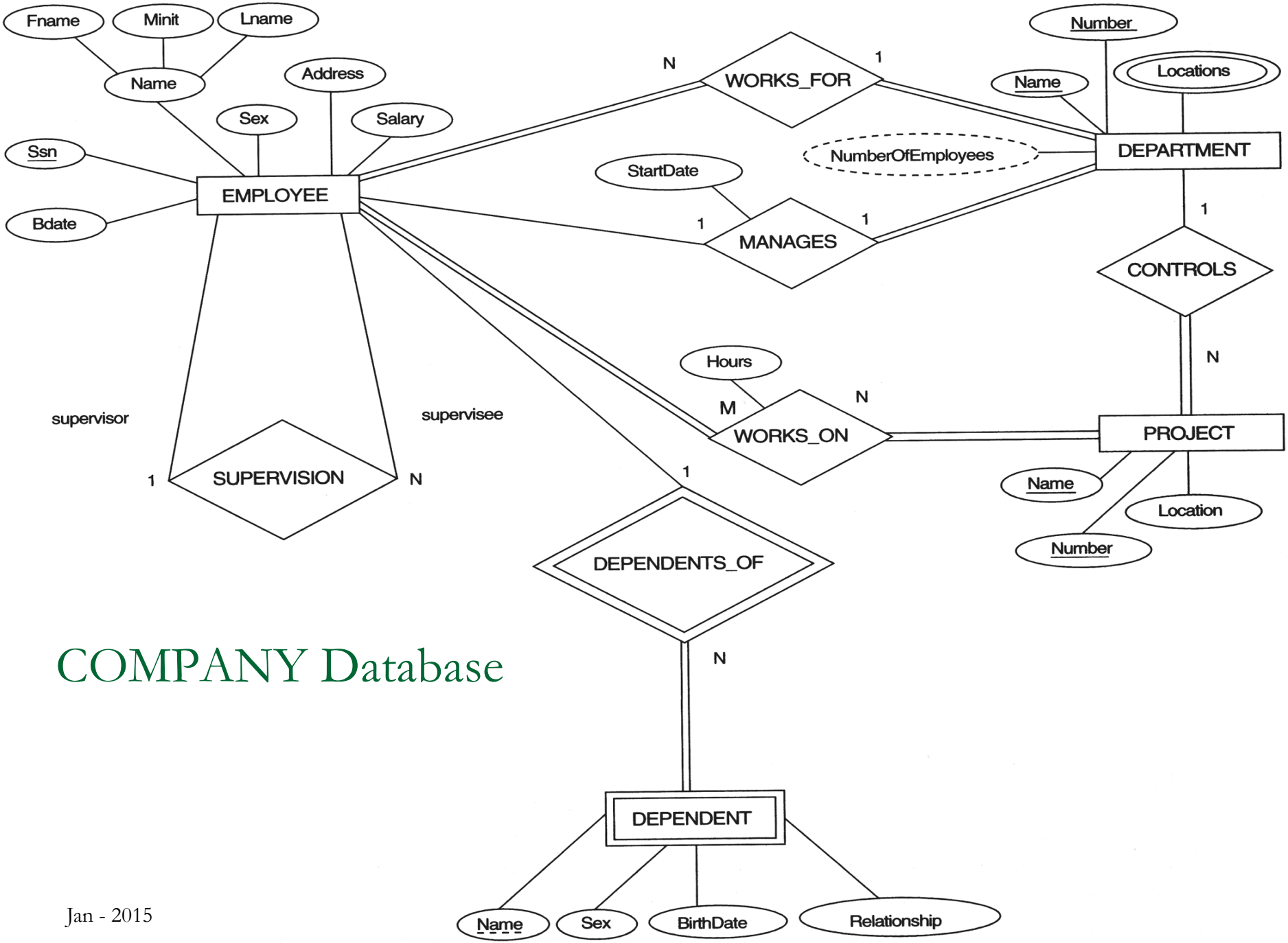
- ER model describes data as:
  - Entities
  - Relationships
  - Attributes

Entities and Attributes

- **Entity** is a thing in the real world with an independent existence.
  - Ex: the EMPLOYEE John Smith, the Research DEPARTMENT, the ProductX PROJECT
- **Attributes** are properties described an entity.
  - Ex: an EMPLOYEE entity may have Name, SSN, Address, Sex, BirthDate
- A specific entity will have a value for each of its attributes
- Each attribute has a **value set** (or data type) associated with it.

Entities and Attributes

- **Types of Attributes**
  - **Simple attributes:** each entity has a single atomic value for the attribute.
  - **Composite attributes:** attribute may be composed of several components.
  - **Multi-valued attributes:** an entity may have multiple values for that attribute.
  - **Derived:** attribute represents a value that is derivable from value of a related attribute, or set of attributes.
  - **Complex attributes:** composite and multivalued attributes can be nested arbitrarily



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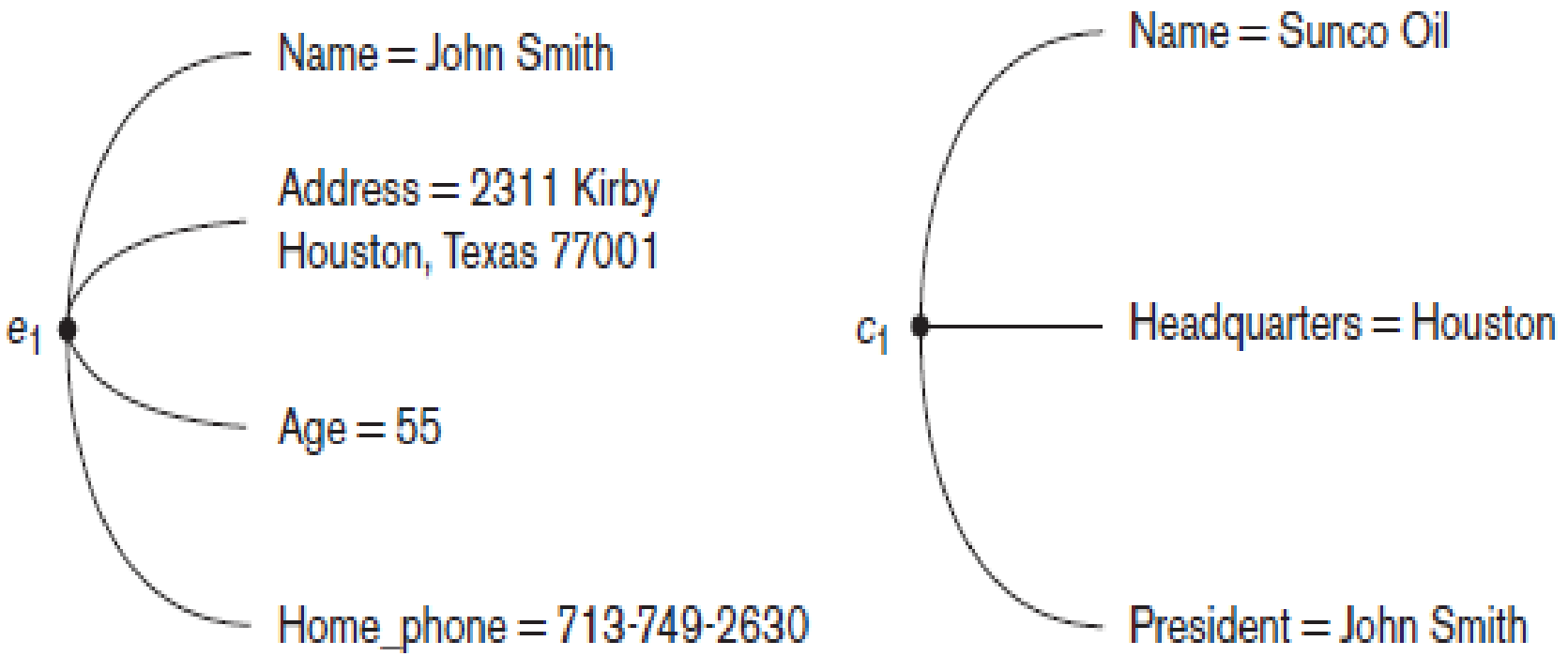
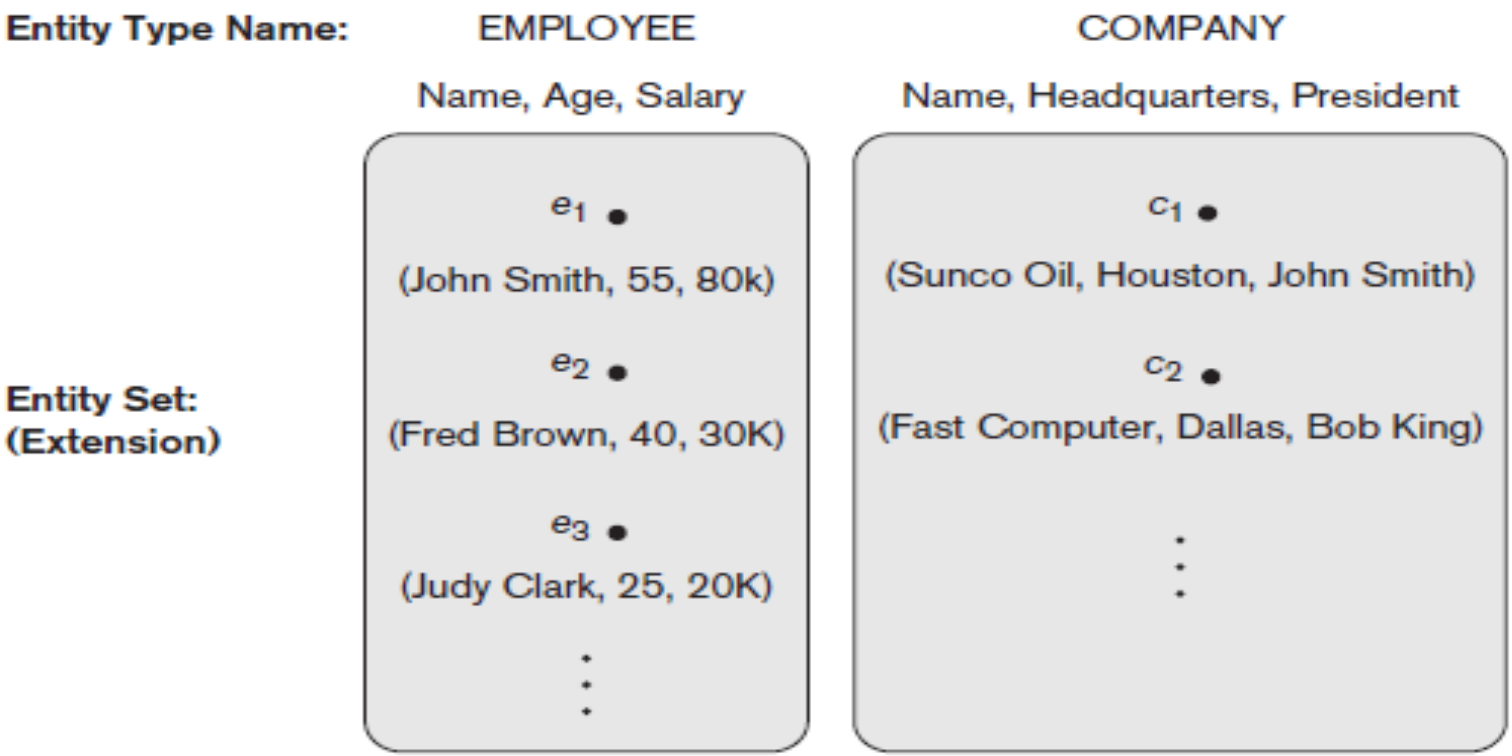
Entities and Attributes



Two entities, EMPLOYEE e1, and COMPANY c1, and their attributes.

Entity Types and Keys

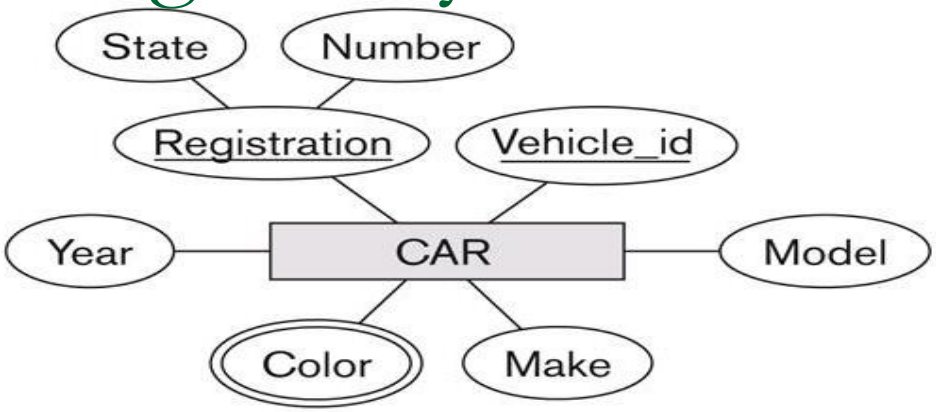
- Entity type
  - Collection (or set) of entities that have the same attributes



Entity Types and Keys

- **Key** or **uniqueness constraint**
  - Attributes whose values are distinct for each individual entity in entity set
  - Uniqueness property must hold for every entity set of the entity type
  - Ex: SSN of EMPLOYEE
- An entity type may have more than one key.
  - Ex: the STUDENT entity type may have two keys (in university context):
    - Citizen ID and
    - Student ID

Entity Type CAR with two keys and a corresponding Entity Set



CAR

Registration (Number, State), Vehicle_id, Make, Model, Year, {Color}

CAR_1

((ABC 123, TEXAS), TK629, Ford Mustang, convertible, 2004 {red, black})

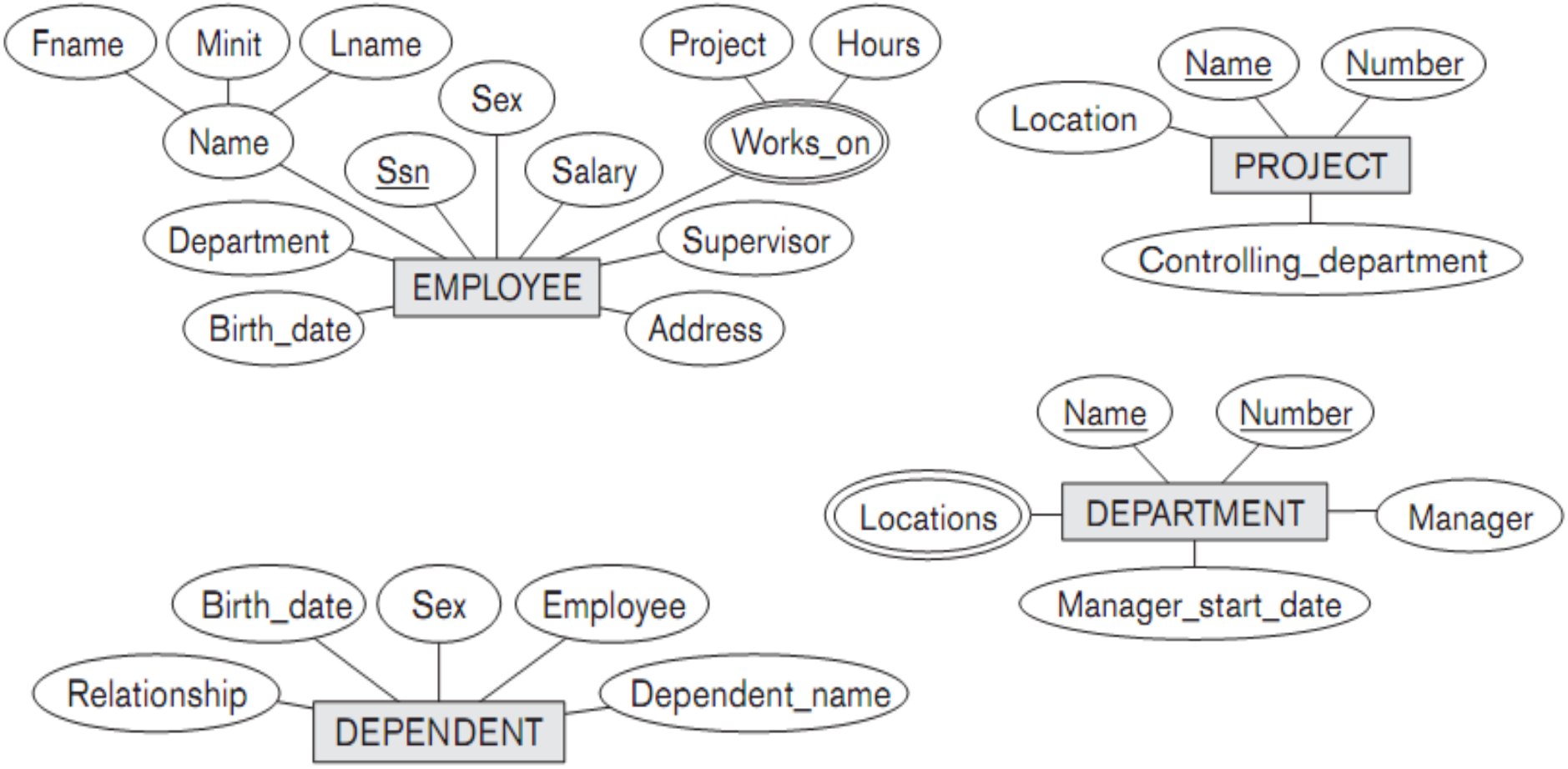
CAR_2

((ABC 123, NEW YORK), WP9872, Nissan Maxima, 4-door, 2005, {blue})

CAR_3

((VSY 720, TEXAS), TD729, Chrysler LeBaron, 4-door, 2002, {white, blue})

Initial Conceptual Design of COMPANY Database



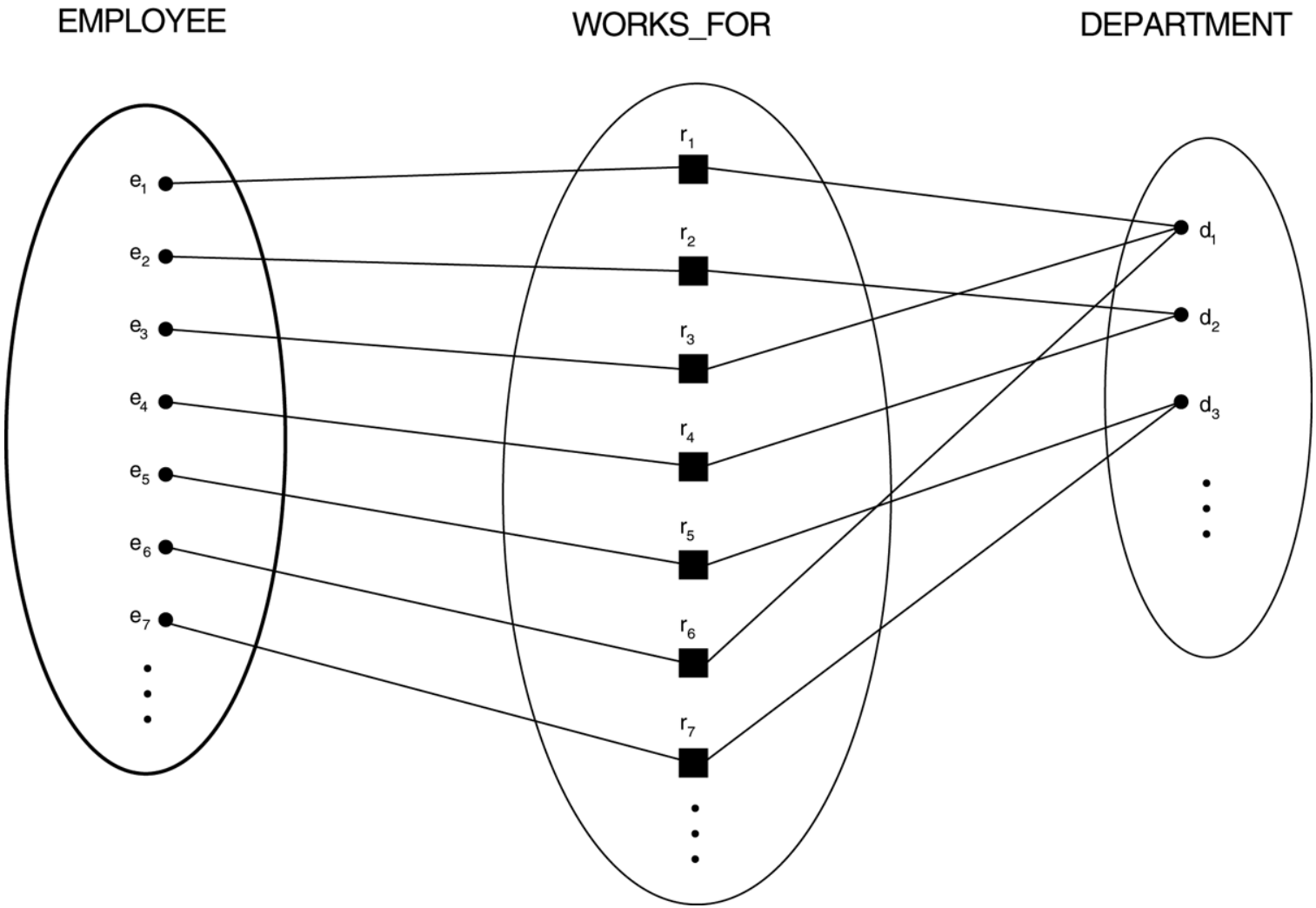
Relationships and Relationship Types

- **Relationship type** *R* among *n* entity types $E_1, E_2, ..., E_n$
  - Defines a set of associations among entities from these entity types
  - Ex: the WORKS_FOR relationship type in which EMPLOYEEs & DEPARTMENTs participate
- **Relationship instances** r_i
  - Each r_i associates n individual entities ($e_1, e_2, ..., e_n$). Each entity e_j in r_i is a member of entity set E_j
  - Ex: EMPLOYEE John Smith works on the ProductX PROJECT

Relationships and Relationship Types

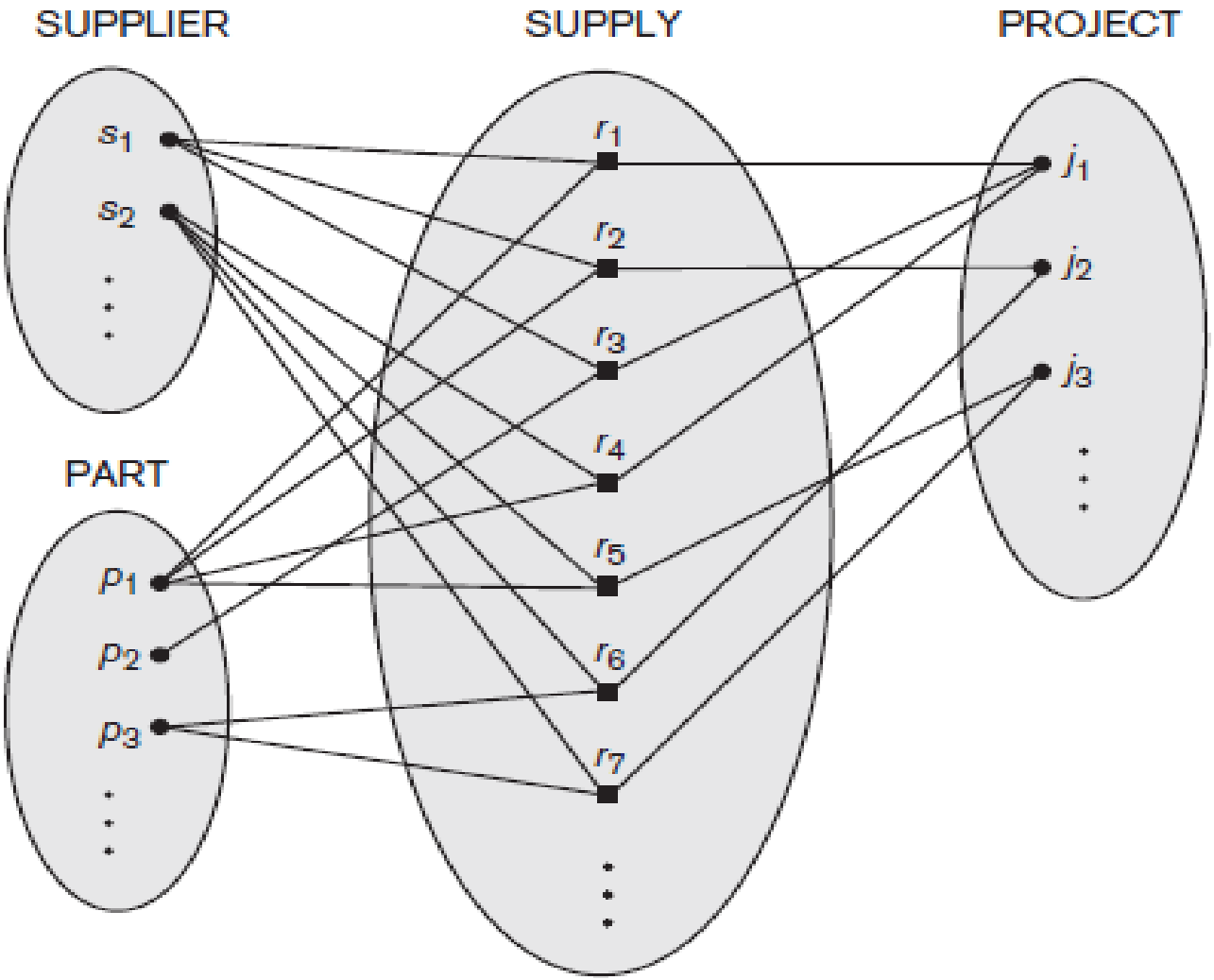
- **Degree** of a relationship type
  - Number of participating entity types
  - Binary (degree 2), ternary (degree 3), and n-ary (degree n)
- More than one relationship type can exist with the same participating entity types.
  - Ex: MANAGES and WORKS_FOR are distinct relationships between EMPLOYEE and DEPARTMENT, but with different meanings and different relationship instances

Example relationship instances

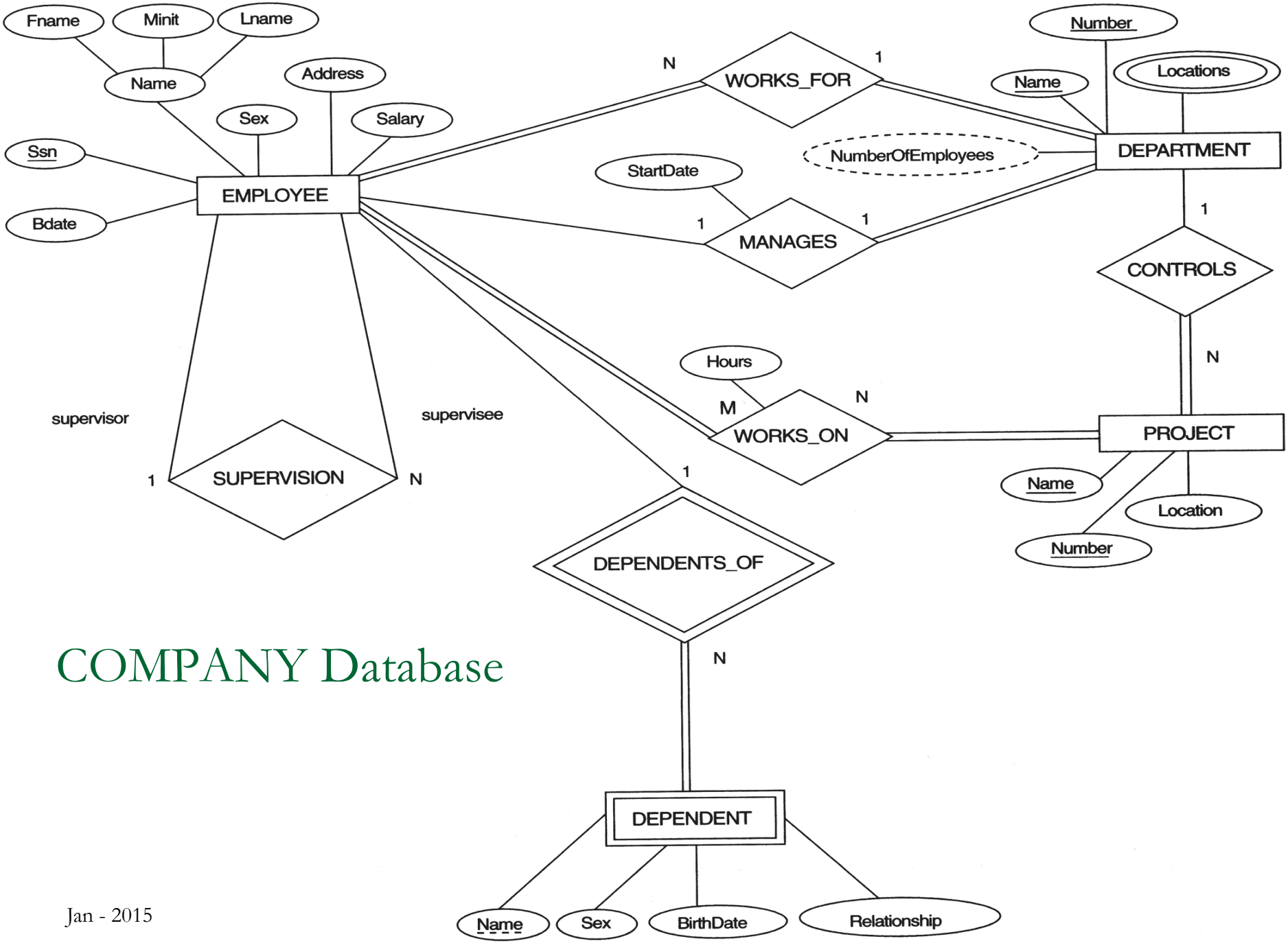


A binary relationship

Example relationship instances



A ternary relationship



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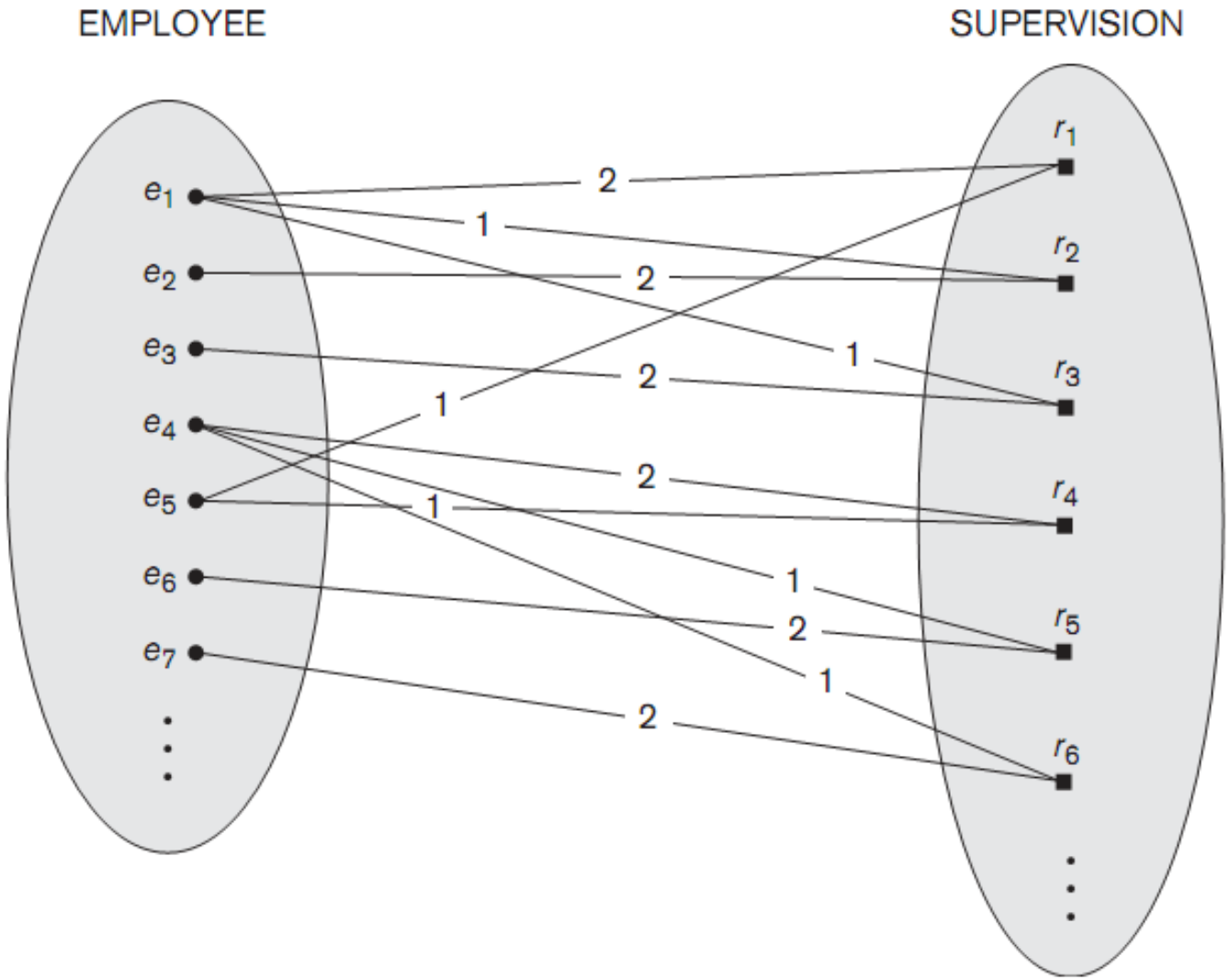
Relationships and Relationship Types

- **Recursive** relationships
  - Same entity type participates more than once in a relationship type in different roles
  - Must specify role that a participating entity plays in each relationship instance
  - Ex: SUPERVISION relationships between EMPLOYEE (in role of supervisor or boss) and (another) EMPLOYEE (in role of subordinate or worker)

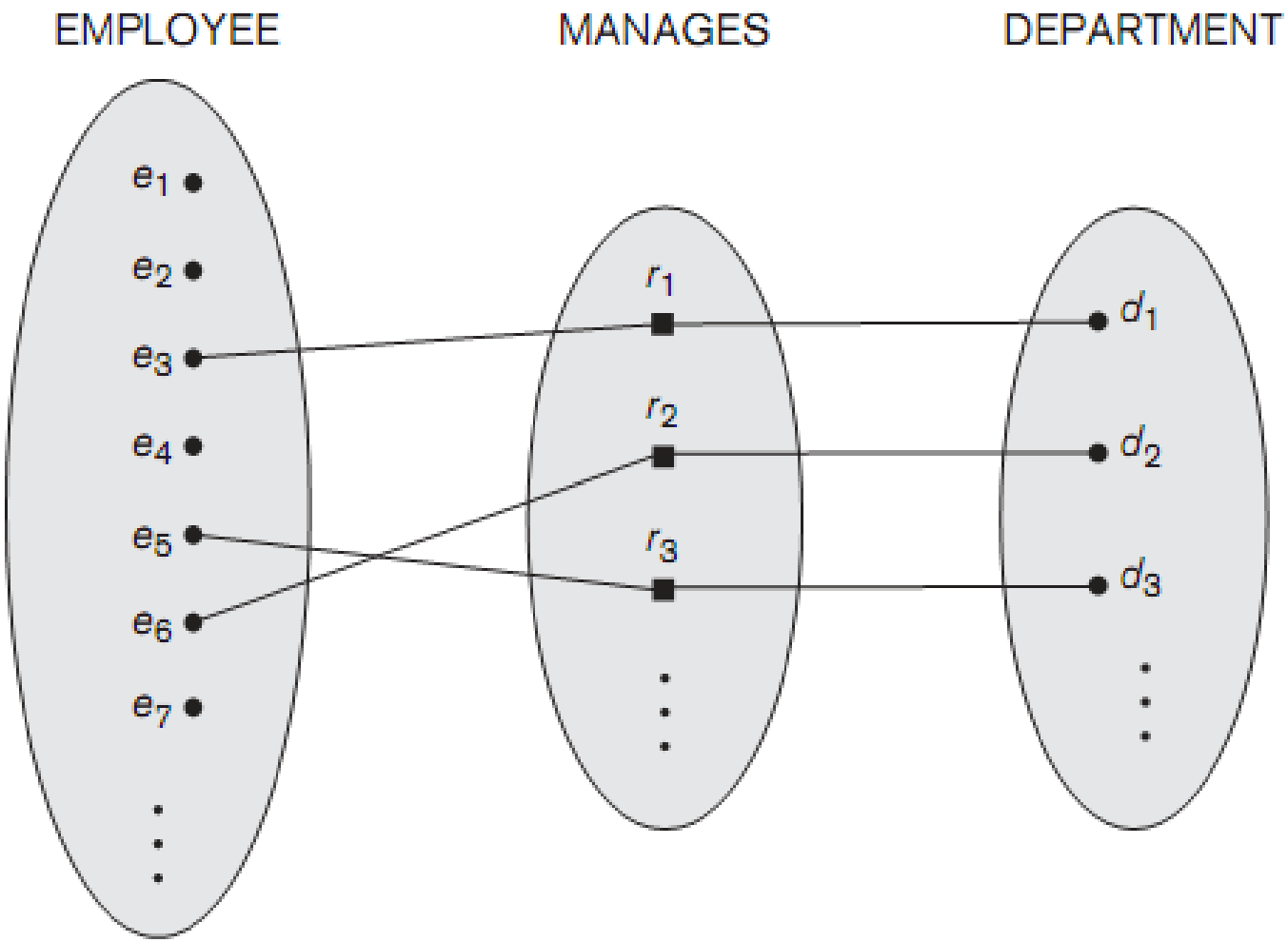
A Recursive Relationship SUPERVISION



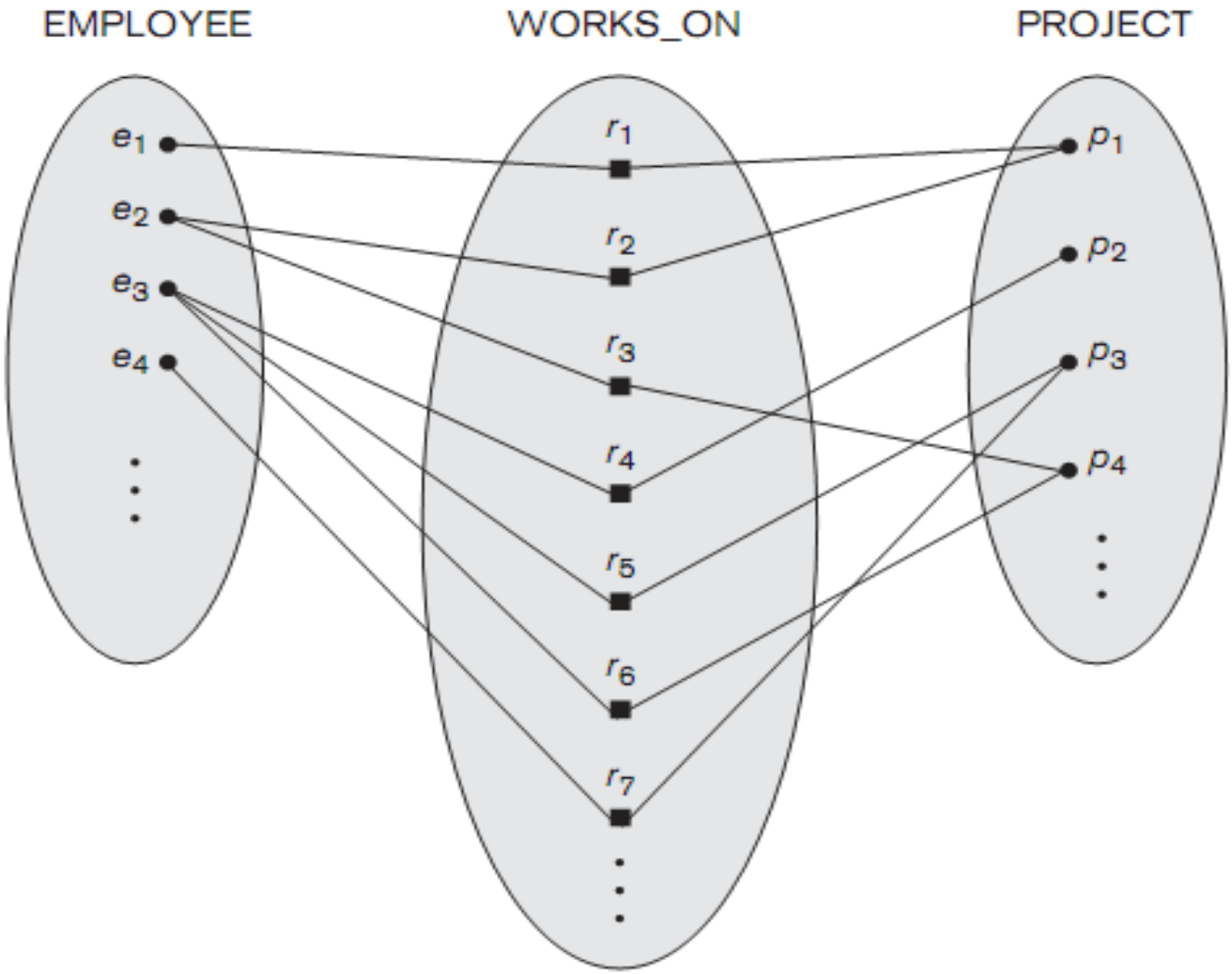
Constraints on Binary Relationship Type

- **Structural constraints**: one way to express semantics of relationship: cardinality ratio and membership class
- **Cardinality ratio**: specifies maximum number of relationship instances that entity can participate in a binary relationship.
  - one-to-one (1:1)
  - one-to-many (1:M) or many-to-one (M:1)
  - many-to-many (M:N)

One-to-one (1:1) Relationship

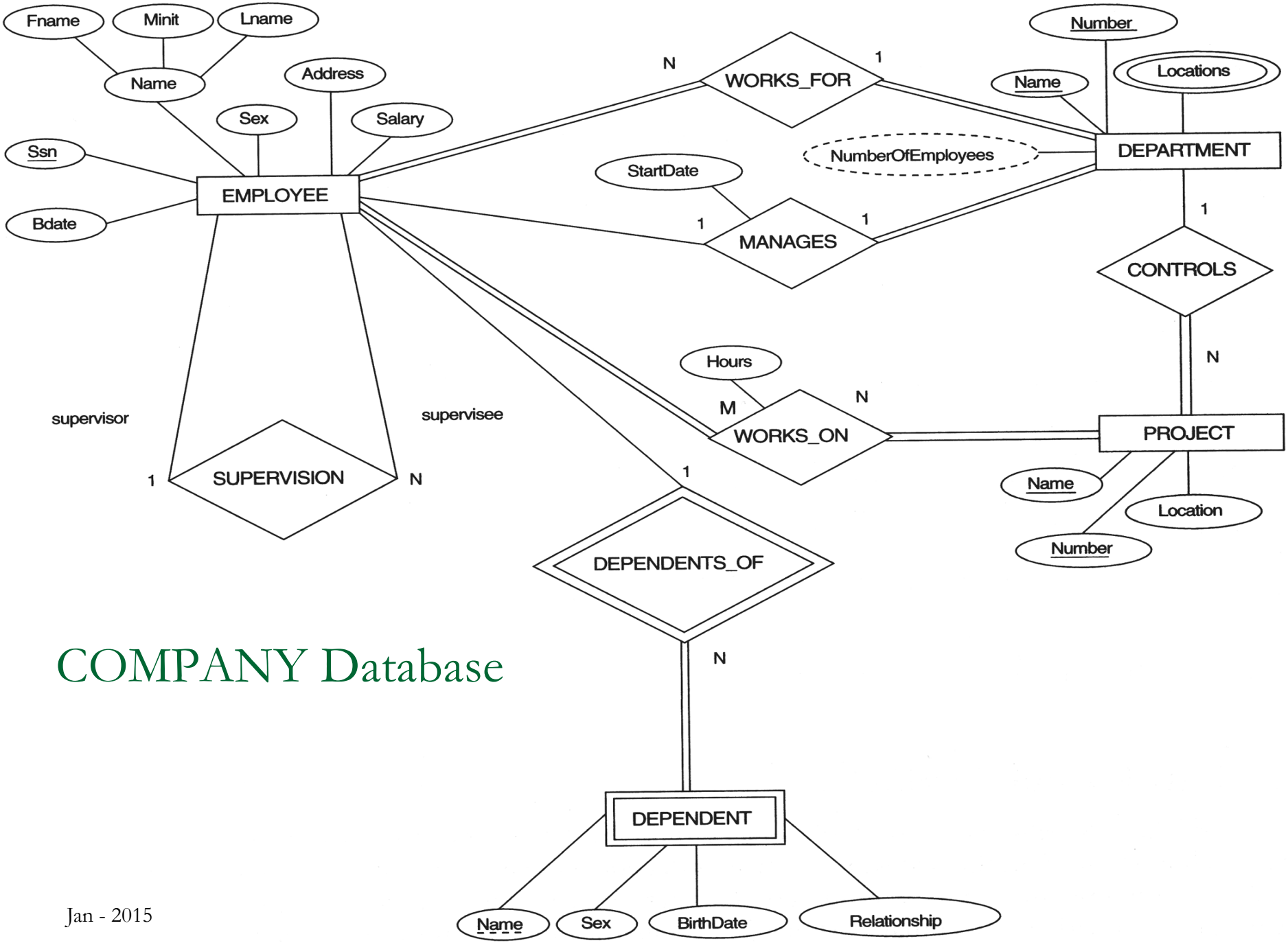


Many-to-many (M:N) Relationship



Constraints on Binary Relationship Type

- **Membership class (or participation constraint):** specifies whether existence of entity depends on its being related to another entity
  - **Mandatory (total participation)** - every instance of a participating entity type must participate in the relationship. (double line)
  - **Optional (partial participation)** - not every instance of a participating entity type must participate in the relationship. (single line)



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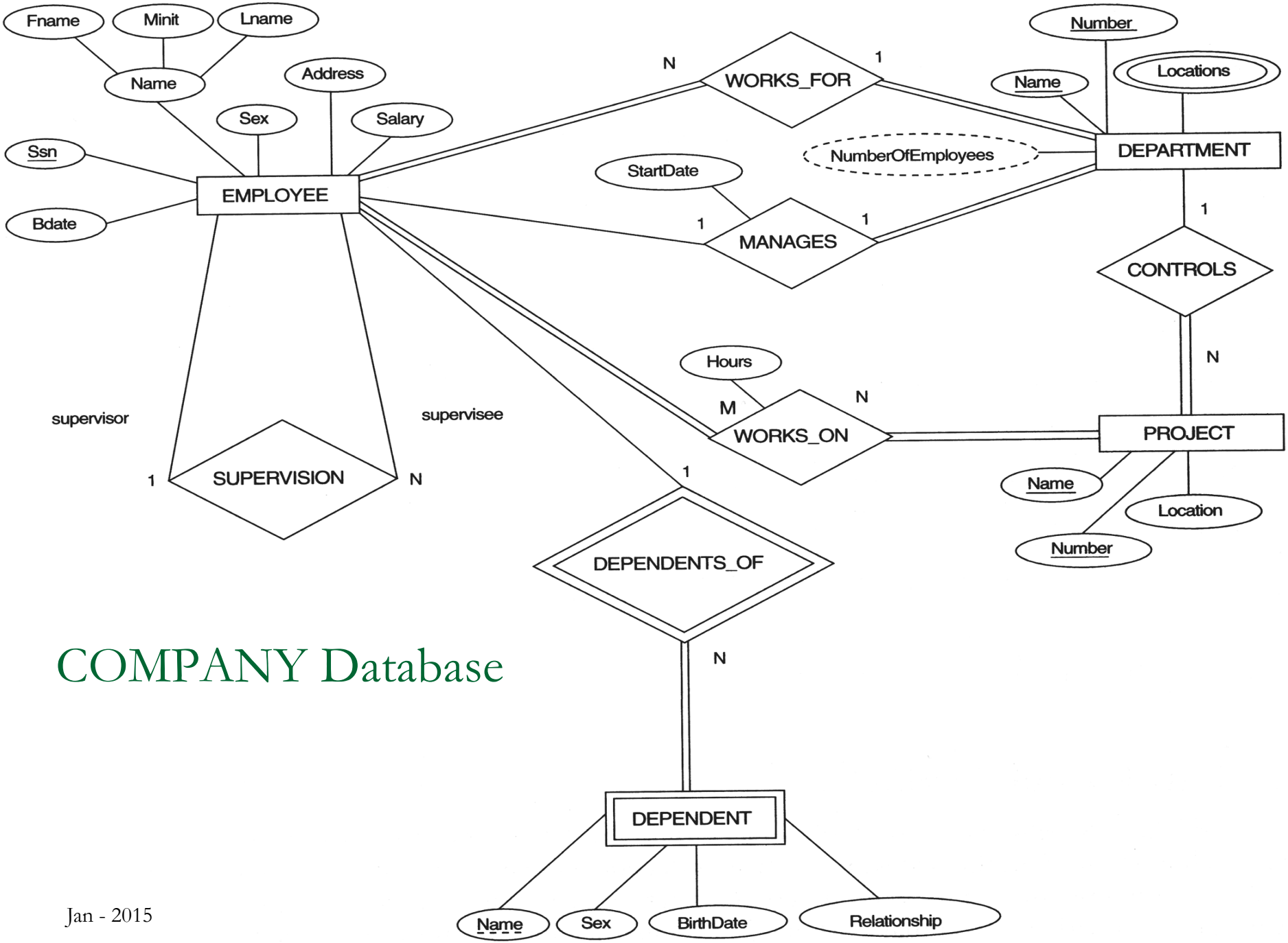
Attributes of Relationship Types

- A relationship type can have attributes.
  - Ex: HoursPerWeek of WORKS_ON
- Attributes of 1:1 or 1:N relationship types can be migrated to one entity type
- For a 1:N relationship type: relationship attribute can be migrated only to entity type on N-side of relationship
- For M:N relationship types: must be specified as relationship attributes

Weak Entity Types

- Do not have key attributes of their own
  - Identified by being related to specific entities from another entity type
- **Identifying relationship**
  - Relates a weak entity type to its owner
- Always has a total participation constraint
- Entities are identified by the combination of:
  - A partial key of the weak entity type
  - The particular entity they are related to in the identifying entity type



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ER Diagram and Naming Conventions

- An ER model can be expressed in the form of the ER diagram.
- Proper Naming of Schema Constructs:
  - Choose names that convey meanings attached to different constructs in schema
  - Nouns give rise to entity type names
  - Verbs indicate names of relationship types
  - Choose binary relationship names to make ER diagram readable from left to right and from top to bottom

Summary of the Notation for ER Diagrams

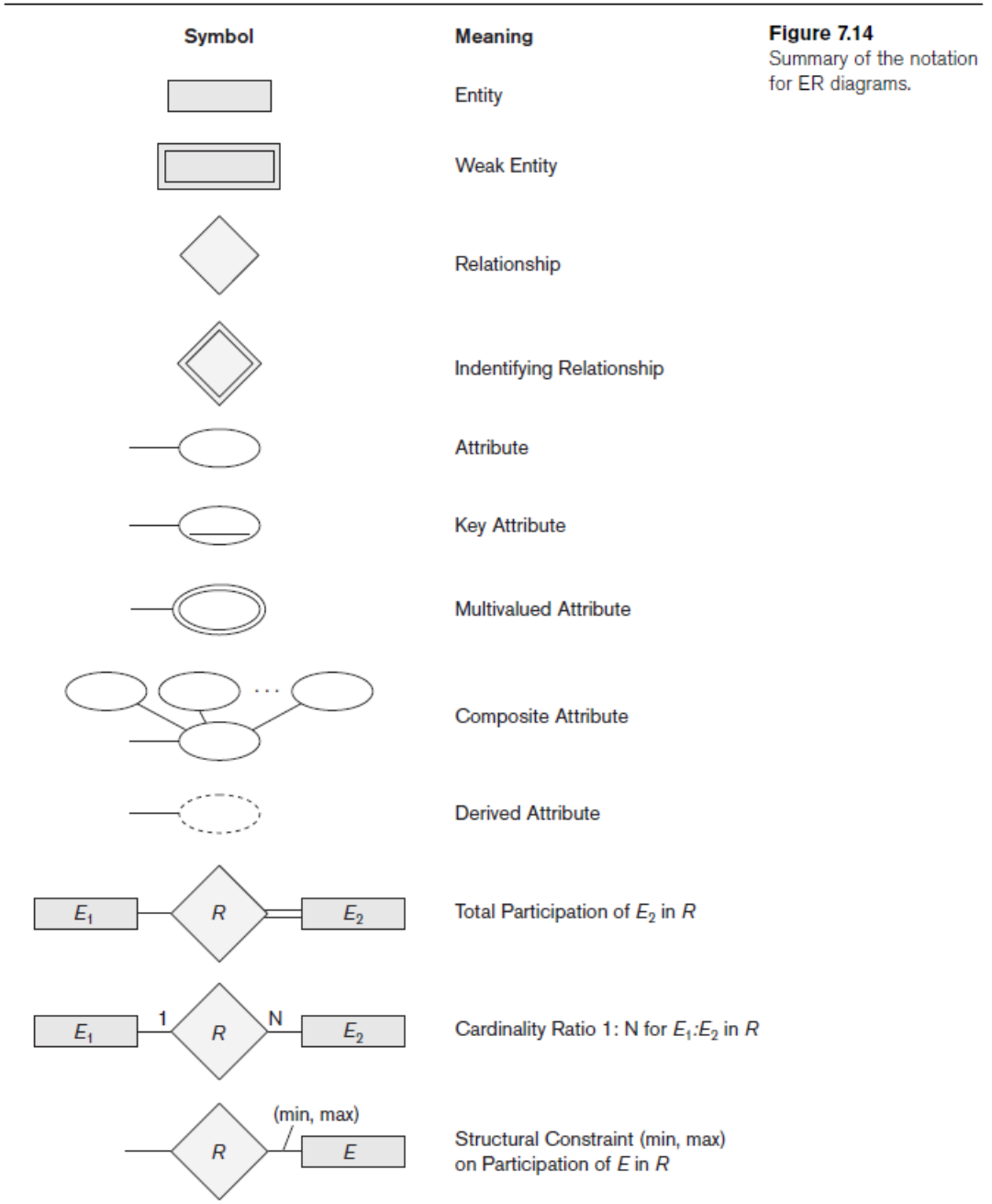
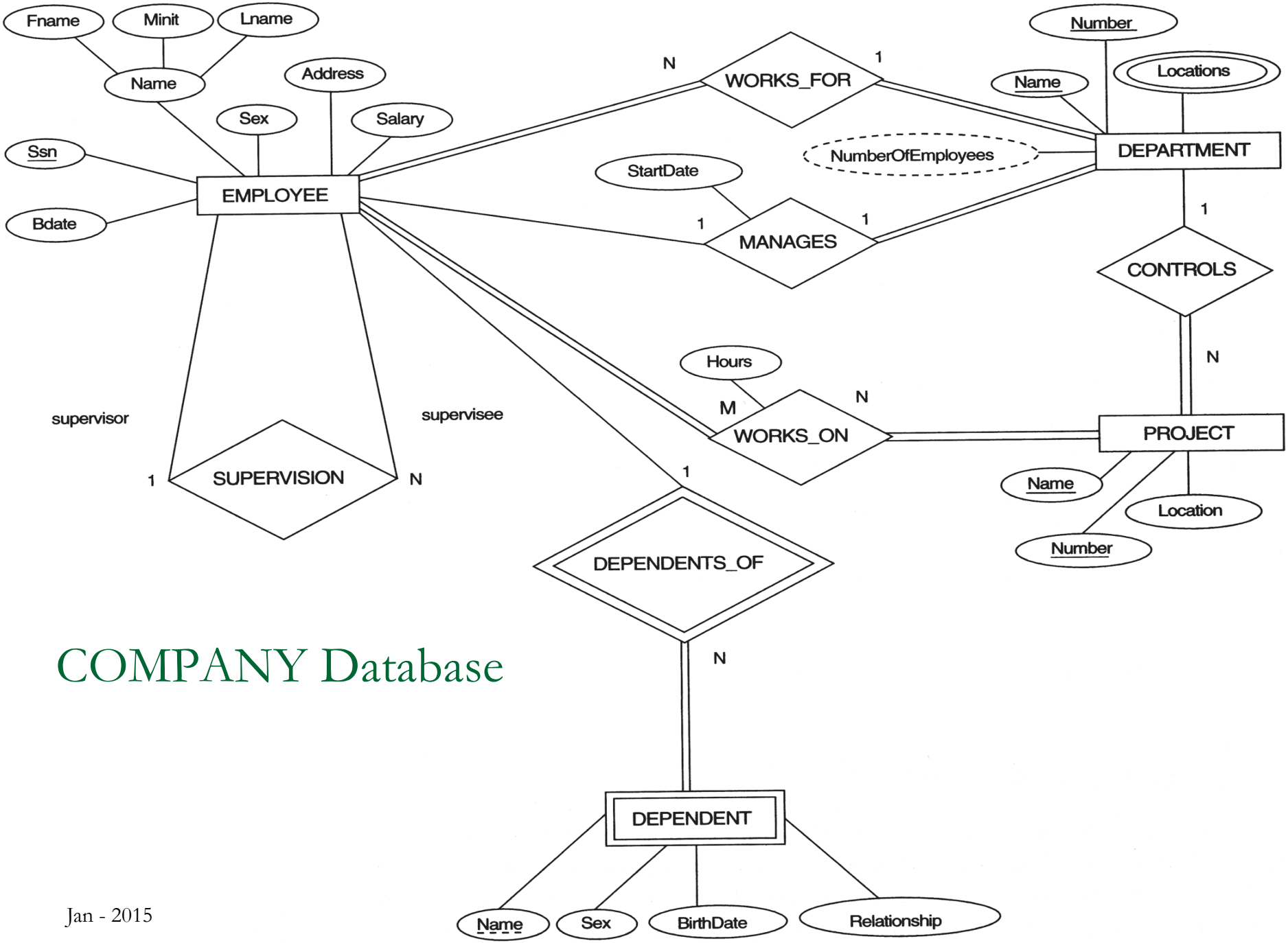


Figure 7.14
Summary of the notation for ER diagrams.



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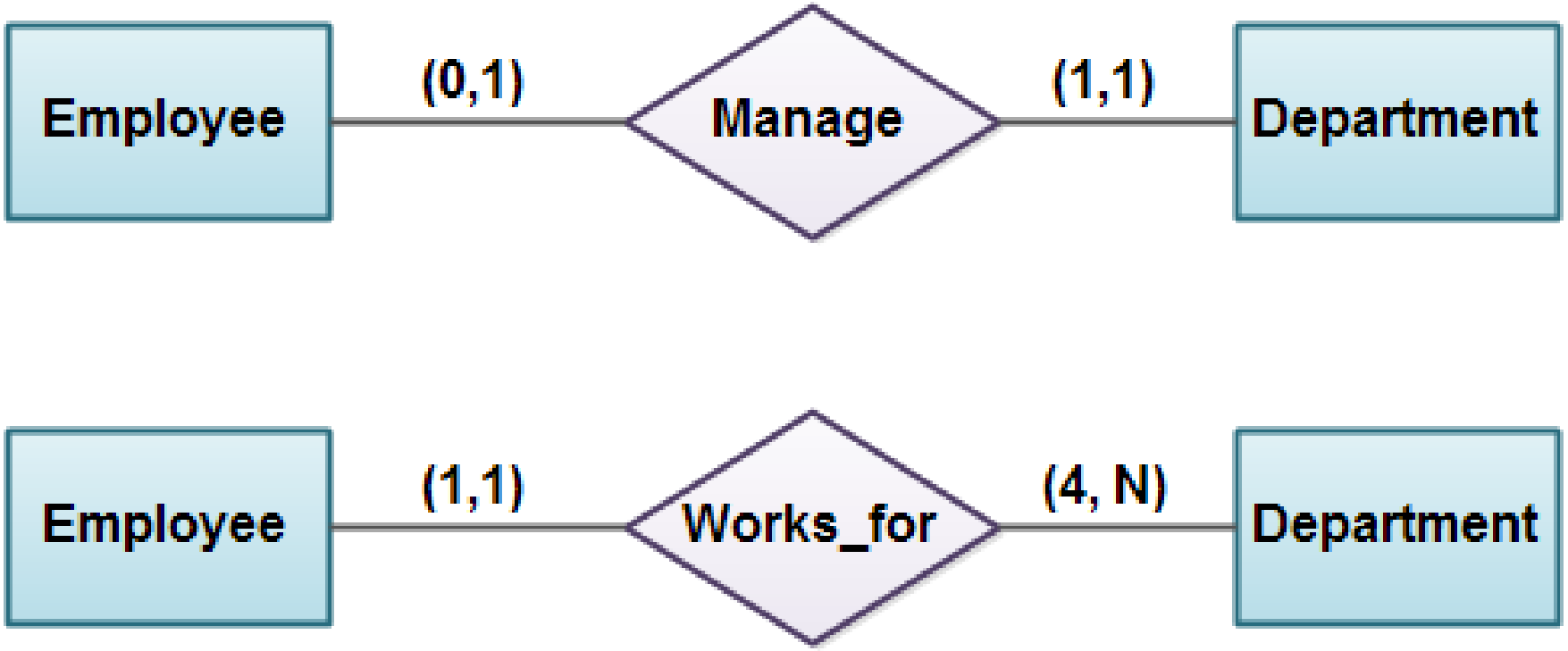
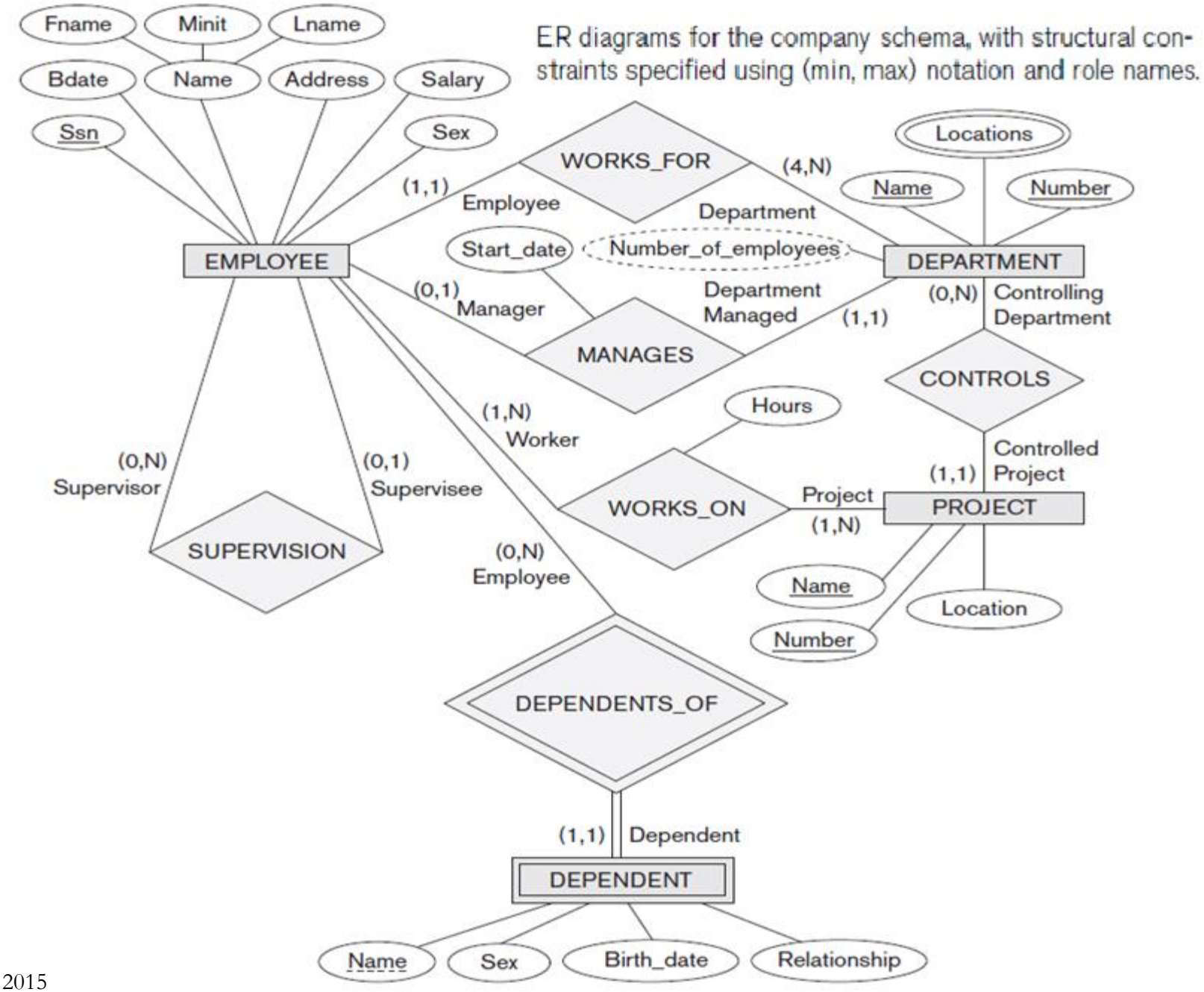
Alternative Diagrammatic Notations

- **(Min-max) notation for relationships**
  - Specify structural constraints on relationships
  - Replaces cardinality ratio (1:1, 1:N, M:N) and single/double line notation for participation constraints
  - Associate a pair of integer numbers (min, max) with each participation of an entity type *E* in a relationship type *R*, where $0 \leq \text{min} \leq \text{max}$ and $\text{max} \geq 1$

(min, max) notation for relationship structural constraints

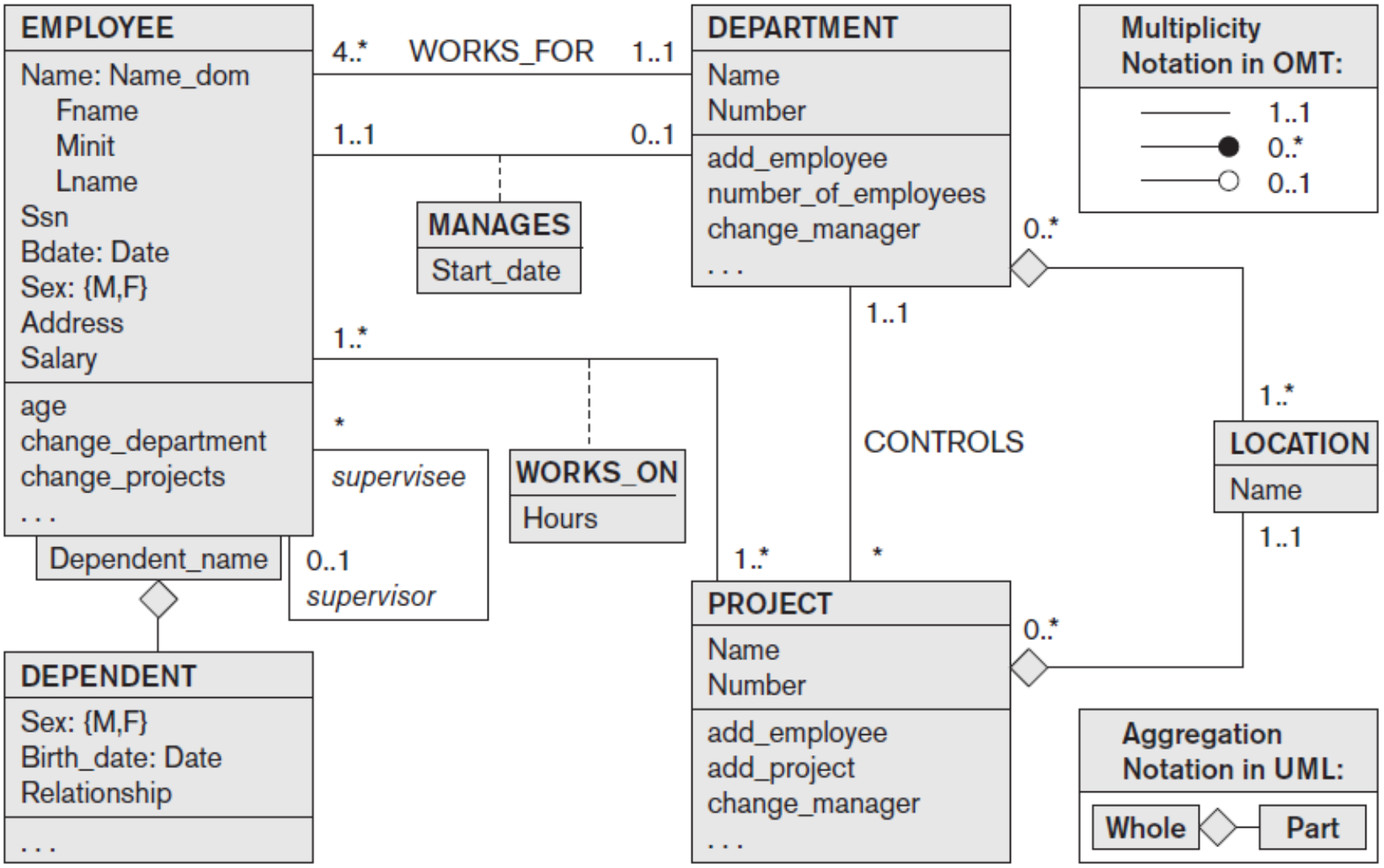



ER diagrams for the company schema, with structural constraints specified using (min, max) notation and role names.
Fname
Minit
Lname
Bdate
Name
Address
Salary
Ssn
Sex
WORKS_FOR
(4,N)
(1,1)
Employee
Department
Locations
Name
Number
Start_date
Number_of_employees
EMPLOYEE
DEPARTMENT
(0,1)
Manager
Department
Managed
(1,1)
(0,N)
Controlling
Department
MANAGES
CONTROLS
Hours
(1,N)
Worker
Controlled
Project
(1,1)
(0,N)
Supervisor
(0,1)
Supervisee
WORKS_ON
Project
(1,N)
PROJECT
SUPERVISION
(0,N)
Employee
Name
Location
Number
DEPENDENTS_OF
(1,1)
Dependent
DEPENDENT
Name
Sex
Birth_date
Relationship

Alternative Diagrammatic Notations

- UML methodology
  - Used extensively in software design
  - Many types of diagrams for various software design purposes
- **UML class diagrams**
  - Entity in ER corresponds to an object in UML

The COMPANY conceptual schema
in UML class diagram notation.



Alternative Diagrammatic Notations

- **UML class diagrams**
  - **Class** includes three sections:
    - Top section gives the class name
    - Middle section includes the attributes;
    - Last section includes operations that can be applied to individual objects
  - **Associations**: relationship types
  - **Relationship instances**: links

Alternative Diagrammatic Notations

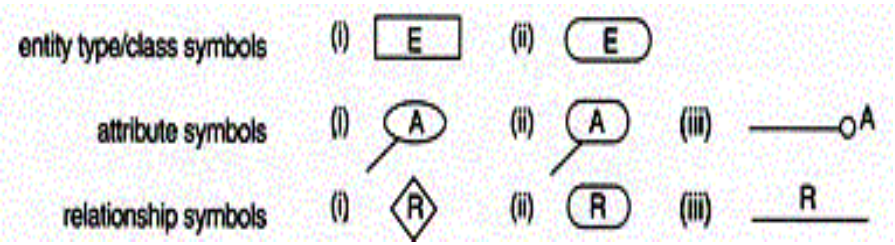
- **UML class diagrams**
  - Binary association
    - Represented as a line connecting participating classes
    - May optionally have a name
  - Link attribute
    - Placed in a box connected to the association's line by a dashed line

Alternative Diagrammatic Notations

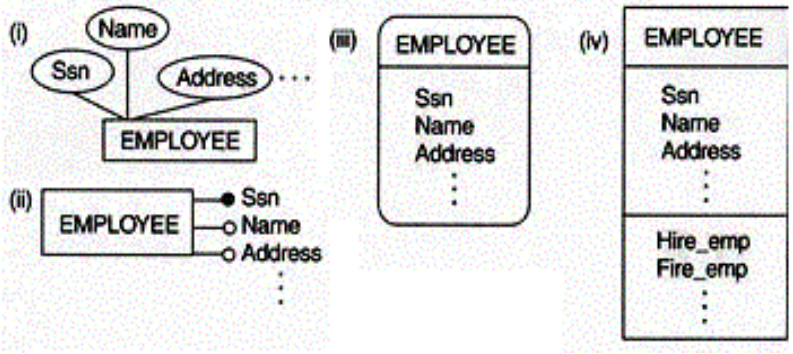
- **UML class diagrams**
  - **Multiplicities**: min..max, asterisk (*) indicates no maximum limit on participation
  - Types of relationships: **association** and **aggregation**
  - Distinguish between **unidirectional** and **bidirectional** associations
  - Model weak entities using **qualified association**

Alternative Diagrammatic Notations

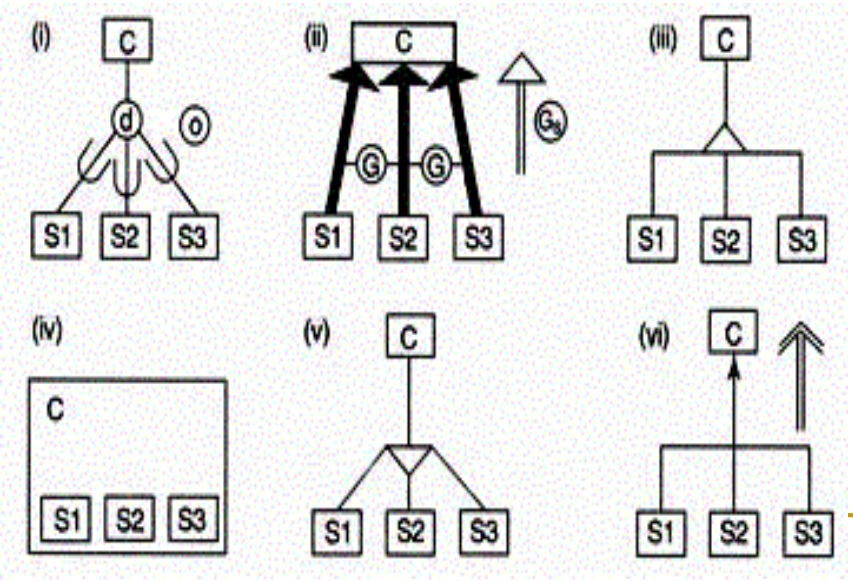
Symbols for entity type / class, attribute and relationship



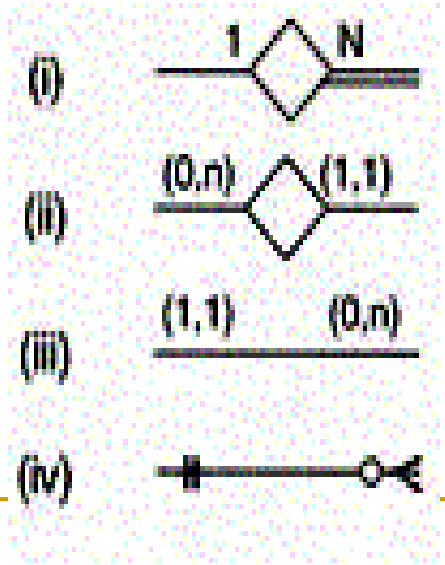
Displaying attributes



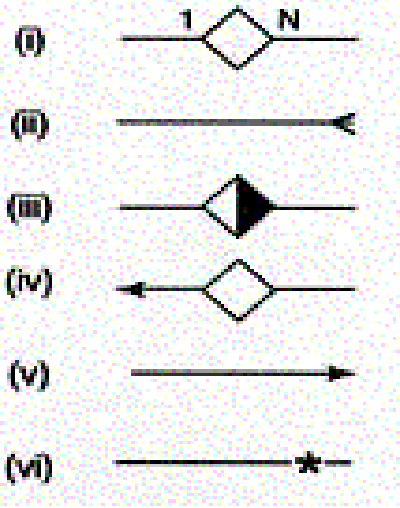
Notations for displaying specialization / generalization



Various (min, max) notations



Displaying cardinality ratios



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Choosing between Binary and Ternary (or Higher-Degree) Relationships

- Some database design tools permit only binary relationships
  - Ternary relationship must be represented as a weak entity type
  - No partial key and three identifying relationships
- Represent ternary relationship as a regular entity type
  - By introducing an artificial or surrogate key

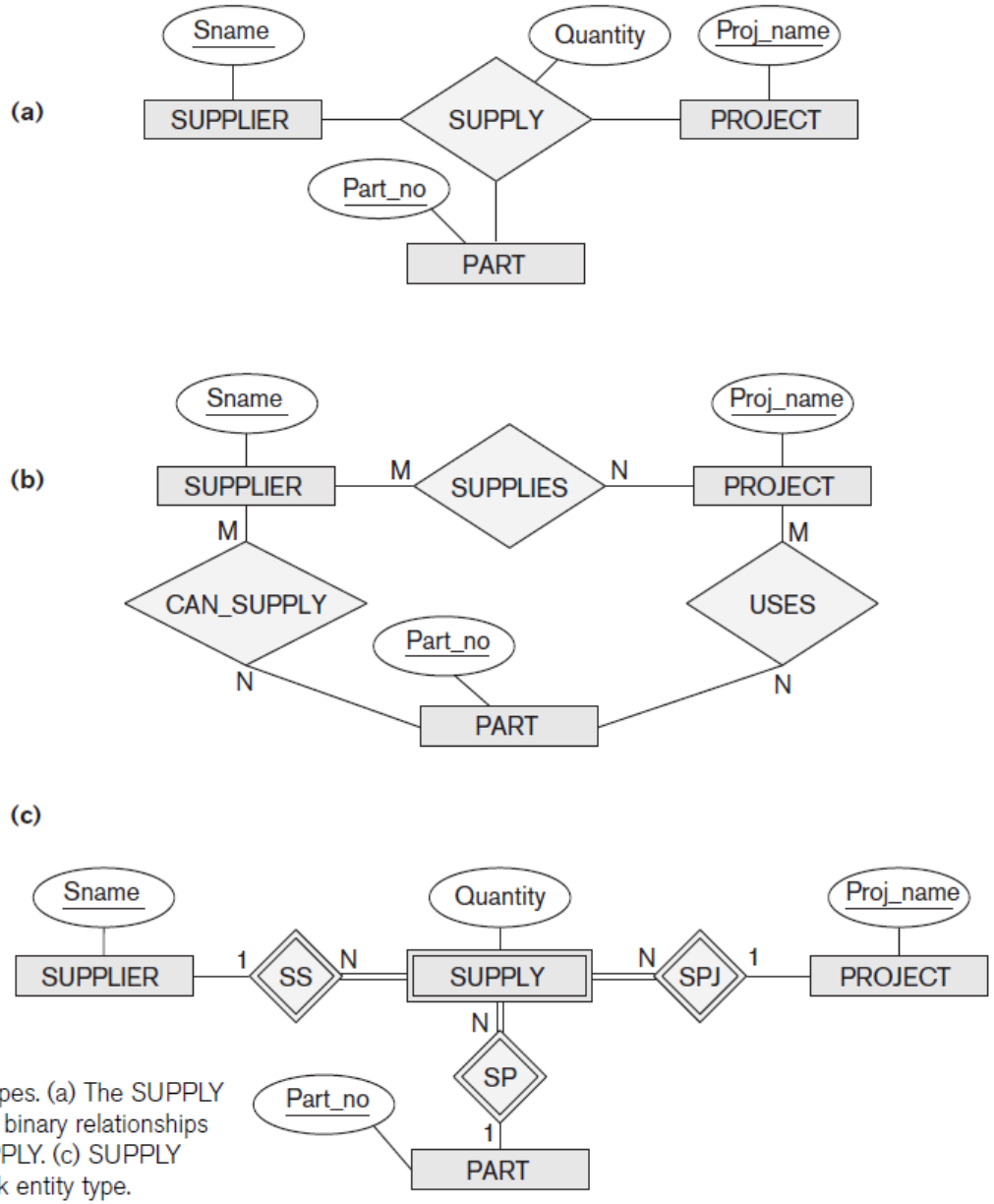


Figure 7.17
Ternary relationship types. (a) The SUPPLY relationship. (b) Three binary relationships not equivalent to SUPPLY. (c) SUPPLY represented as a weak entity type.

Constraints on Ternary (or Higher-Degree) Relationships

- Notations for specifying structural constraints on *n*-ary relationships
  - Should both be used if it is important to fully specify structural constraints

Contents

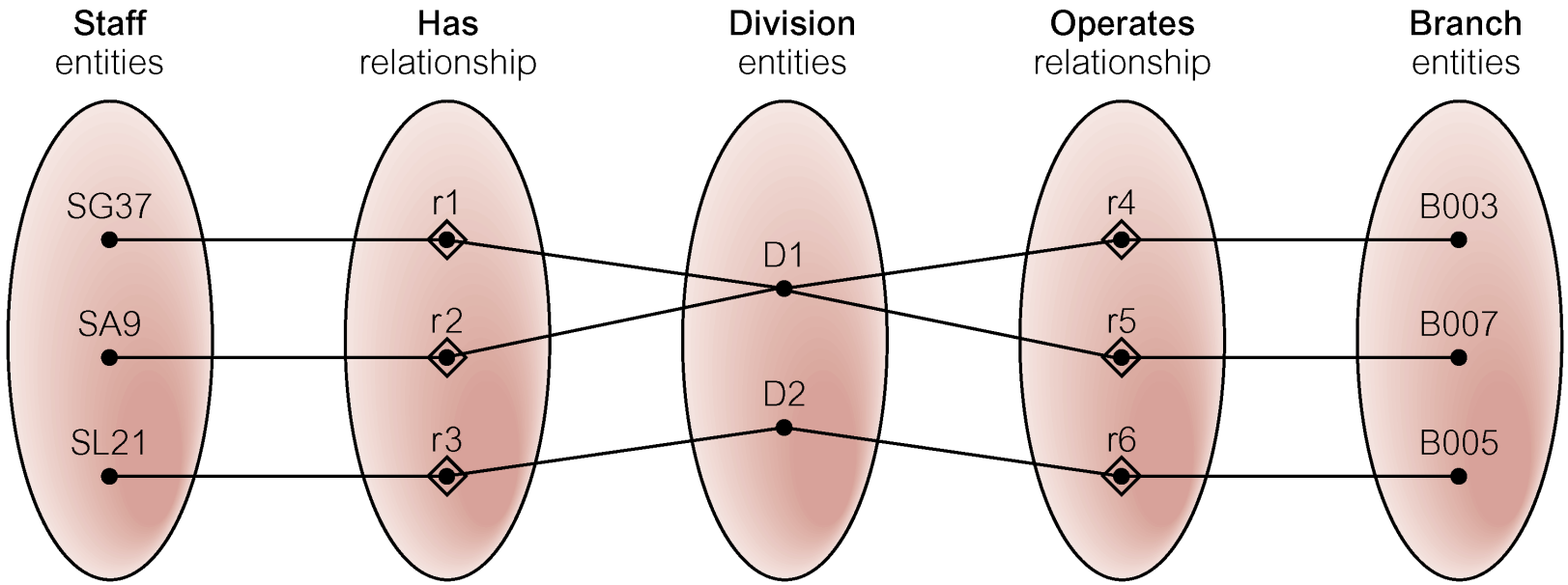
Problems with ER Models

- Problems may arise when designing a conceptual data model called **connection traps**
- Often due to a misinterpretation of the meaning of certain relationships
- Two main types of connection traps are called fan traps and chasm traps

Problems with ER Models

- Fan Trap
  - Where a model represents a relationship between entity types, but pathway between certain entity occurrences is ambiguous
  - Usually: two or more 1:N relationships fan out from the same entity
- Chasm Trap
  - Where a model suggests the existence of a relationship between entity types, but pathway does not exist between certain entity occurrences
  - Usually: optional participation

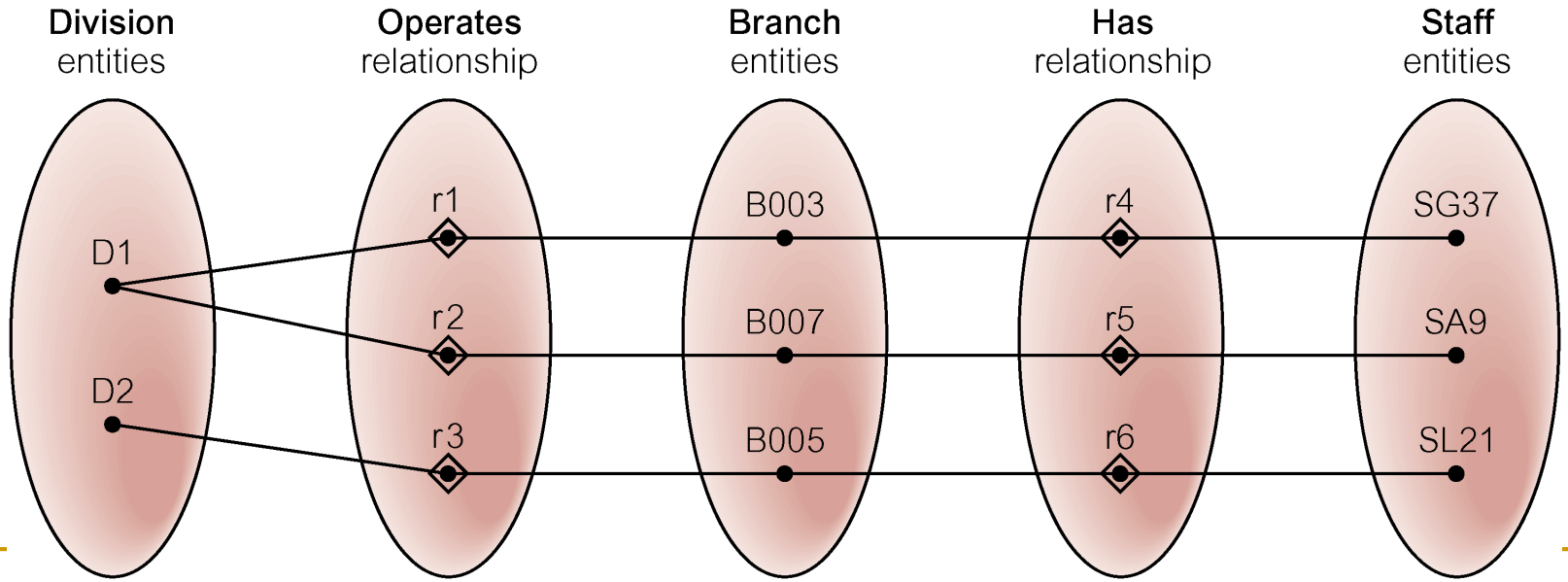
An Example of a Fan Trap



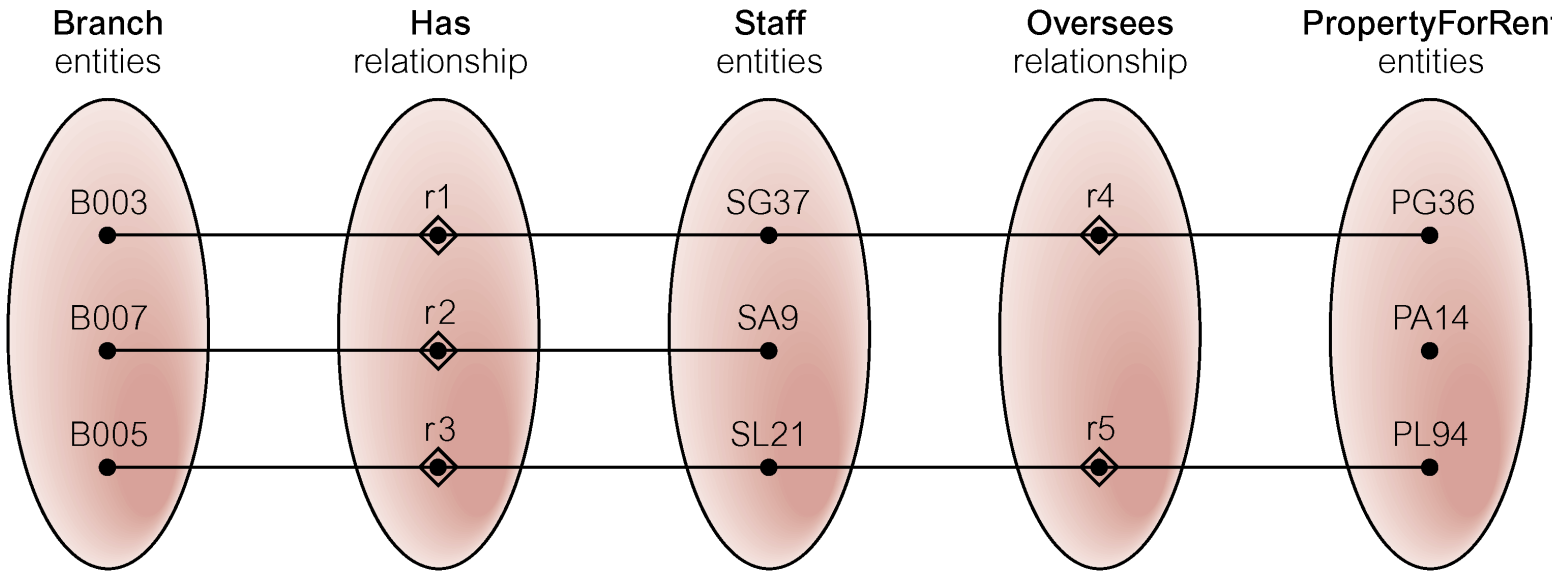
At which branch office does staff number SG37 work?

Restructuring ER model to remove Fan Trap

- SG37 works at branch B003

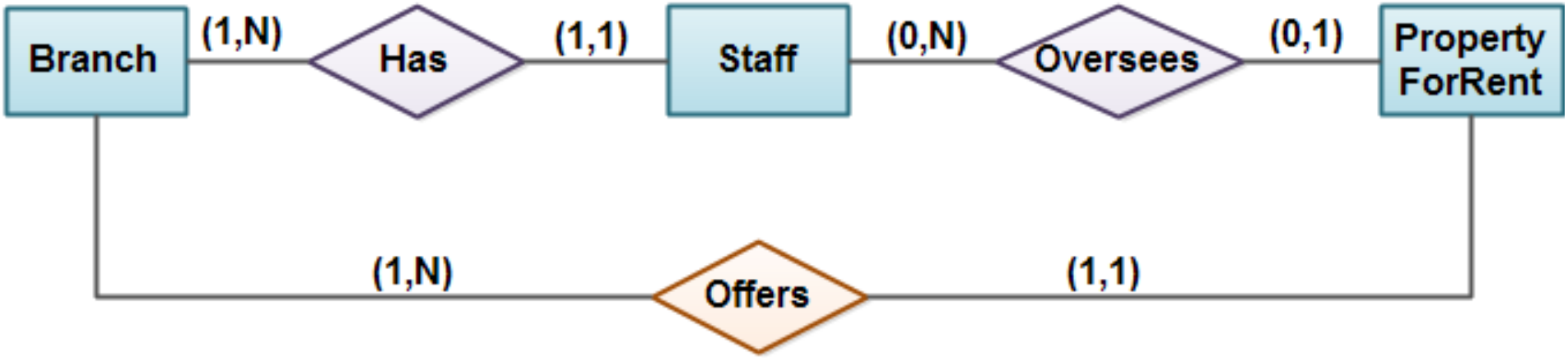


An Example of a Chasm Trap



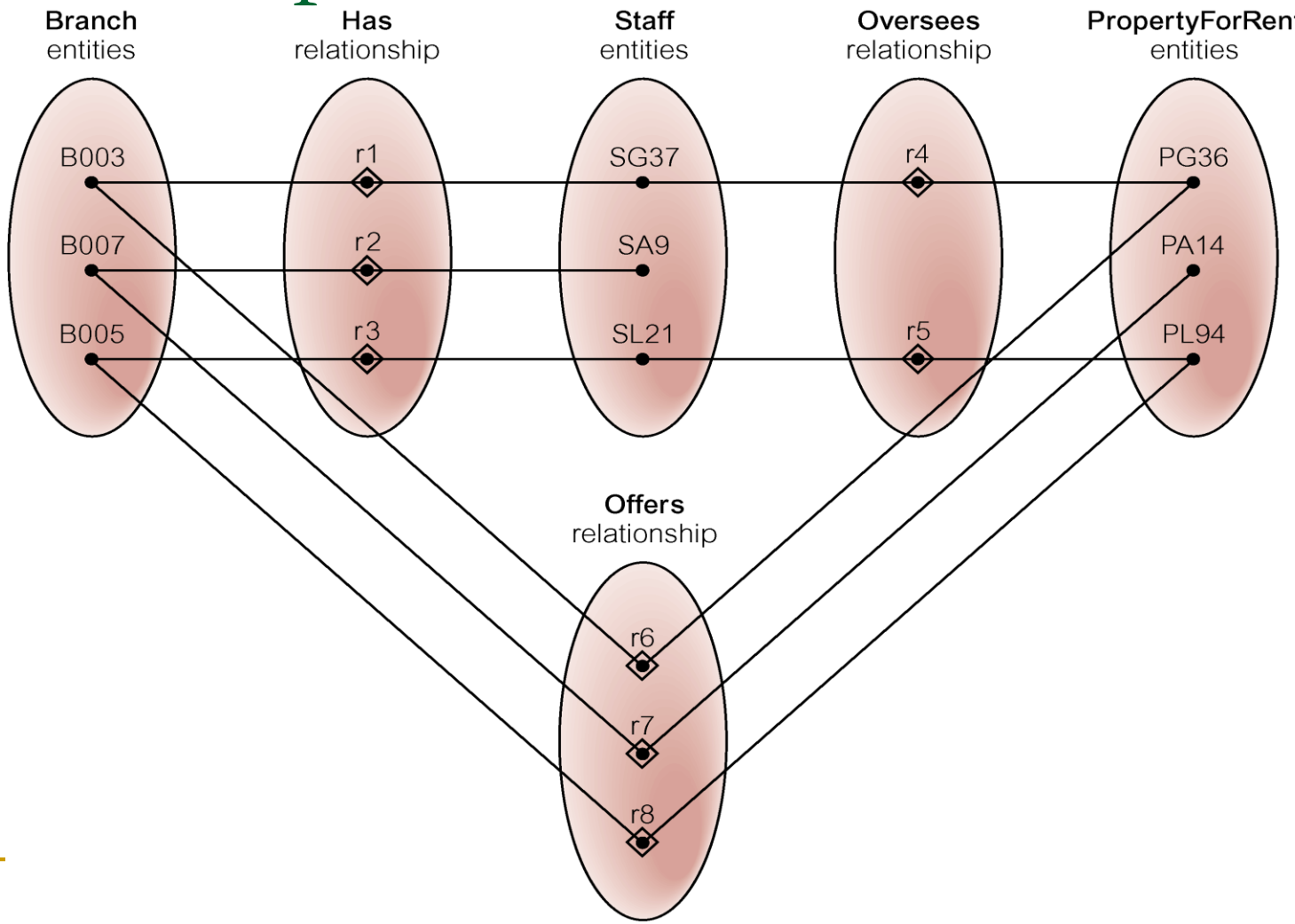
At which branch office is property PA14 available?

ER Model restructured to remove Chasm Trap



- Adding the ***Offers*** relationship resolves the chasm trap

ER Model restructured to remove Chasm Trap



Summary

1	Overview of Database Design Process
2	What is ER Model? And Why?
3	A Sample Database Application
4	ER Model Concepts
5	ER Diagram and Naming Conventions
6	Alternative Diagrammatic Notations
7	Relationship Types of Degree Higher than Two
8	Problems with ER Models

Q & A

Exercise: University Database

- The university database maintains records of its departments, lecturers, course modules, and students.
  - The university consists of **departments**. Each department has a unique name and some other descriptive attributes.
  - A department must also **have** a number of lecturers, one of which is the head of department
  - All **lecturers** have different names (we assume so anyway). They must **teach** one or more modules. A lecturer can only **belong** to one department.
  - **Modules** are **offered** by departments and taught by lecturers. They must also be attended by some students. Each module has a unique module number.
  - **Students** must **enroll** for a number of modules. Each student is given a unique student number

Review questions

1) What is meant by a **recursive relationship** type? Give an example of recursive relationship types.
2) When is the concept of a **weak entity** used in data modeling? Define the terms *owner entity type*, *weak entity type*, *identifying relationship type*, and *partial key*.
3) Can an **identifying relationship** of a weak entity type be of a degree greater than two? Give an example to illustrate your answer.