Relational Model

CS 377: Database Systems

ER Model: Recap

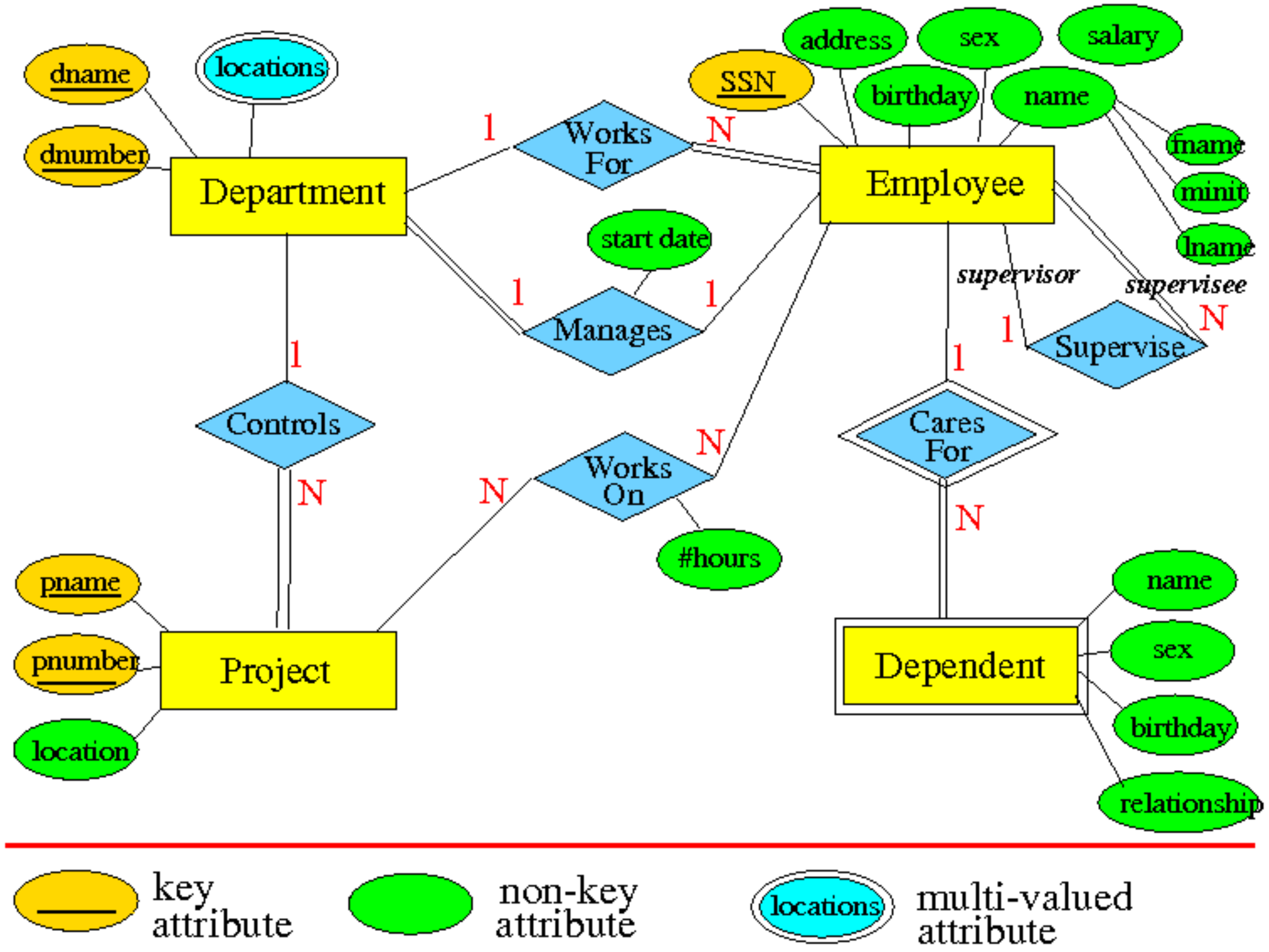
Recap: Conceptual Models

- A high-level description of the database
- Sufficiently precise that technical people can understand it
- But, not so precise that non-technical people can participate in the process

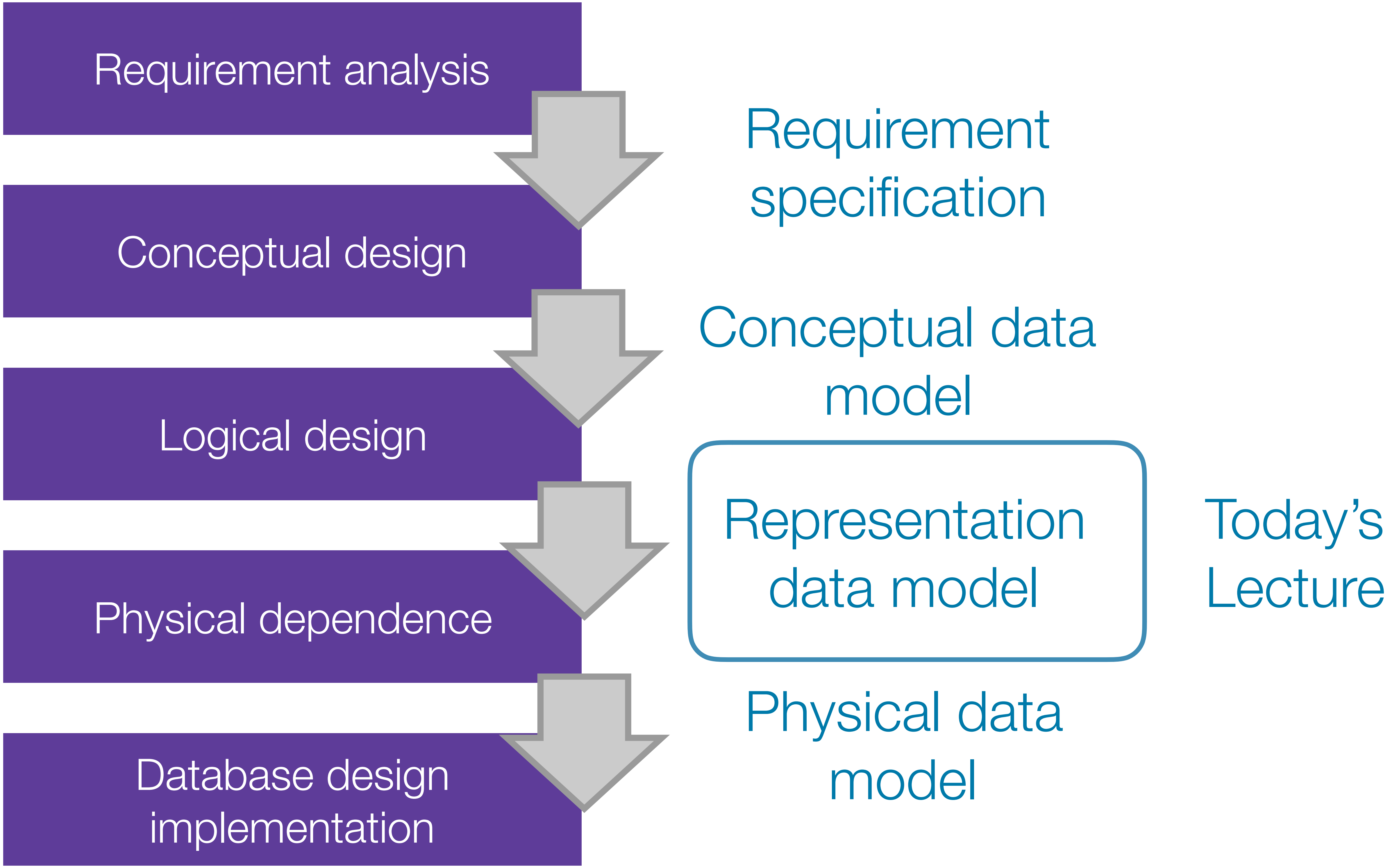
This is where ER models fit in

Recap: ER Model

- Entities
  - Attributes
- Relationships
  - Degree
  - Cardinality
  - Participation



Recap: Building a Database System



Requirement analysis

Conceptual design

Logical design

Physical dependence

Database design implementation

Requirement specification

Conceptual data model

Representation data model

Today's Lecture

Physical data model

Today’s Lecture

1. Relational Model

2. ER to Relational Mapping

    - Example: Company Database

    - Exercise: Football

Relational Model

- First formal database model
- Introduced by Ted Codd in 1970
- Conceptual basis of relational databases
    - Simple and based on the mathematical relations
    - Declarative method for specifying data and queries
- Previous models include hierarchical and network models

Relational Model: Relation

Data is stored in **tables** (**relations**)

PRODUCT

Name	Category	Price	Manufacter
iPad	Tablet	$399.00	Apple
Surface	Tablet	$299.00	Microsoft
Kindle	eReader	$79.00	Amazon
…	…	…	…

Relational Model: Schema

Relational schema R(A_1, A_2, …, A_n): made of of a relation name R and a set of attributes A_1, A_2, …, A_n

Product(name, category, price, manufacturer)

PRODUCT

Name	Category	Price	Manufacter
iPad	Tablet	$399.00	Apple
Surface	Tablet	$299.00	Microsoft
Kindle	eReader	$79.00	Amazon
…	…	…	…

Relational Model: Attribute

Attribute is a column header in the table

PRODUCT

Name	Category	Price	Manufacter
iPad	Tablet	$399.00	Apple
Surface	Tablet	$299.00	Microsoft
Kindle	eReader	$79.00	Amazon
…	…	…	…

Relational Model: Tuple

Tuple or **row** or **record** is a single entry in the table having the attributes specified by the schema

PRODUCT

Name	Category	Price	Manufacter
iPad	Tablet	$399.00	Apple
Surface	Tablet	$299.00	Microsoft
Kindle	eReader	$79.00	Amazon
...	...	...	...

Relational Model: Instance

Instance of a relation is a set of tuples or records

PRODUCT

Name	Category	Price	Manufacter
iPad	Tablet	$399.00	Apple
Surface	Tablet	$299.00	Microsoft
Kindle	eReader	$79.00	Amazon
…	…	…	…

Relation Definitions

- **Domain**: set of atomic values that are assigned to an attribute (e.g., name: string, category: string, price: real)
    - In practice, the domain is added for each attribute of the relational schema
- **Degree of a relation**: number of attributes in the relation schema
    - this is different than the degree in ER model!

Database: Schema & Instance

- **Database schema**: a collection of relation schemas

- **Instance of a database**: a collection of relation instances

- Schemas are stable over long periods of time while instance changes constantly with data inserts, updates, and deletions

Can view schemas as types while instances as values in a programming language

Relational Model Notation

Notation	Description
$R(A_1, A_2, \ldots, A_n)$	Relation schema R of degree n
Q, R, S	Relation names
q, r, s	Relations
t, u, v	Tuples
$t(a_1, a_2, \ldots, a_n)$	tuple t of a relation
$t[A_i]$	the value of the attribute A_i in the tuple t
$t[A_i, A_j, A_k]$	value of the attributes A_i, A_j ,A_k in the tuple t

Relational Model Constraints

- Restrictions on actual values in a database
- **Inherent model-based constraints** or **implicit constraints**: inherent in the data model (e.g., no duplicate tuples)
- **Schema-based constraints** or **explicit constraints**: can be directly expressed in schemas of the data model
- **Application-based / semantic constraints**, or **business rules**: cannot be directly expressed in schemas and can only be enforced and expressed in the application program

Schema-based Constraints: Domain Constraints

- Value of attribute A: atomic value from the domain of A
- Typical data types associated with domains

PRODUCT

Should be numeric, not string

Name	Category	Price	Manufacter
iPad	Tablet	$399.00	Apple
Surface	Tablet	$299.00	Microsoft
Kindle	eReader	$79.00	Amazon
…	…	…	…

Schema-based Constraints: Key Constraints

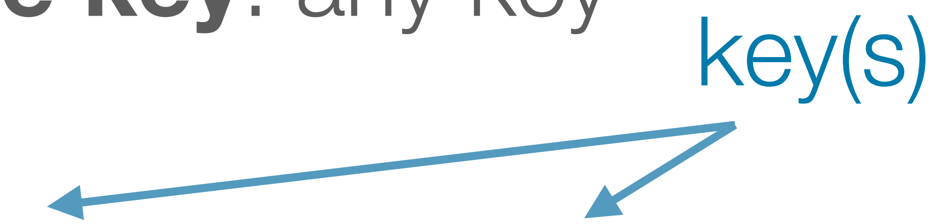
- No two tuples can have the same combination of values for all their attributes
- **Superkey**: set of attributes in a relation R such that no 2 different tuples will have the same values for that set of attributes

$$\forall t_1, t_2 \in R : t_1[SK] \neq t_2[SK]$$

Schema-based Constraints: Key Constraints

- **Key**: minimal set of attributes in relation R such that no 2 tuples have the same values (i.e., key is a minimal superkey)

- **Candidate key**: any key



PERSON

PID	SSN	Name	Address
52032	111-12-2345	John Doe	123 My Street
12345	444-23-1234	Jane Smith	555 South Street
79823	555-67-8910	Tom Thumb	224 First Street
…	…	…	…

Schema-based Constraints: Key Constraints

- **Primary key**: key chosen to be used to identify tuples in a relation
    - Once chosen, you must use that primary key throughout the database
    - Other candidate keys are unique keys
    - Every relation schema must have a primary key
- **Foreign key**: set of attributes inside some relation *R1* that is a primary key of another relation *R2*

Example: Primary & Foreign Key

PERSON

primary key

PID	SSN	Name	Address
52032	111-12-2345	John Doe	123 My Street
12345	444-23-1234	Jane Smith	555 South Street
79823	555-67-8910	Tom Thumb	224 First Street
…	…	…	…

PURCHASE

primary key

foreign key

TID	PID	Product	Price
123456778	52032	iPad Air 2	$399.00
123470901	52032	Kindle	$79.00
234096701	79823	Surface	$499.00
…	…	…	…

Schema-based Constraints: Entity Integrity

- Primary key values cannot have NULL values
- Primary key is used to identify a tuple
- NULL value means not applicable or not available which hinders the ability to identify a tuple

PERSON

PID	SSN	Name	Address
52032	111-12-2345	John Doe	123 My Street
NULL	444-23-1234	Jane Smith	555 South Street
…	…	…	…

Not allowed!

Schema-based Constraints: Referential Integrity

- A tuple in one relation (t_1 in R_1) that refers to another relation (t_2 in R_2) must refer to an existing tuple in that relation (t_2 must exist): $t_1[FK] = t_2[PK]$

- R_1 is the referencing relation and R_2 is the referenced relation

PURCHASE

tuple must exist in PERSON table

TID	PID	Product	Price
123456778	52032	iPad Air 2	$399.00
123470901	52032	Kindle	$79.00
234096701	79823	Surface	$499.00
…	…	…	…

Relational Model Virtues

- Physical & logical independence
- Declarative
- Simple, elegant and clean: everything is a relation

Why did it take so long?
Doubted it could be done efficiently

ER Model vs Relational Model

ER model (conceptual model)

- Several concepts: entities, relationships, attributes
- Well-suited for capturing application requirements
- Not well-suited for computer implementation

Relational model (implementation model)

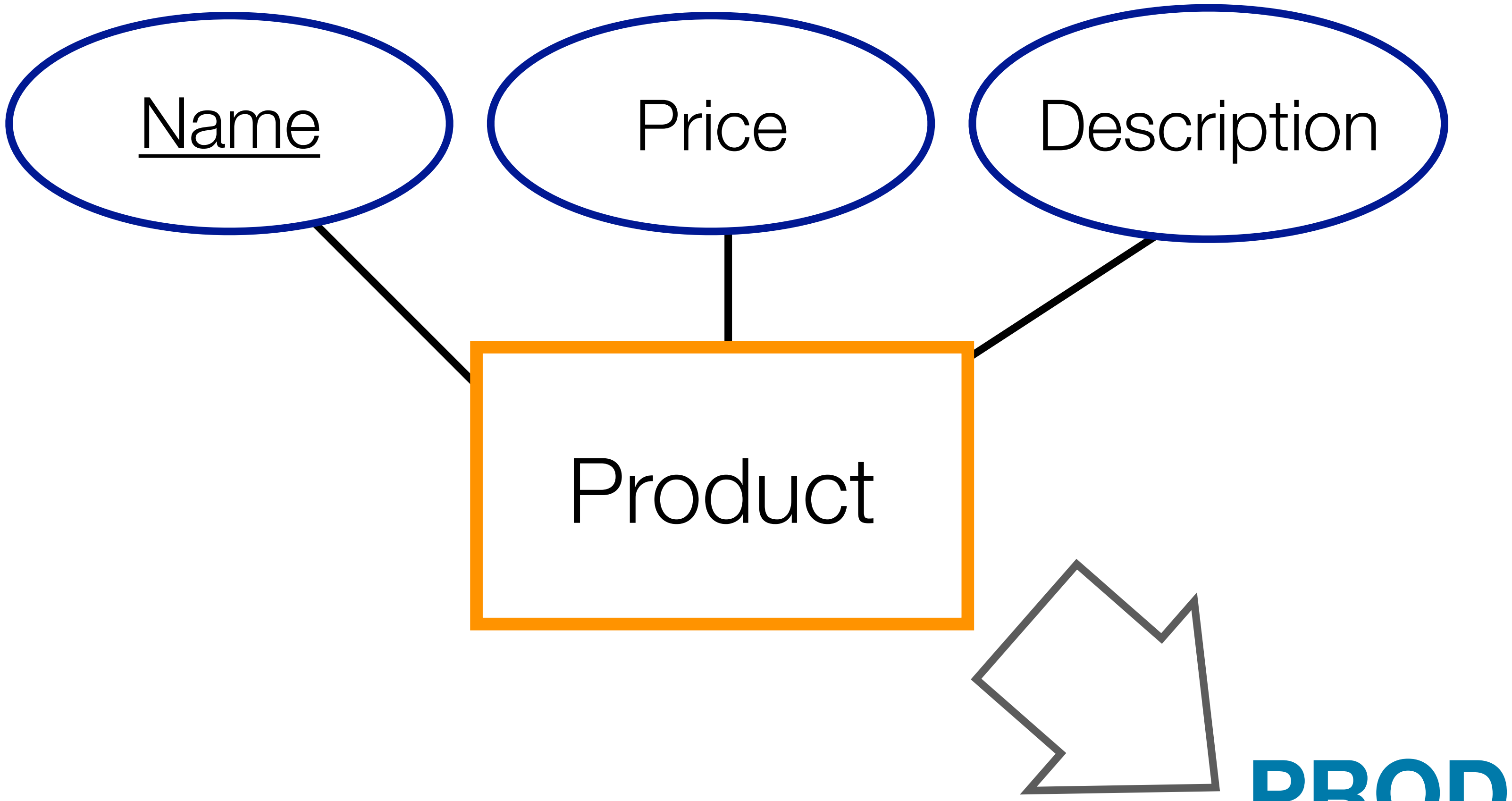
- Single concept: relation (not same as mathematical concept!)
- Everything is represented with a collection of tables
- Well-suited for efficient manipulations on computers

ER-to-Relational Mapping: Step 1

Convert Entities to Relations

- Basic case: entity set E —> relation with attributes of E
- Special case: weak entity & multi-valued attributes

Basic Case: Entity to Relation



PRODUCT

Name	Price	Description
…	…	…

Special Case: Multi-valued Attribute

- Naive storing of multi-valued attributes:
  - Variable-length records causes inefficient in storage
  - Multiple tuples leads to lots of redundancy

STORE

Number	Name	{Locations}
1	Apple	Cumberland Mall
1	Apple	Lenox Square
2	Macys	Lenox Square
2	Macys	Cumberland Mall
…	…	…

Special Case: Multi-valued Attribute

- ~~Naive storing of multi-valued attributes:~~
  - ~~Variable-length records causes inefficient in storage~~
  - ~~Multiple tuples leads to lots of redundancy~~
- Use the key concept
  - Convert multi-valued attribute to new relation X
  - Add foreign key to that relation

Special Case: Multi-valued Attribute

STORE_LOC

locID	Location
1	Lenox Square
2	Cumberland Mall
…	…

STORE

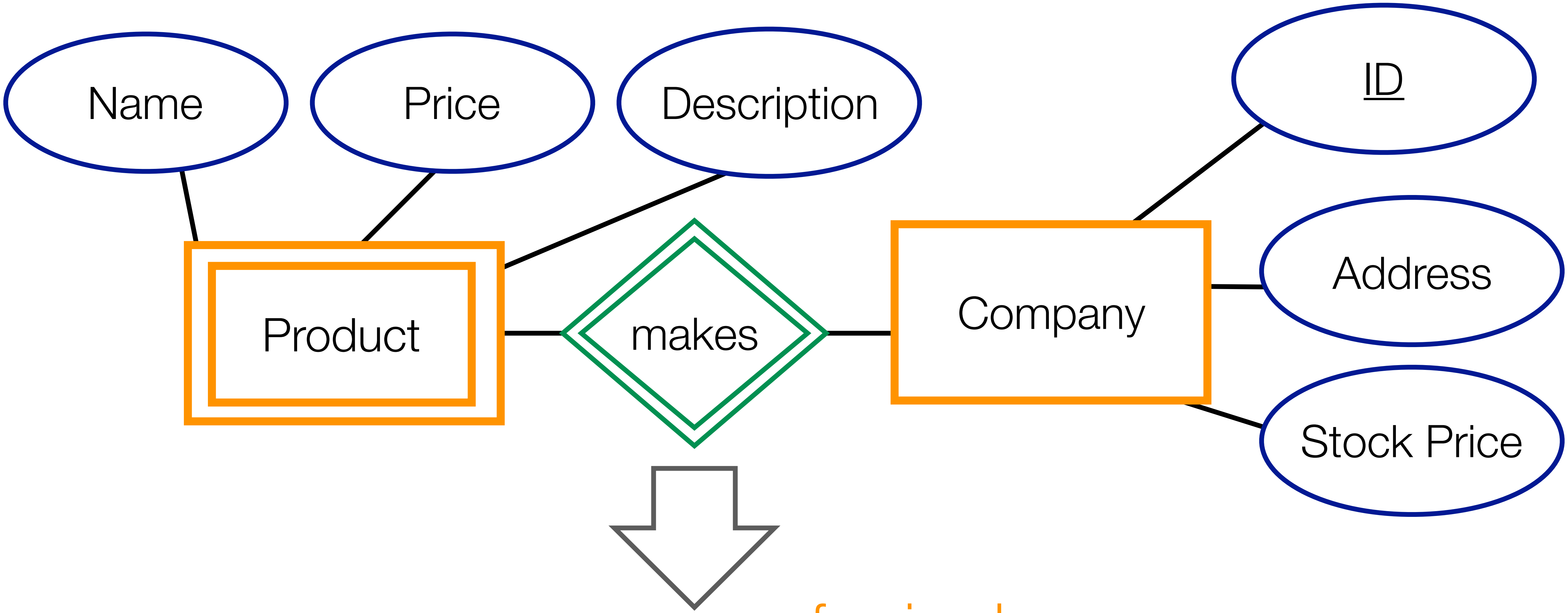
sNumber	Name	locID
1	Apple	1
1	Apple	2
2	Macys	1
2	Macys	2
…	…	…

foreign key: referential integrity

Special Case: Weak Entity

- Weak entity does not have a key —> relation violation
- Borrow key from the other entity in the identifying relationship (E) and add it to the weak entity (W)
- Result: key of weak entity consists of the key of the related entity and some identifying attribute of the weak entity

Special Case: Weak Entity



PRODUCT

foreign key

Name	cID	Price	Manufacter
…	…	…	…

weak entity key

ER-to-Relational Mapping: Step 2

Map Relationships to Relations

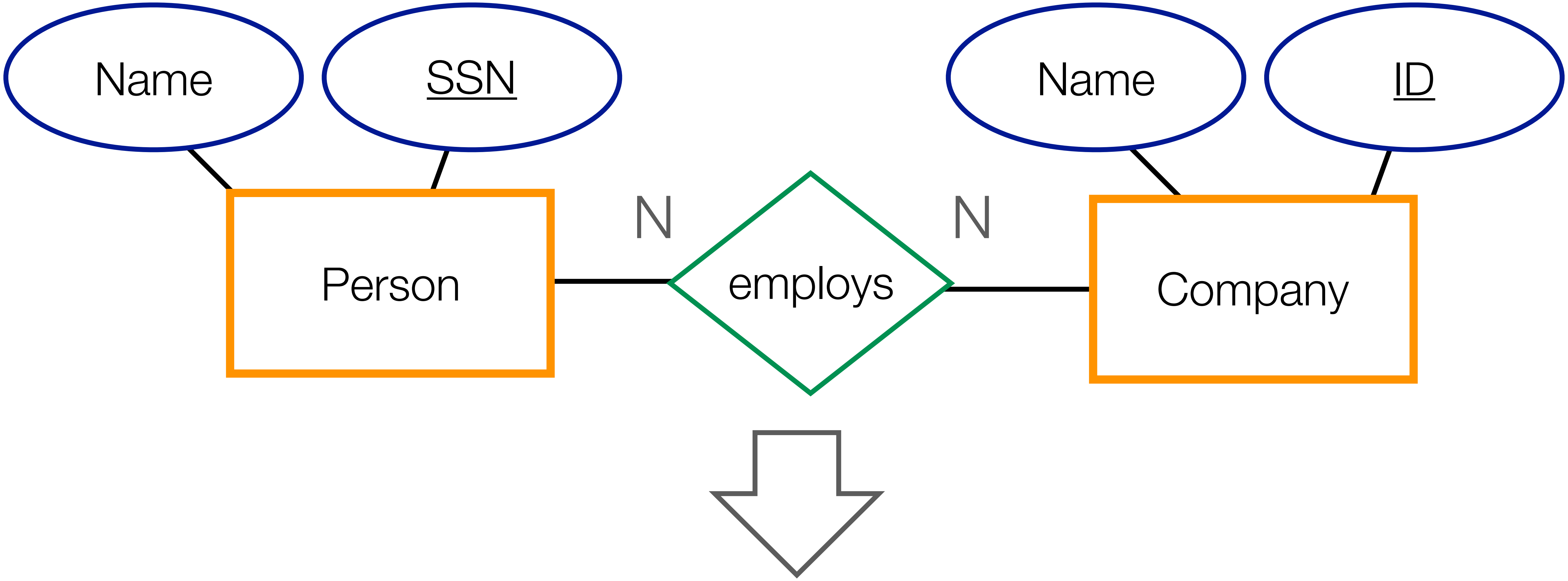
- Basic case: relationship R —> relation with attributes being keys of related entity sets and attributes of R
- Special case: expansion, merging, & n-ary relationship types

Basic Case: Relationship to Entity

Create a new relation (S — R — T)

- New tuples of relationship R stored in this table with foreign keys from the entities S and T
- Pro: always possible
- Con: Increasing the number of relations

Basic Case: Relationship to Entity



EMPLOY

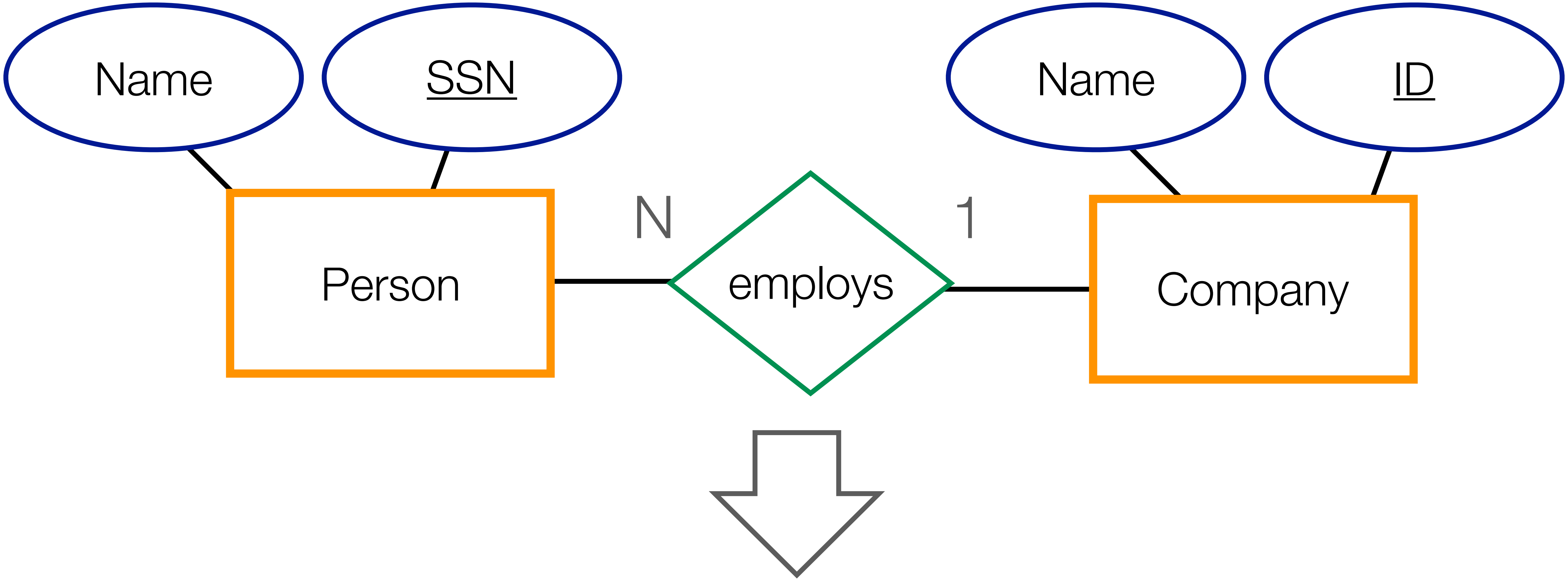
SSN	cID
…	…

Special Case: Expansion

Expand an existing relation (foreign key approach)

- Tuples of relationship are stored inside the table of an existing entity
- Use key of that entity to store tuples of the relationship
- Pro: only makes an existing relation a bit larger
- Con: not always possible

Special Case: Expansion



PERSON

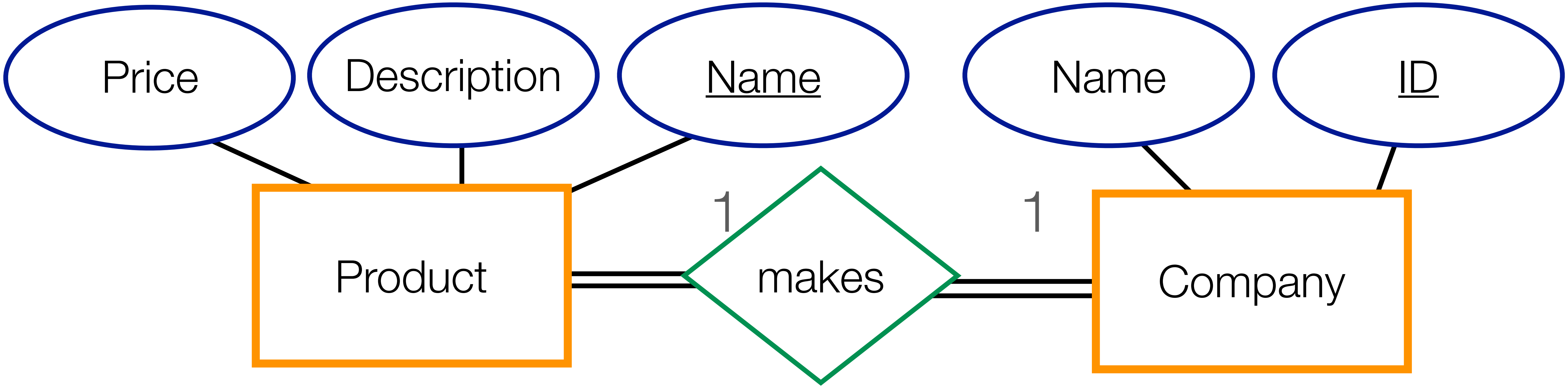
SSN	Name	cID
…	…	…

Special Case: Merging

Merge two existing relations

- Merge two entity types and relationship into one relation
- Only possible in 1:1 mapping and both have total participation
- Pro: reduction of relations
- Con: rarely used

Special Case: Merging



COMPANY_PROD

<u>pName</u>	cName	cID	Price	Description
…	…	…		

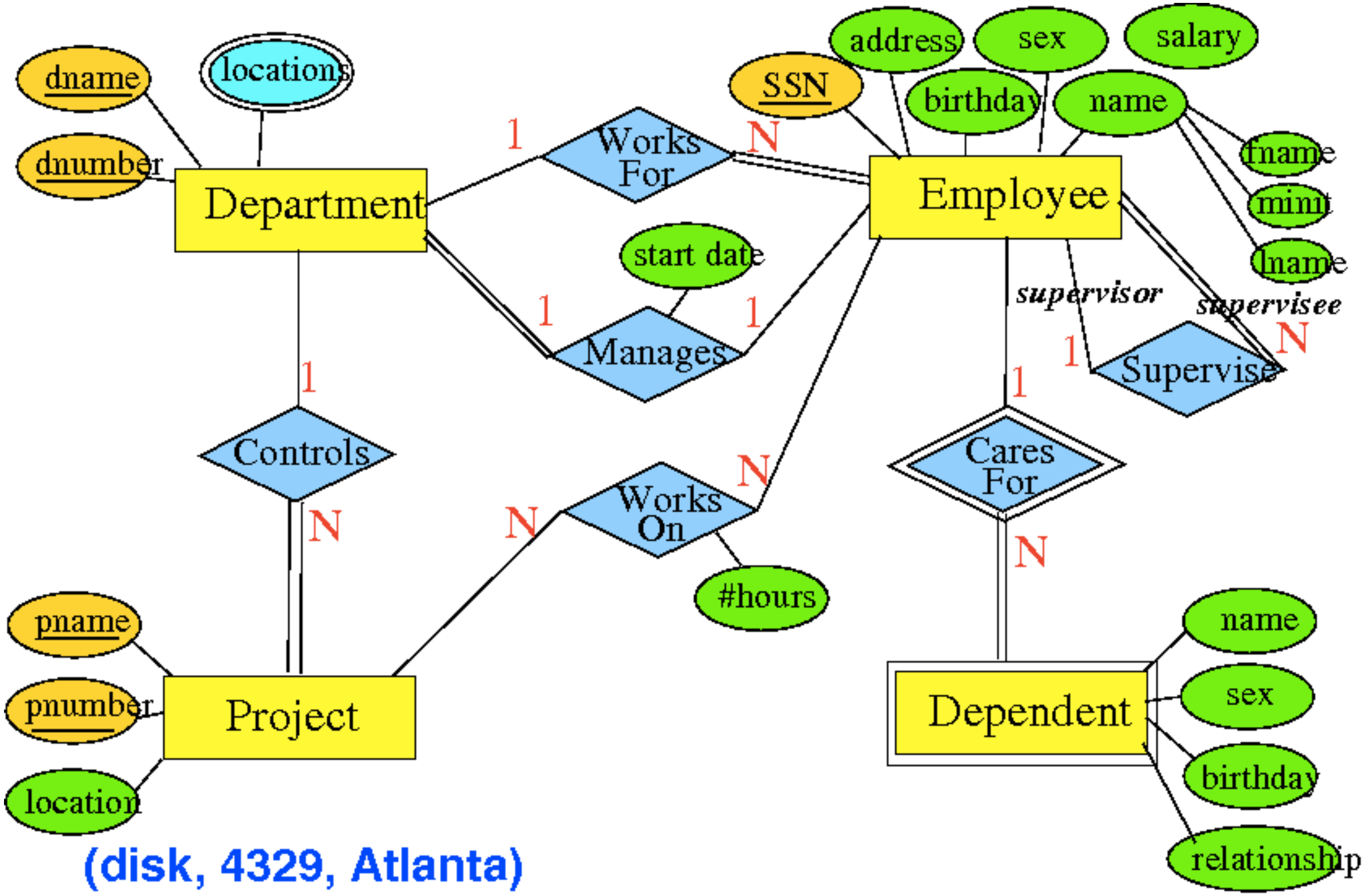
Relation Mapping Design Principles

- Relationship R where Entity1: Entity2 = 1:N —> expand the relation that represents Entity2

- Relationship R where Entity1: Entity2 = 1:1 -> expand either Entity1 or Entity2

- Avoid having attributes that can take on NULL values (e.g., expand a relationship where entity is total participation over entity with partial participation)

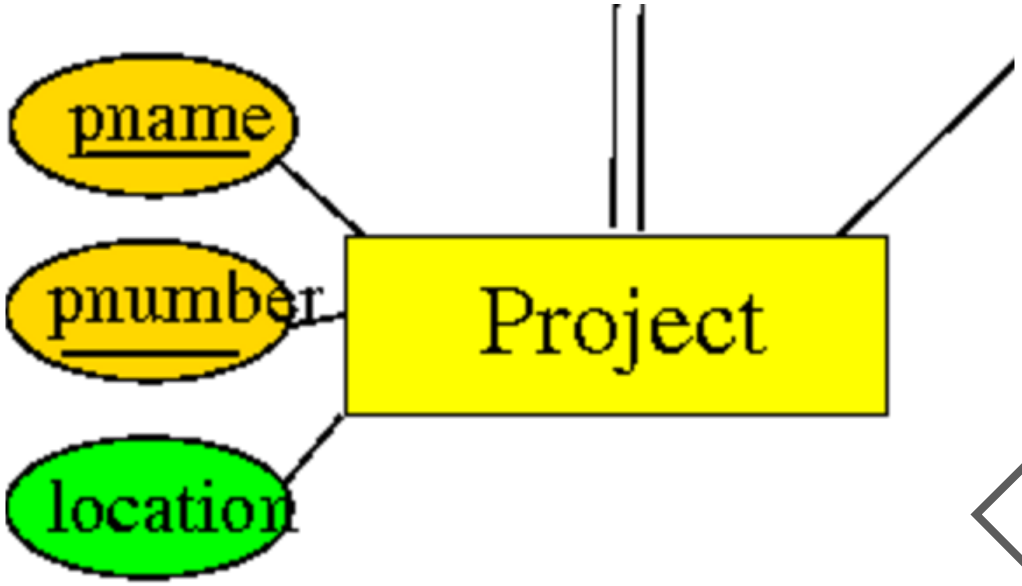
Example: Company database



(disk, 4329, Atlanta)
(CPU, 1562, Boston)
(Printer, 7862, Denver)
...

Example from Prof Cheung's lectures

Step 1: Project Entity

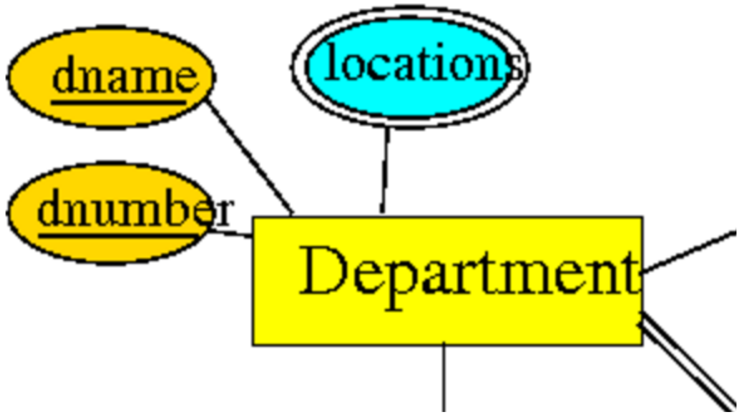


Pick one of the candidate keys to be primary key

PROJECT

PName	<u>PNumber</u>	Location
…	…	…

Step 1: Employee & Department Entities



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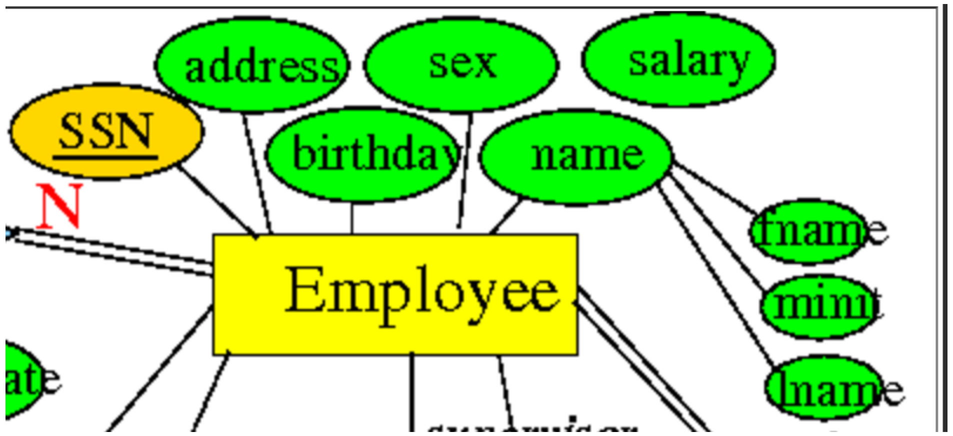


EMPLOYEE

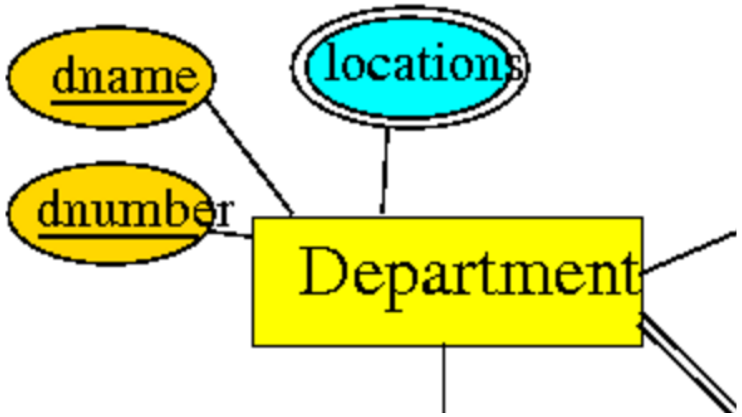
SSN	FName	MI	LName	Sex	Address	BDate	Salary
…	…	…					

DEPARTMENT

DNumber	DName	{Locations}
…	…	…

Attribute values are not ATOMIC!

Step 1: Department Location



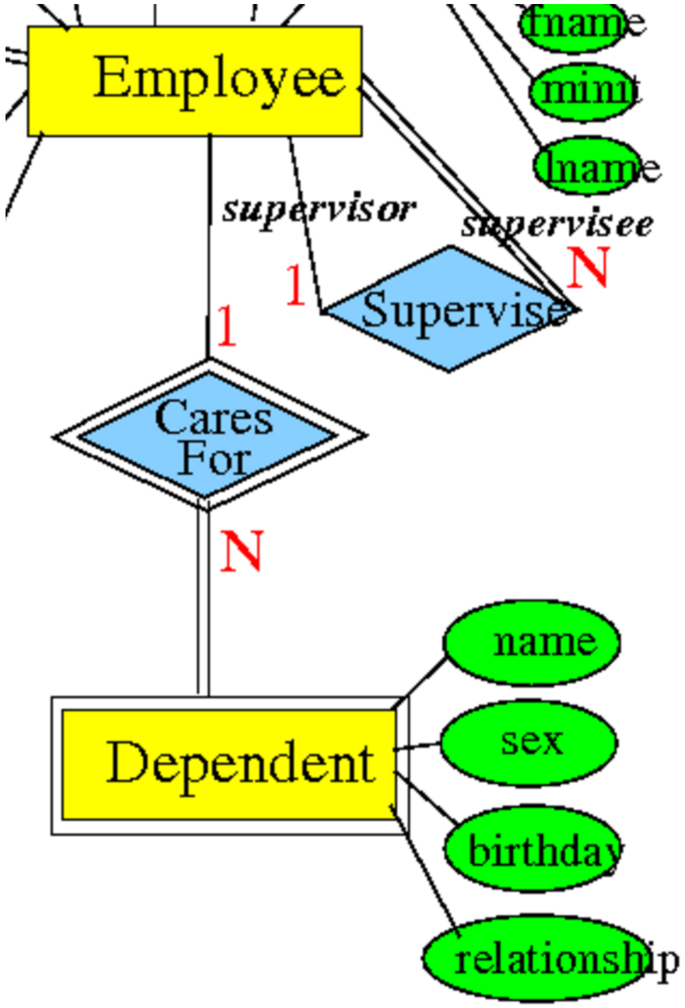
DEPARTMENT

DName	DNumber
Manufacturing	D1234
Research	D7652
…	…

DEPT_LOC

DNumber	Location
D1234	Atlanta
D1234	New York
D1234	Denver
D7652	San Jose
D7652	Austin
…	…

Step 1: Dependent Entity

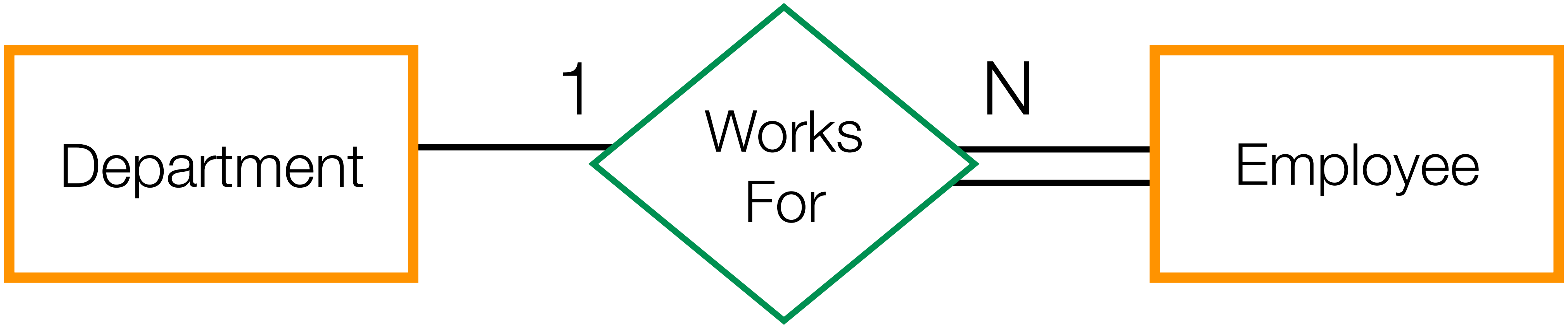


Necessary to identify weak entity

DEPENDENT

<u>ESSN</u>	<u>FName</u>	Sex	BDate	Relationship
	…	…	…	

Step 2: WorksFor Relationship



Use expansion by adding attribute to Employee because 1:N relationship

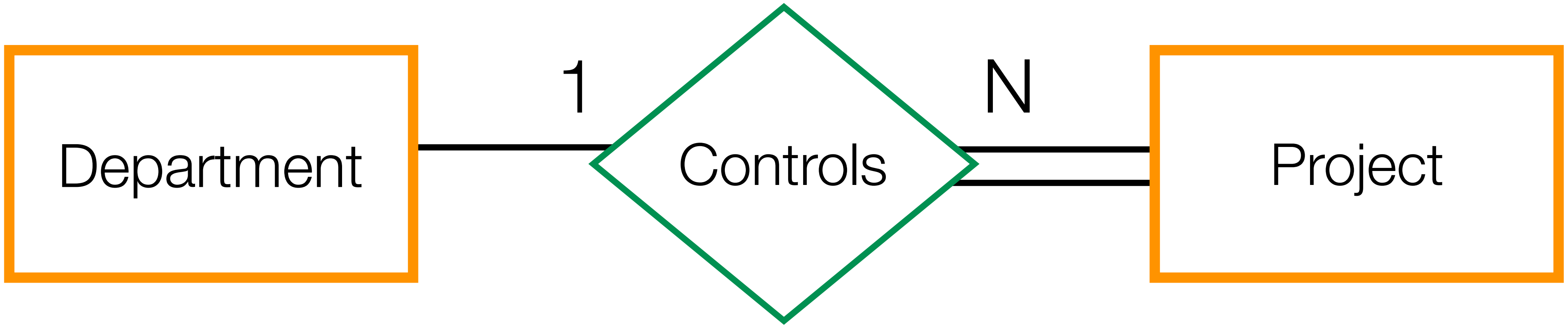
EMPLOYEE

SSN	FName	MI	LName	Sex	Addres	BDate	Salary	DNo
…	…	…						

DEPARTMENT

DName	DNumber
…	…

Step 2: Controls-Project

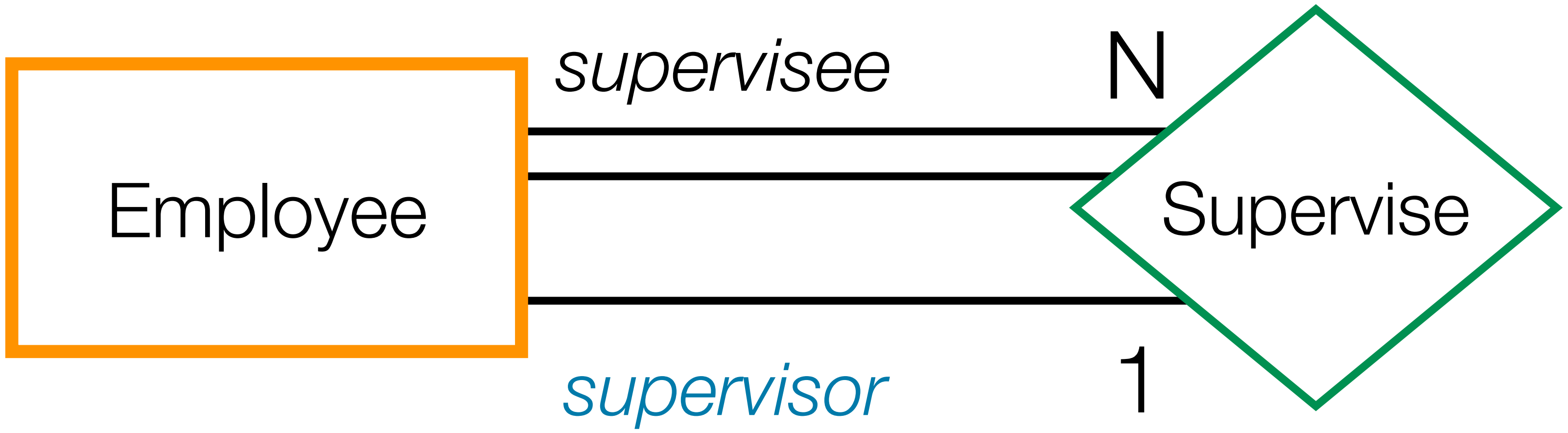


Expand Project because of the 1:N relationship

PROJECT

PName	PNumber	Location	DNum
…	…	…	

Step 2: Supervisor

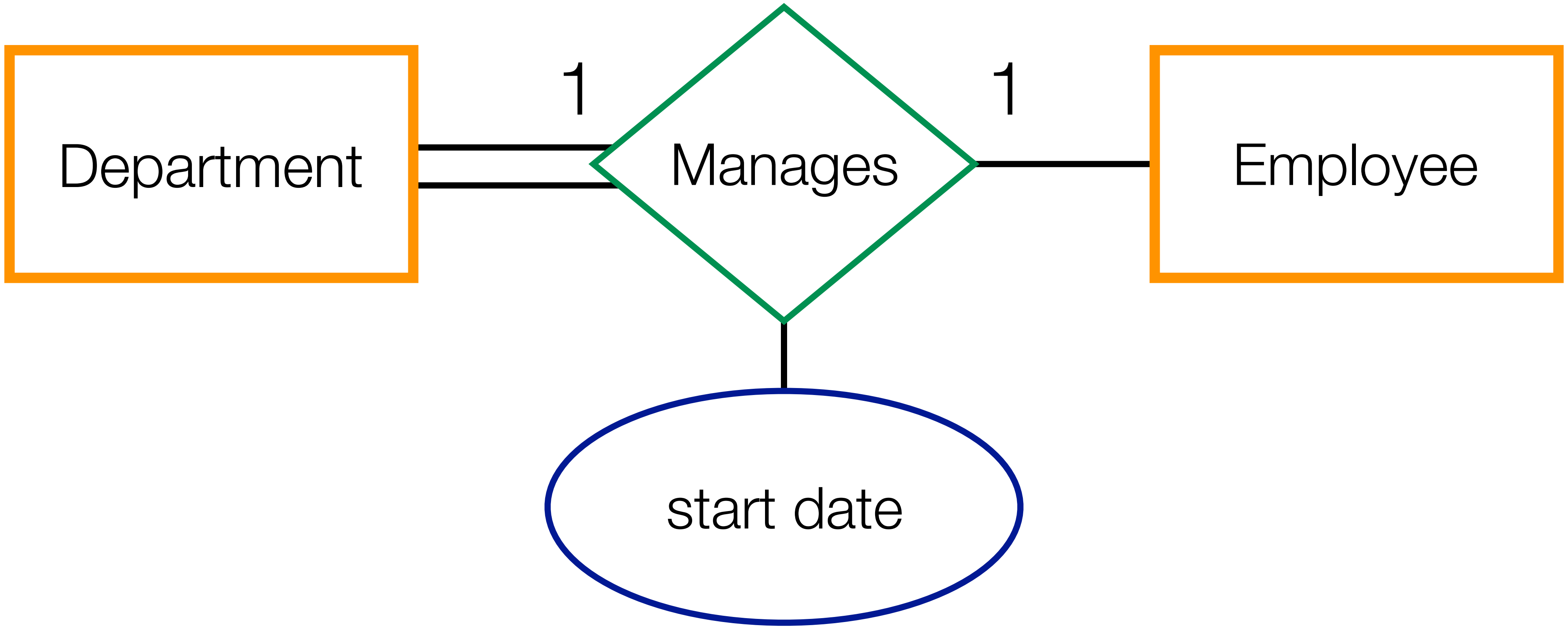


Expand supervisor because of the 1:N relationship

EMPLOYEE

SSN	FName	MI	LName	Sex	Address	BDate	Salary	superSSN	DNo
…	…	…							

Step 2: Manager

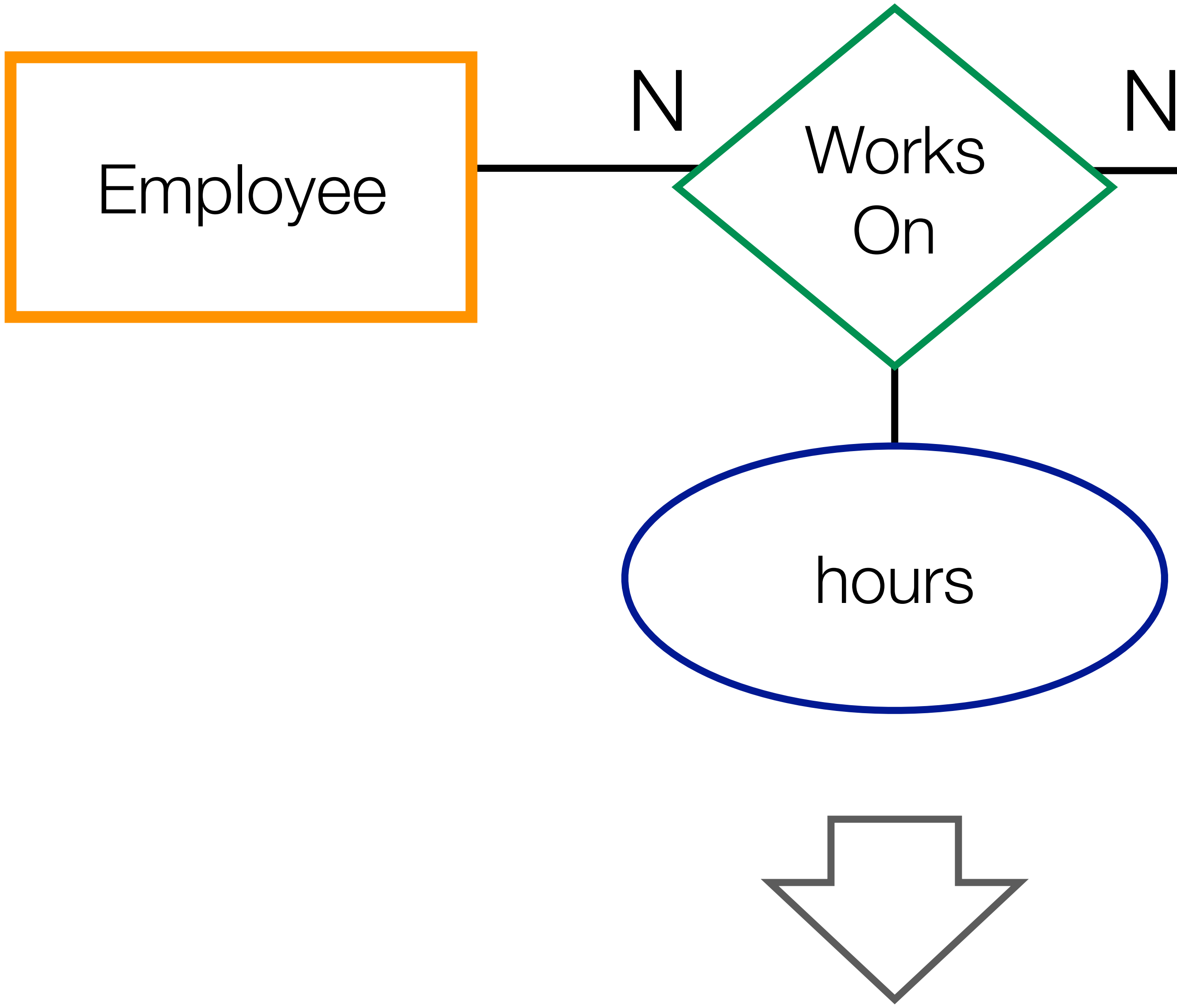


Expand Department because of total participation

DEPARTMENT

DName	DNumber	mgrSSN	mgrStart
…	…		

Step 2: Works On



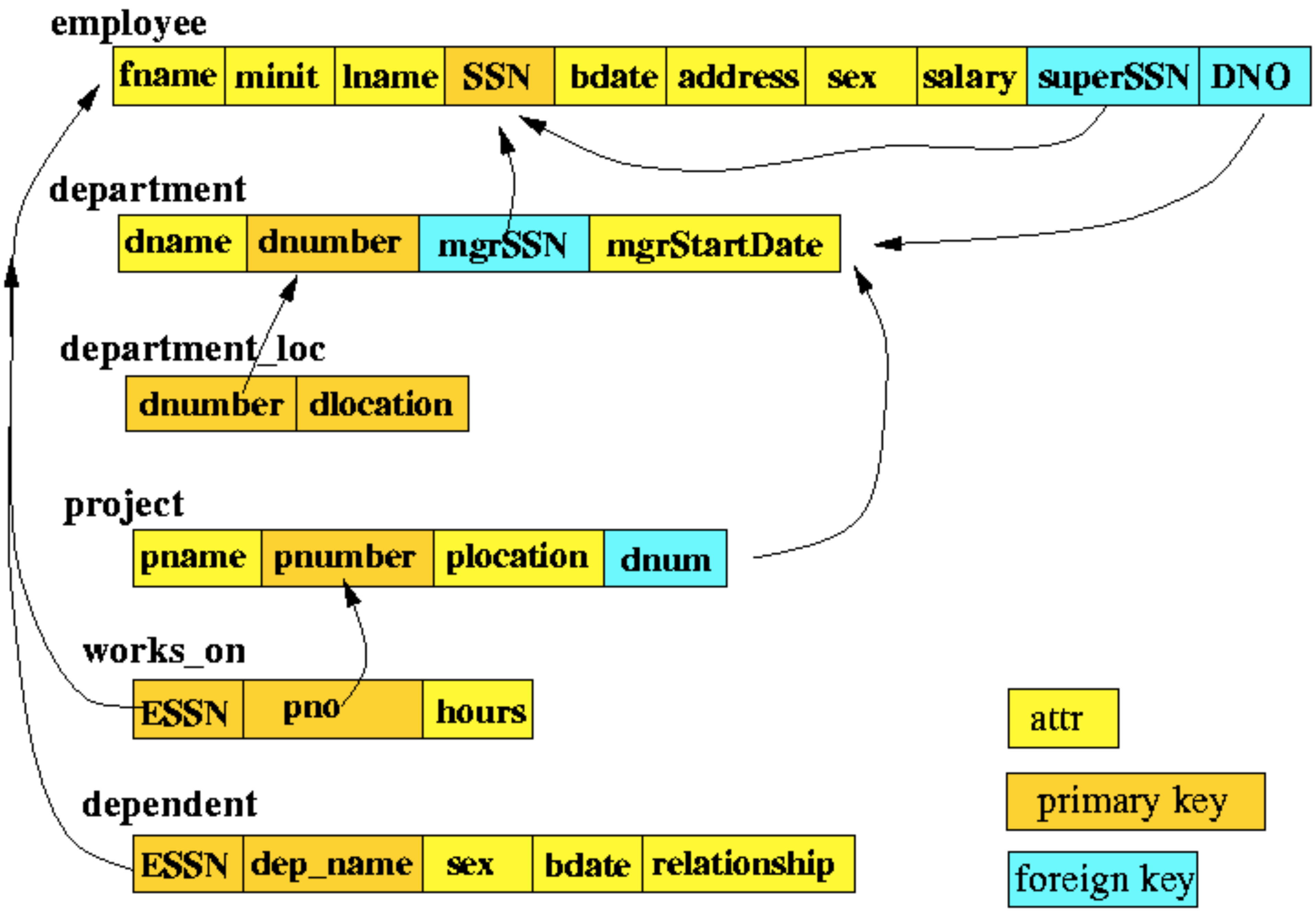
Expansion?

- Employee w/ attribute WorkedOnProject leads to multi-valued attribute
- Project w/ attribute WorkerSSN also results in multi-valued attribute

WORKS_ON

ESSN	PNO	Hours
…	…	

Example: Full Relational Model



http://www.mathcs.emory.edu/~cheung/Courses/377/Syllabus/3-Relation/rel-db-design2.html

Mapping Summary

ER Model	Relational model
Entity type	Entity relation
1:1 or 1:N relationship	Expand (or create R relation)
M:N relationship	Create R relation with two foreign keys
n-ary relationship type	Create R relation with n foreign keys
Simple attribute	Attribute
Composite attribute	Set of simple component attributes
Multivalued attribute	Relation and foreign key
Key attribute	Primary (or secondary) key

Exercise: Football ER Model

Relational Model: Recap

- Relational Model
  - Relation, attributes
  - Schema vs instance
  - Relational model constraints
- ER to Relational
  - Entity set, relationship —> relation