Databases : Lecture 11:
Entity/Relationship modelling
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Lent Term 2010

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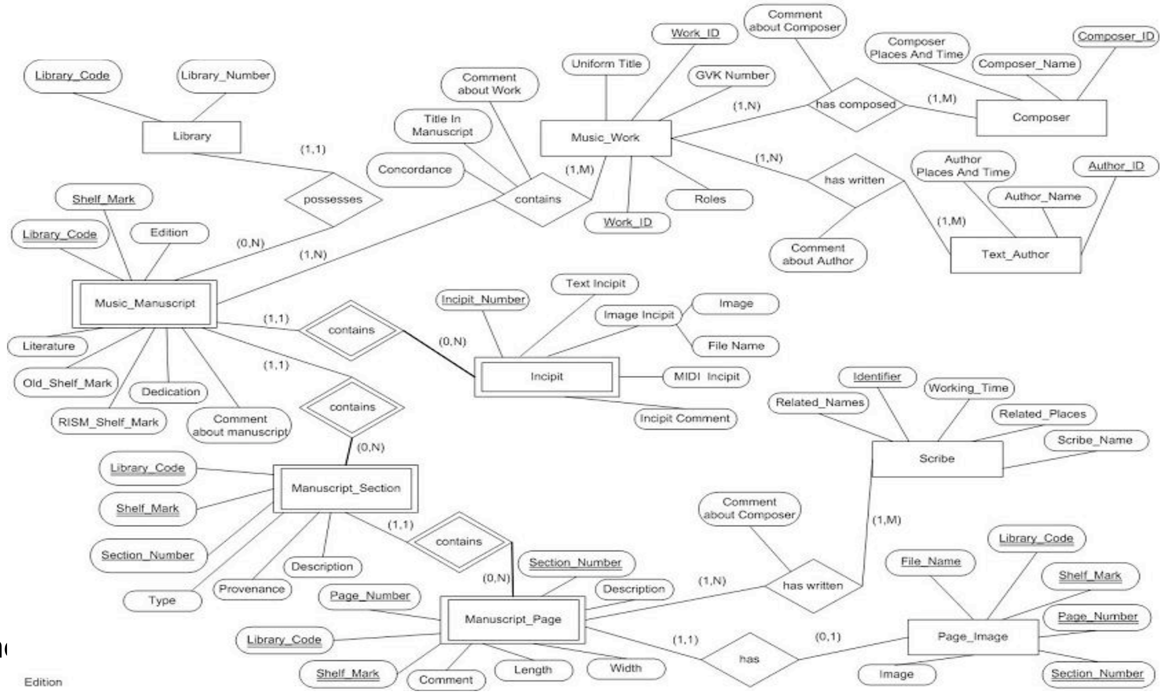


Conceptual Design

- What are the *entities* and *relationships* in the enterprise?
- What information about these entities and relationships should we store in the database?
- What are the integrity constraints (business rules) that hold?
- We can represent this information pictorially in E/R diagrams (and then map these to a relational schema later).

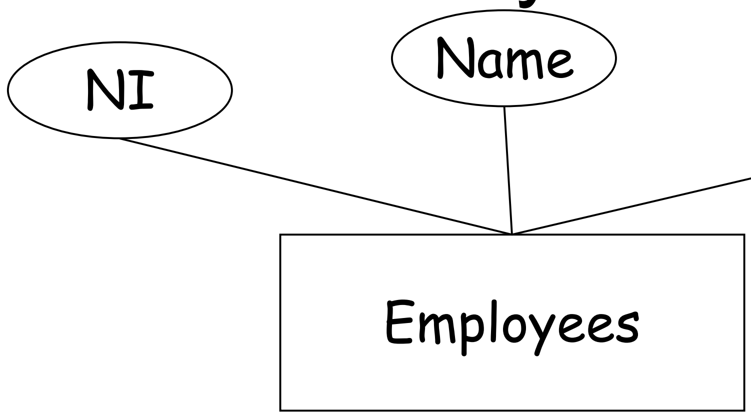
E/R basics

- An **entity** is a real-world object that is distinguishable from other objects
- Each entity has **attributes** (with domains)
- A particular entity will have a value for each of its attributes
- An **entity type** defines a set of entities that have the same attributes
- An **entity set** is the collection of all entities of a particular entity type (at a particular point in time)

Entities and attributes

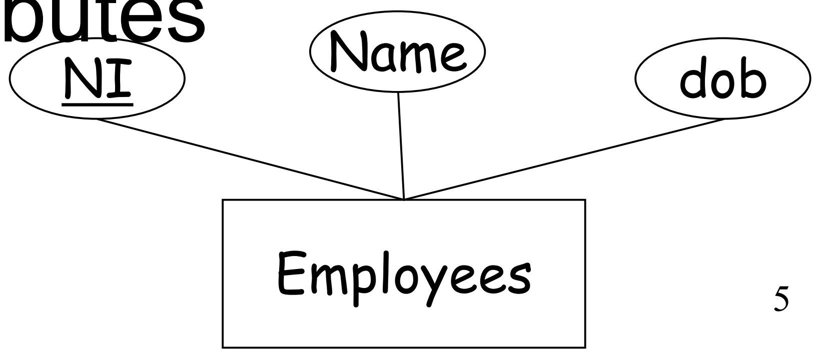
- Entity types are drawn as rectangles, e.g.

- Attributes are drawn as ovals, and attached to the entity sets with lines, e.g.



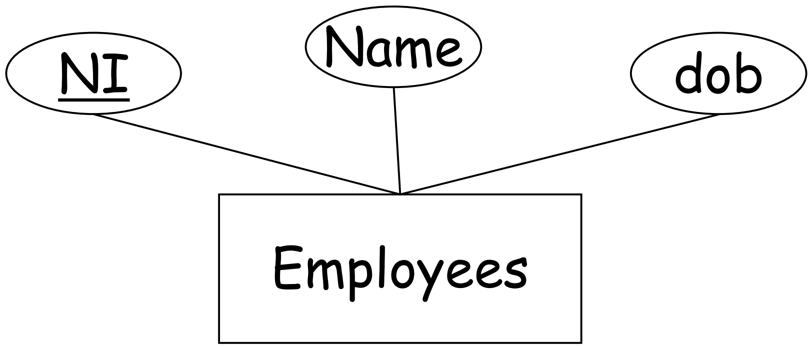
Key attributes

- A **key attribute** of an entity type is an attribute whose values are distinct for each entity
- Sometimes several attributes (a composite attribute) together form a key
  - NB: Such a composite should be **minimal**
- We <u>underline</u> key attributes



Entity types to relations

- A (strong) entity type maps to a relation schema in the obvious way, e.g.



is mapped to the relation schema

$$\text{Employees}(\overline{\text{NI}:\tau_1}, \text{Name}:\tau_2, \text{dob}:\tau_3)$$

Relationships

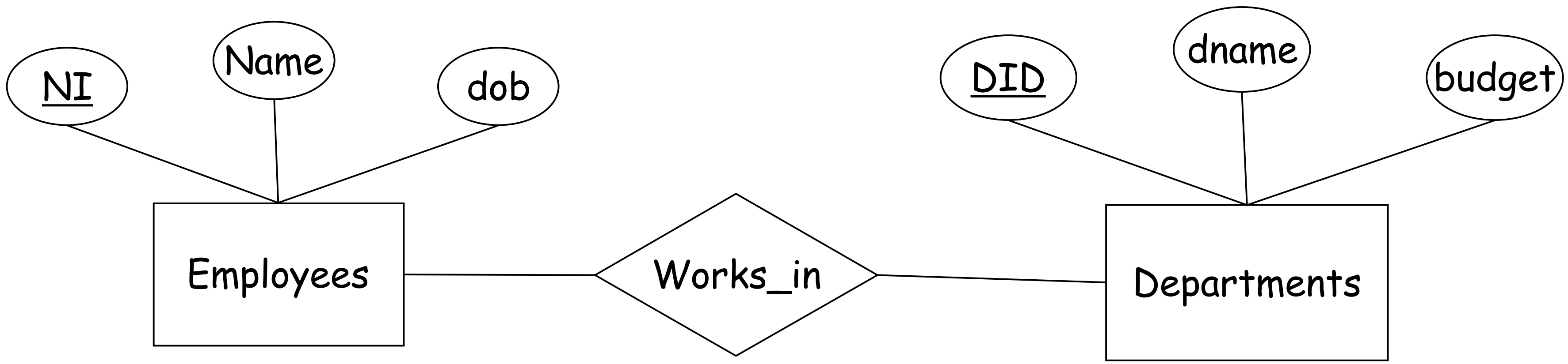
- A **relationship type** among two or more entity types defines a set of associations between entities from those types
  - Mathematically, relationship type R

$$R \subseteq E_1 \times \ldots \times E_n.$$

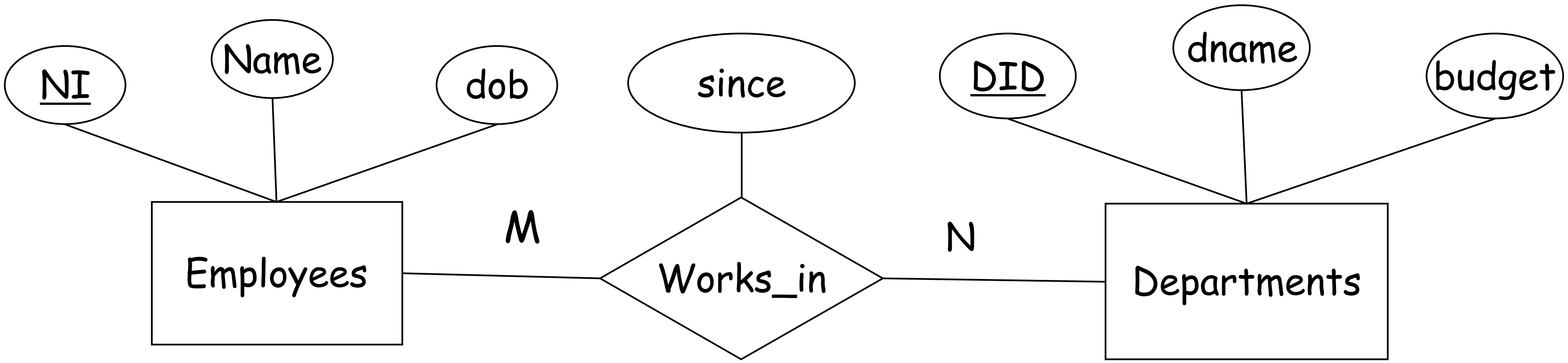
- The set of instances of the relationship type is called the **relationship set**

Relationships in E/R

- Relationship types are represented by diamonds
- They connect the participating entity types with straight lines, e.g.



Map to relation

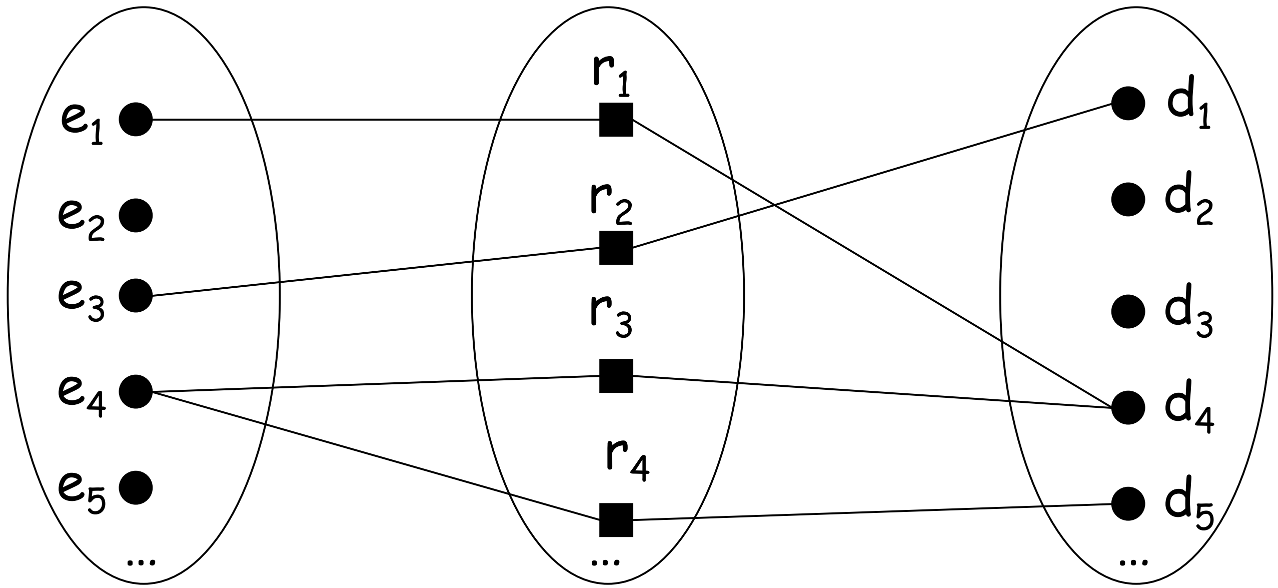


is mapped to the relation schema:

$$\text{Works\_in}(\overline{\text{NI}:\tau_1, \text{DID}:\tau_2}, \text{since}:\tau_3)$$

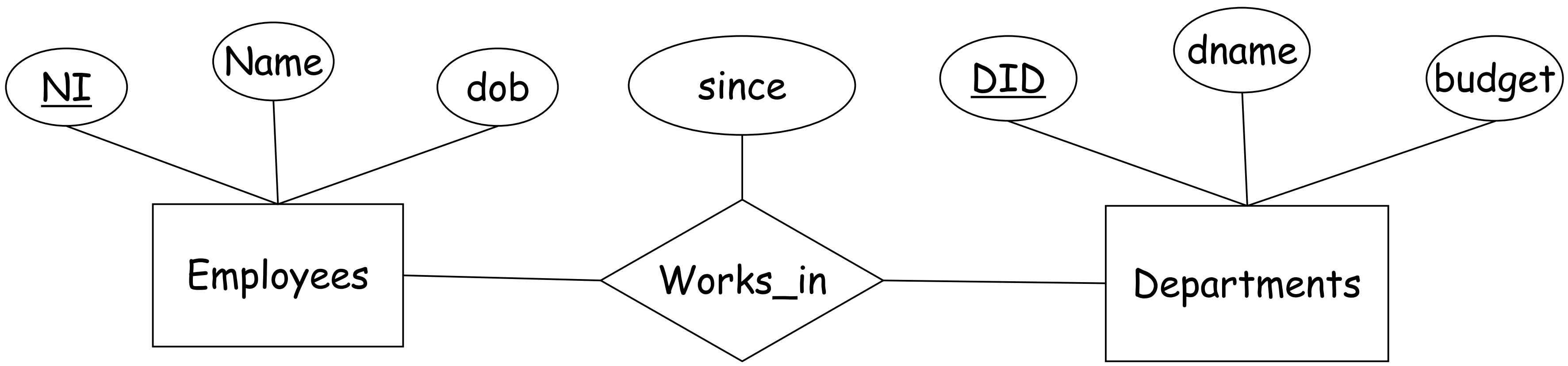
Relationship set diagrams

- Sometimes its useful to represent the relationship set diagrammatically



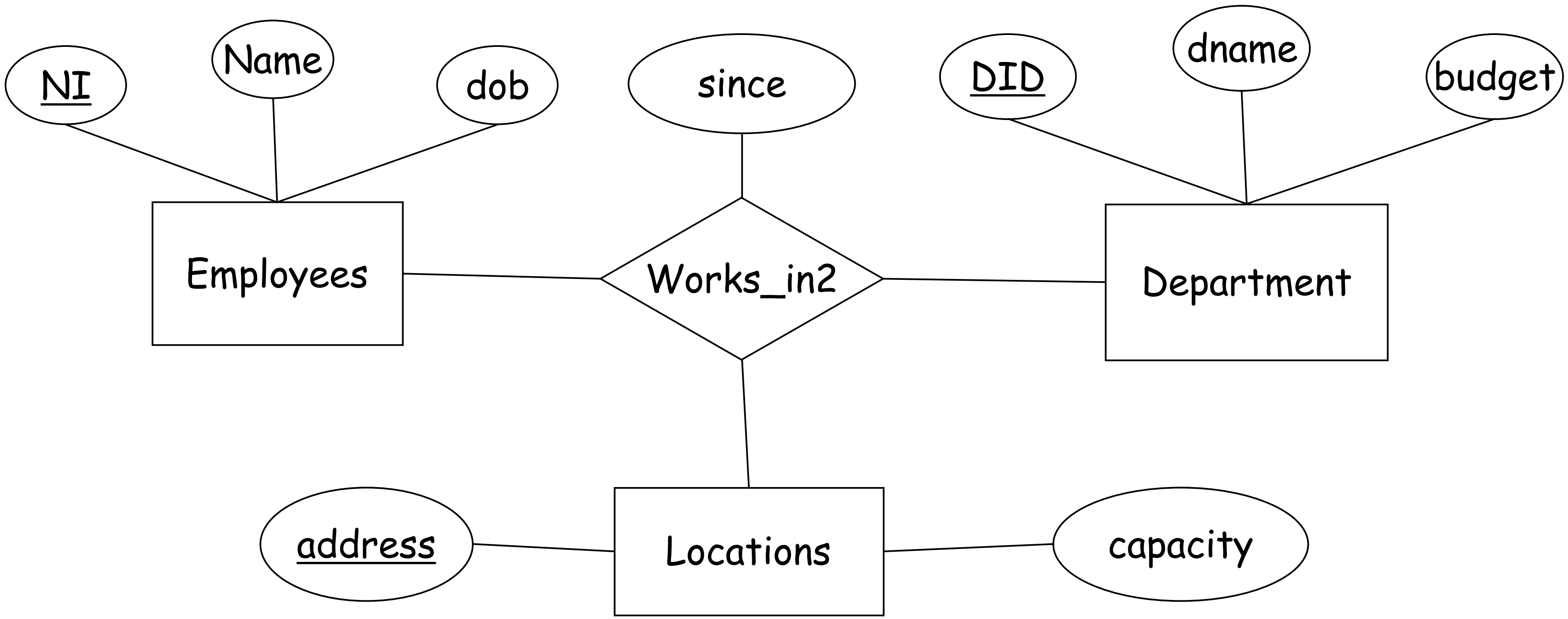
Relationship attributes

- Relationships can also have **attributes**
  - NB: A relationship must be uniquely determined by the entities, without reference to the relationship attributes



N-ary relationships

- Although relatively rare, we can have n-ary relationships, e.g.

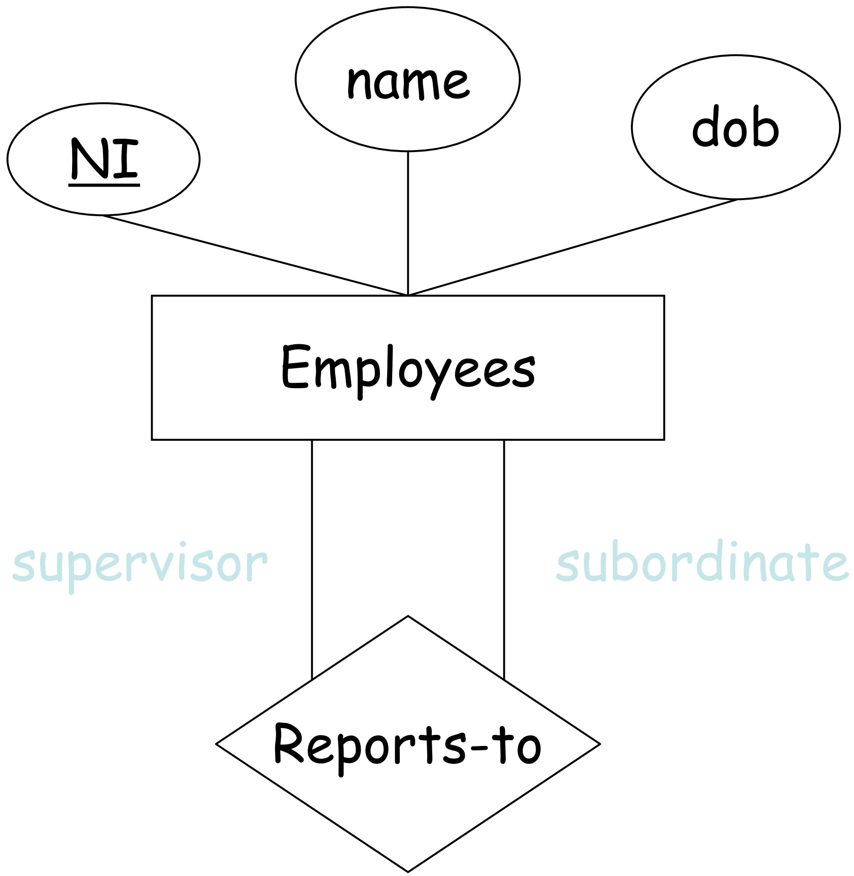


Recursive relationships

- Each entity type in a relationship plays a particular **role**, which is associated with a **role name** (this is usually suppressed)
- An **recursive relationship** is when an entity type plays more than one role in the relationship type
- In this case the role name is required

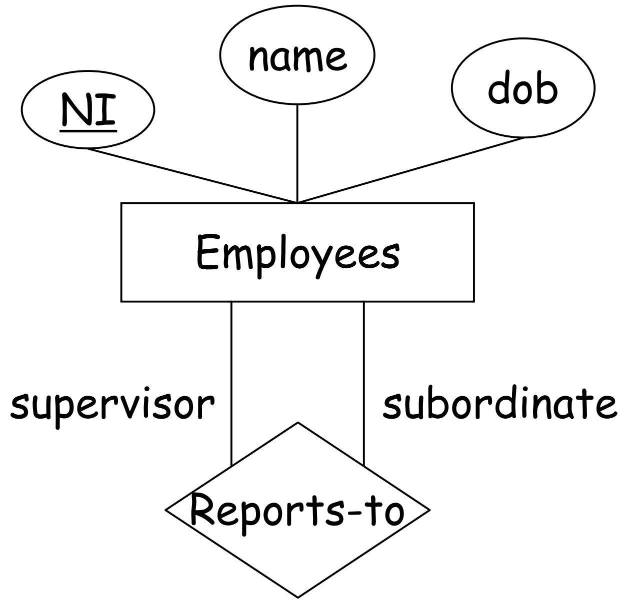
Recursive relationships in E/R

e.g.



Recursive relationship sets

- Just pick appropriate field names! E.g.



is mapped to

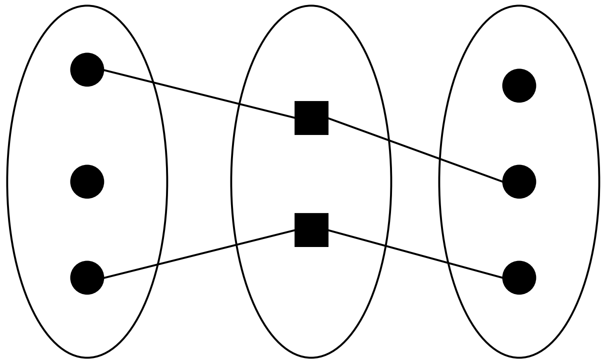
$$\text{Reports\_to}(\text{sup\_NI}:\tau_1,\ \text{sub\_NI}:\ \tau_1)$$

Constraints on relationship types

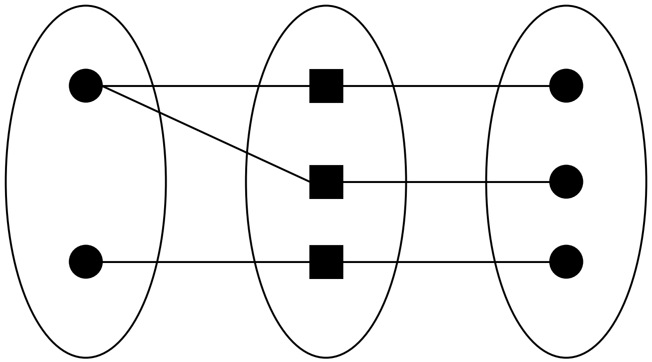
- For example:
  - An employee can work in many departments; a department can have many employees
  - In contrast, each department has at most one manager
- Thus we need to be able to specify the number of relationship instances that an entity can participate in.
- For binary relationships the possible ratios are: **1:1**, **1:N**, **N:1**, **M:N**

Cardinality ratios

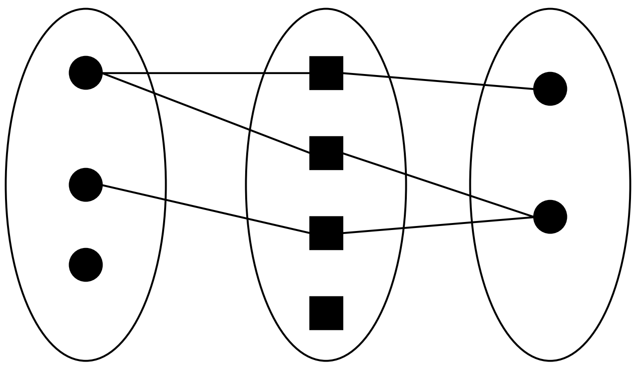
1:1



1:N



M:N

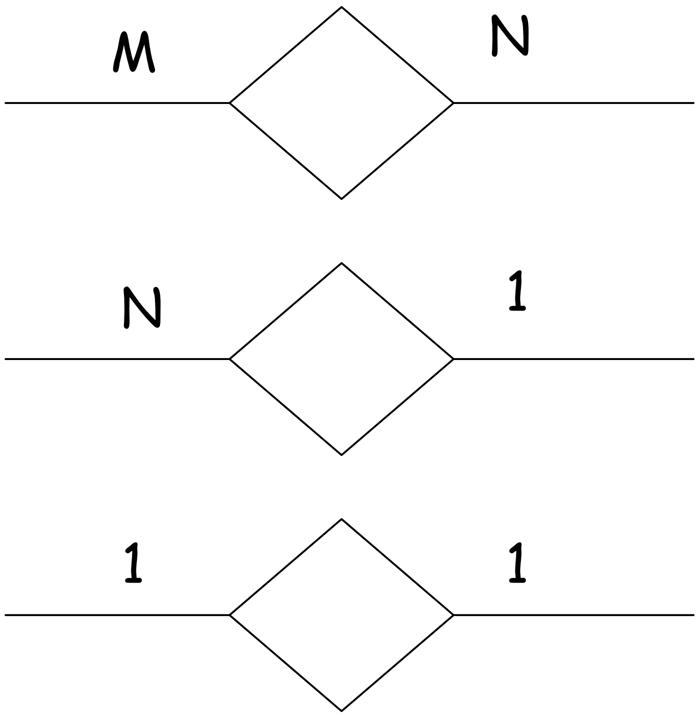


Cardinality ratios in E/R

M:N

N:1

1:1



Note: Sometimes this is written using different arrowheads

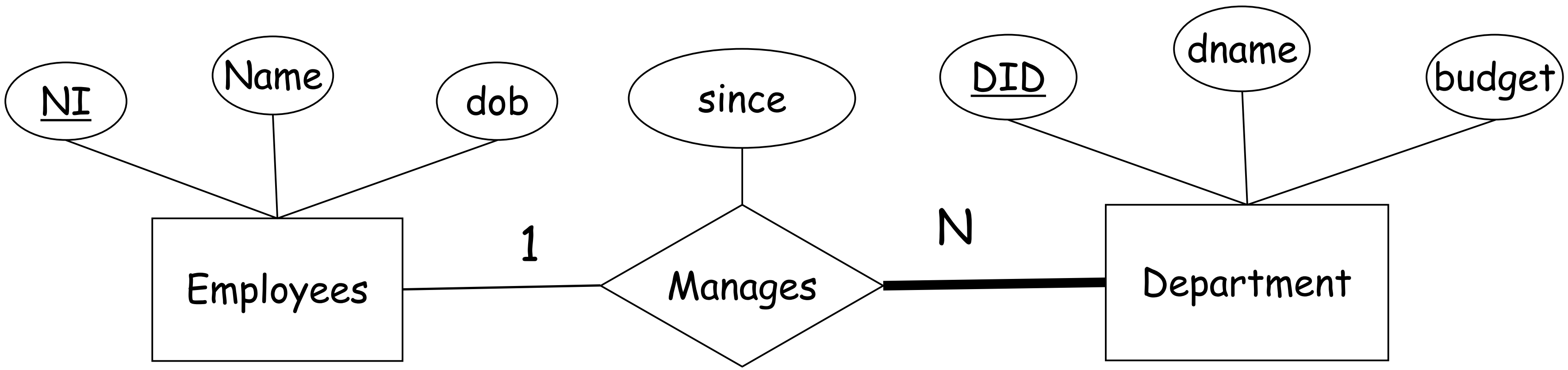
Participation constraints

Every department must have a manager

- This is an example of a **participation constraint**
- The participation of an entity set, E, in a relationship set R is said to be **total** if every entity in E participates in at least one relationship in R. (If not its participation is said to be **partial**)

Participation in E/R diagrams

- Total participation is displayed as a **bold** line between the entity type and the relationship
  - NB. Sometimes this is written as a double line

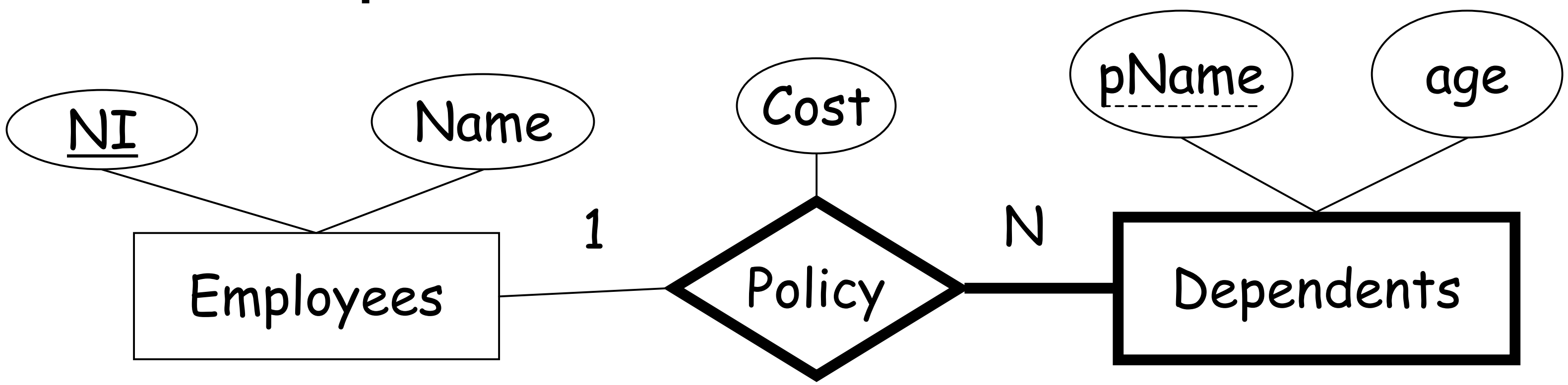


Weak entity types

- An entity type may not have sufficient attributes to form a primary key
- Such an entity type is called a **weak entity type**
- A weak entity can only be identified uniquely by considering the primary key of another (**owner**) entity

Weak entity types cont.

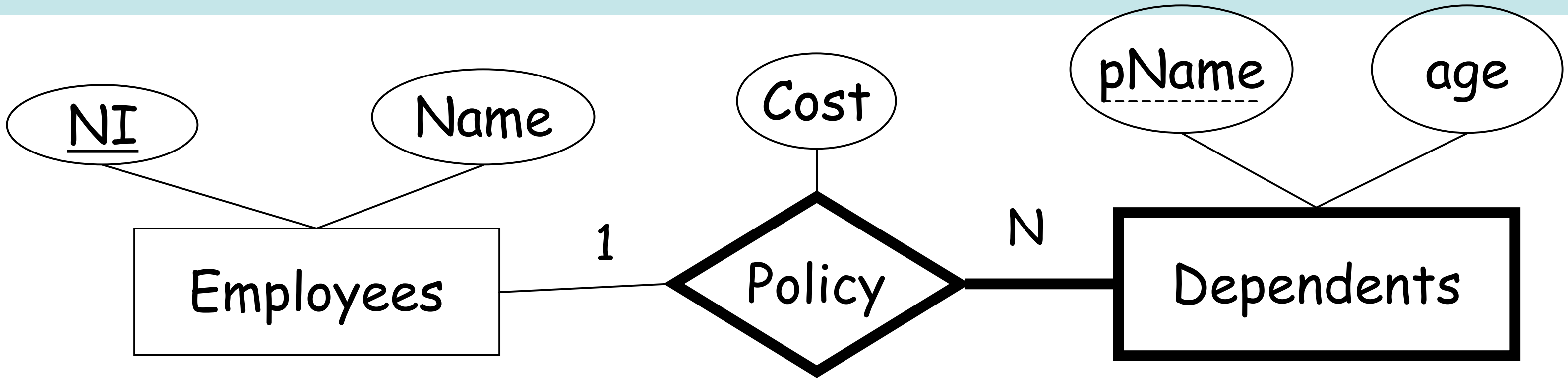
- Thus the owner and weak entity types must participate in a **1:N** relationship
- Weak entity set must have total participation in this **identifying** relationship set.



Implementng Weak entity types

- Given a weak entity type, W, we generate a relation schema with fields consisting of the attributes of W, and the primary key attributes of the owner entity type
- For any relationship in which W appears we generate a relation schema which must take as the key for W all of its key attributes, including those from its owner set

Example



is mapped to the following schema:

$\text{Dependents}(\overline{\text{pName}:\tau_1, \text{NI}:\tau_2}, \text{age}:\tau_3)$

$\text{Policy}(\overline{\text{pName}:\tau_1, \text{NI}:\tau_2}, \text{Cost}:\tau_4)$

Alternatively:

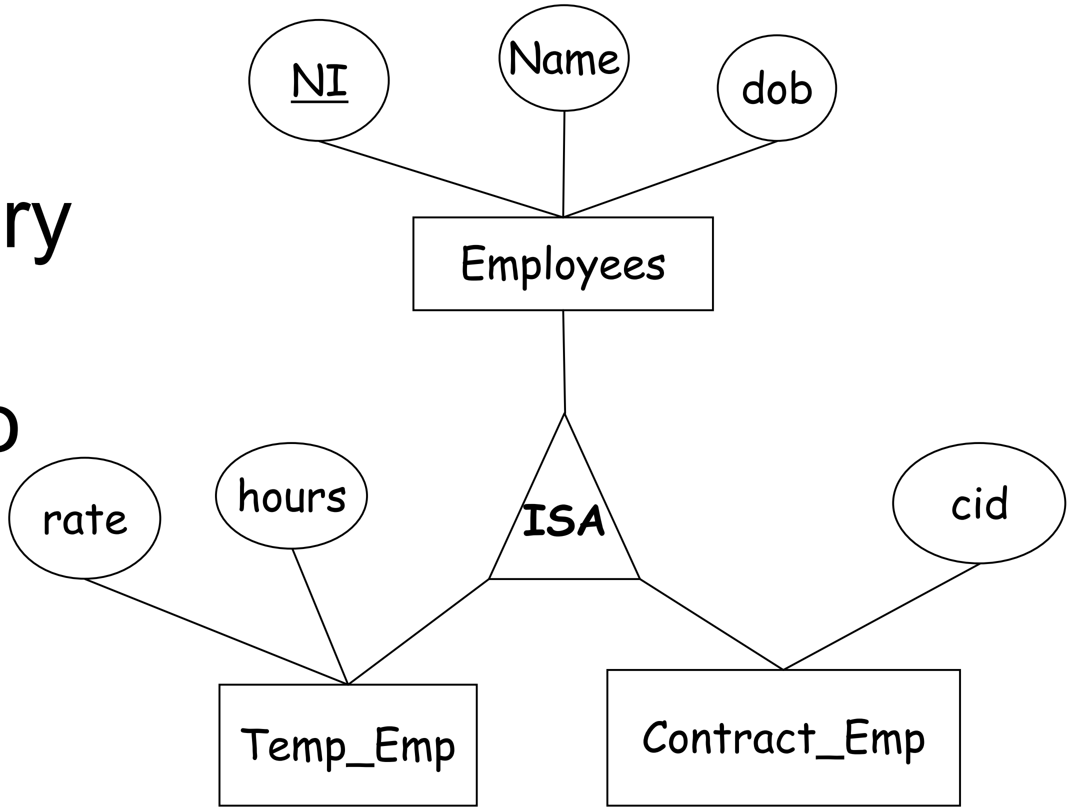
$\text{Policy}(\text{pName} :\tau_1, \text{NI} :\tau_2, \text{age} :\tau_3, \text{Cost} :\tau_4)$

Extended E/R modelling

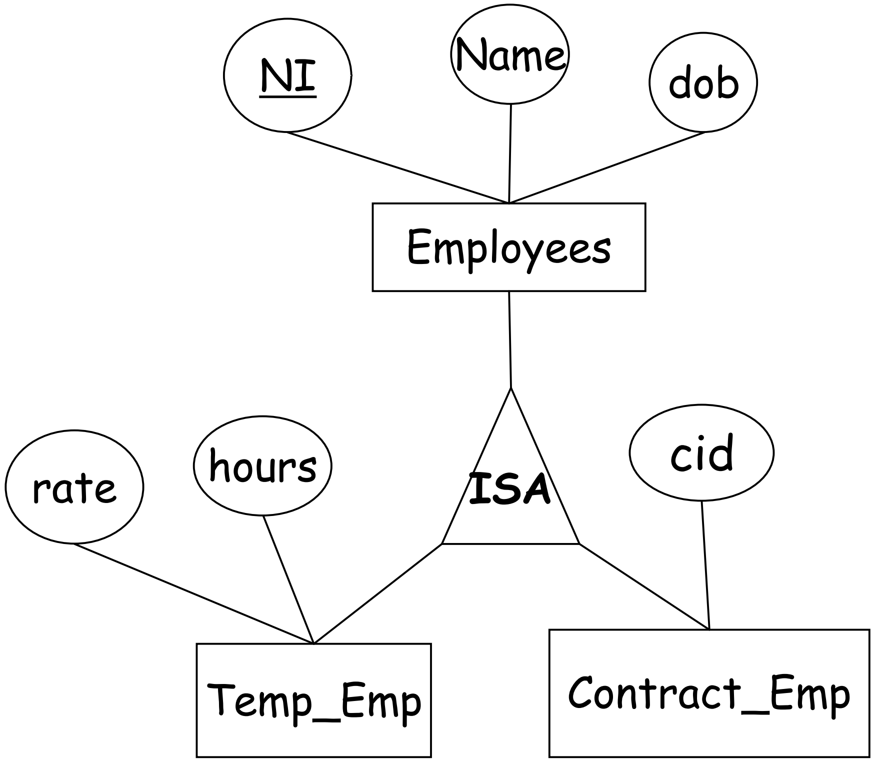
- What we've seen so far is "classic" E/R
- Over the years a number of features have been added to the model and the modelling process
- These features include:
  - Sub- and super-classes
  - Specialisation
  - Generalisation
  - Categories
  - Higher/Lower-level entity sets
  - Attribute inheritance
  - Aggregation

ISA hierarchies

- We can devise **hierarchies** for our entity types
- If we declare *A* **ISA** *B*, every *A* entity is considered to be a *B* entity



ISA Hierarchies



Two choices:

1. 3 relations

   (Employees, Temp_Emp and Contract_Emp)

2. 2 relations

   (Temp_Emp and Contract_Emp)

Databases Lecture 12: Database Systems

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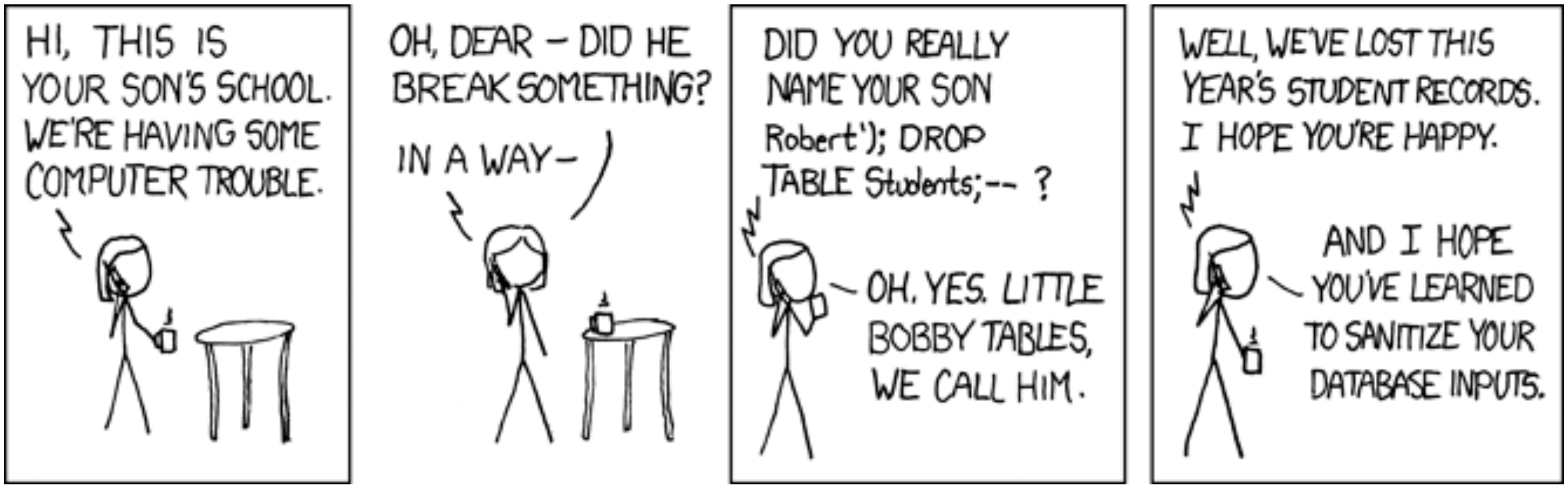


What is a database system?

- A **database** is a large, integrated collection of data
- A database contains a model of something!
- A **database management system** (DBMS) is a software system designed to store, manage and facilitate access to the database

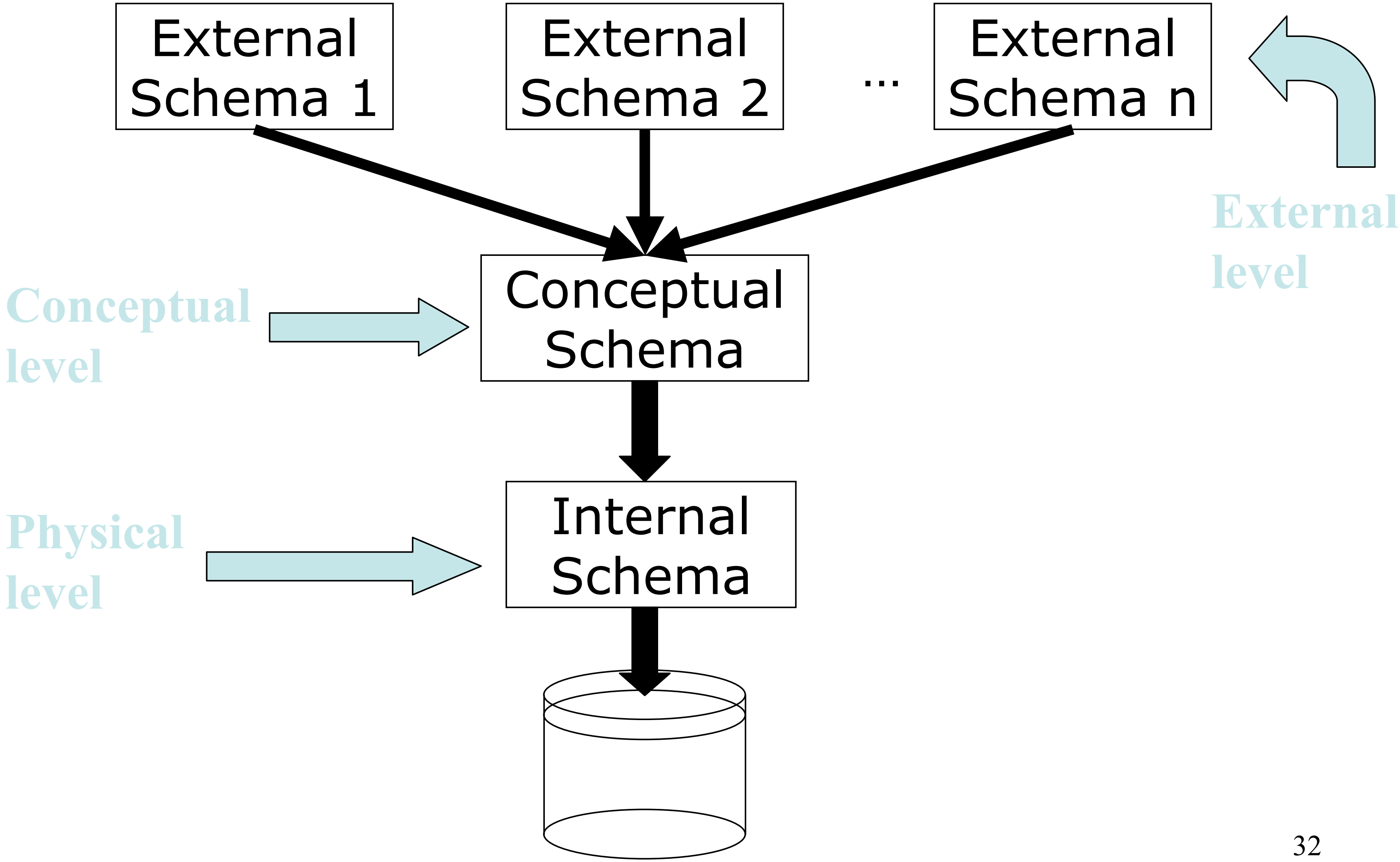
What does a database system do?

- Manages Very Large Amounts of Data
- Supports **efficient** access to Very Large Amounts of Data
- Supports **concurrent** access to Very Large Amounts of Data
- Supports **secure**, **atomic** access to Very Large Amounts of Data

Database system architecture

- It is common to describe databases in two ways
  - **The logical level**:
    - What users see, the program or query language interface, …
  - **The physical level**:
    - How files are organised, what indexing mechanisms are used, …
- It is traditional to split the logical level into two: overall database design (**conceptual**) and the views that various users get to see
- A **schema** is a description of a database

Three-level architecture



Logical and physical data independence

- **Data independence** is the ability to change the schema at one level of the database system without changing the schema at the next higher level
- **Logical data independence** is the capacity to change the conceptual schema without changing the user views
- **Physical data independence** is the capacity to change the internal schema without having to change the conceptual schema or user views

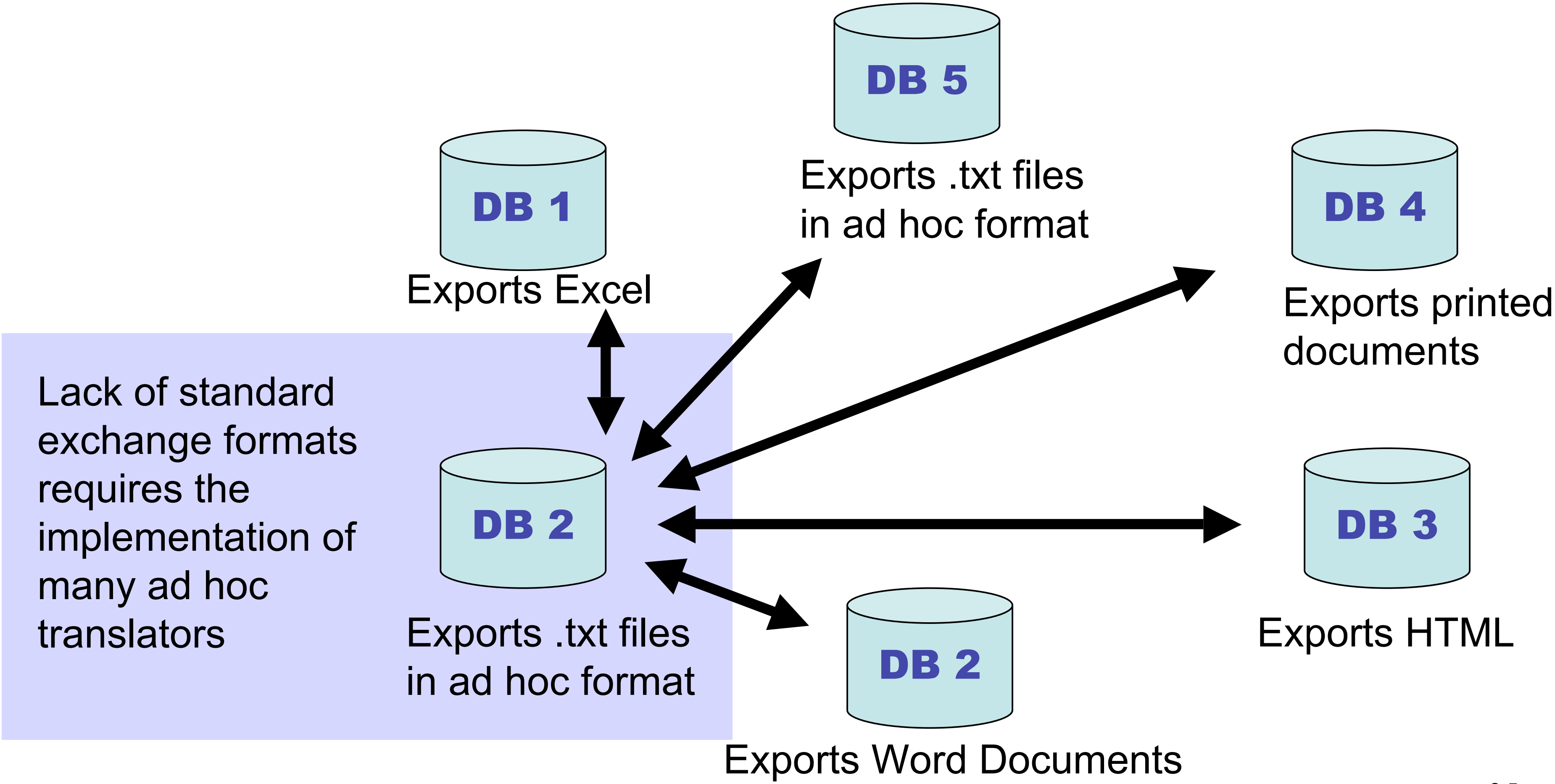
Database Context

Database systems are more and more likely to support features that "unlock" databases and allow them to aasily interact in a larger context

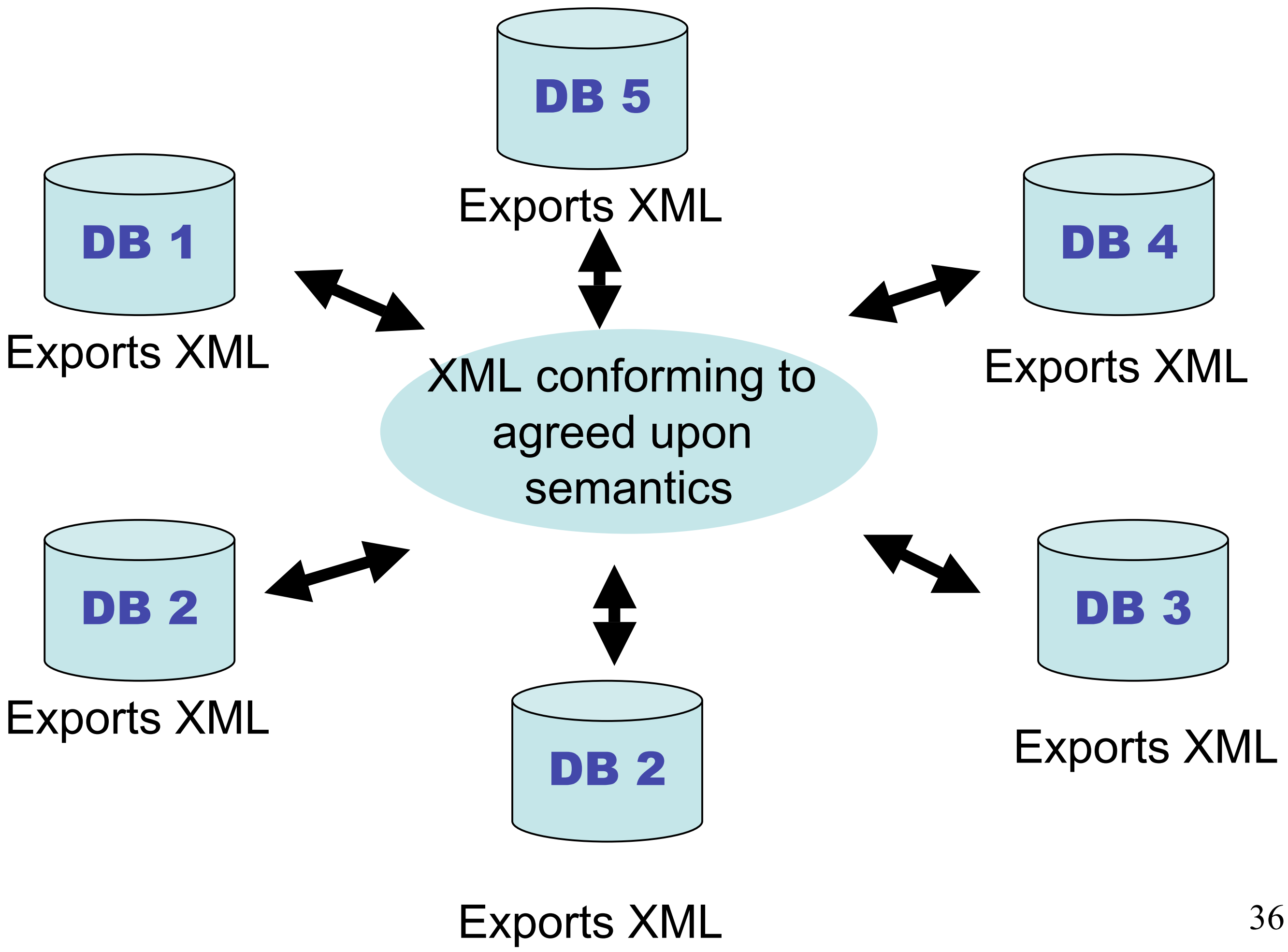
- Data-warehousing features
  - Data cube
- Inter-database exchange features
  - XML

The “Data Publishing” Problem

Need to share data without exposing internal details of your database.



XML as a data exchange format



XML and Databases

- **XML-enabled databases:**
  - Data stored in structured (usually relational) format.
  - XML primarily used as a data exchange format
  - Interfaces and SQL extensions provided to facilitate generation of XML and parsing of XML.
  - "Data-centric"
- **Native XML database:**
  - Allows direct storage and manipulation of XML data.
  - "Document-centric"

What is XML?

- Extensible Markup Language
- W3C proposal, Current version 1.0 (3rd ed.) February 2004
- Authors:
  - Tim Bray (Netscape)
  - Jean Paoli (Microsoft)
  - C.M. Sperberg-McQueen (W3C)
  - Eve Maler (Sun)
  - François Yergeau

http://www.w3.org/TR/REC-xml

XML has roots in HTML

HTML

- *Lingua-franca* for publishing hypertext on the web
- Designed to inform a web-browser both what information to render, **and** how it should be rendered
  - (Actually these shouldn't be mixed up)
- Easy to learn (Big win)
- Fixed tag set, rather odd syntax

HTML: An example

Opening tag

Text
(PCDATA)

Closing tag

Attribute
(name and value)

```
<HTML>
 <HEAD>
  <TITLE>
    Welcome to gmb's homepage
  </TITLE>
 </HEAD>
 <BODY>
  <H1>Background info</H1>
  <IMG SRC="me-and-britney.jpg">
  I have a lot of great friends
 …
 </BODY>
</HTML>
```

XML structure

- The fundamental construct is the **element**, which is essentially a pair of matching tags and the text between them, e.g.
  - `<name>Britney</name>` is an element
  - `<name>Victoria</nom>` is not an element
- XML documents must have single root element
- No fixed set of tags
- Elements can be properly nested, thus
  - `<name> … <address> … </address> … </name>` ☺
  - `<name> … <address> … </name> … </address>` ☹

XML structure cont.

- We can represent various structures using nesting and repetition
- Tuple (Record):

```
<person>
  <name>Emma Bunton</name>
  <tel>020 8777 1234</tel>
  <email>baby@spicegirls.com</email>
</person>
```

- Lists:

```
<addresses>
  <person> … </person>
  <person> … </person>
  <person> … </person>  …
</addresses>
```

XML structure cont.

- Nesting can be used to avoid joins, e.g.

```
<bank>
  <cust><name>Britney Spears</name>
        <address>Florida</address>
  </cust>   …
  <acc>
      <accno>BS001</accno>
      <branch>Florida High Street</branch>
      <balance>10,000,000</balance>
  </acc>    …
  <saver>
    <sname>Britney Spears</sname>
    <saccno>BS001</saccno>
  </saver>      …
 </bank>
```

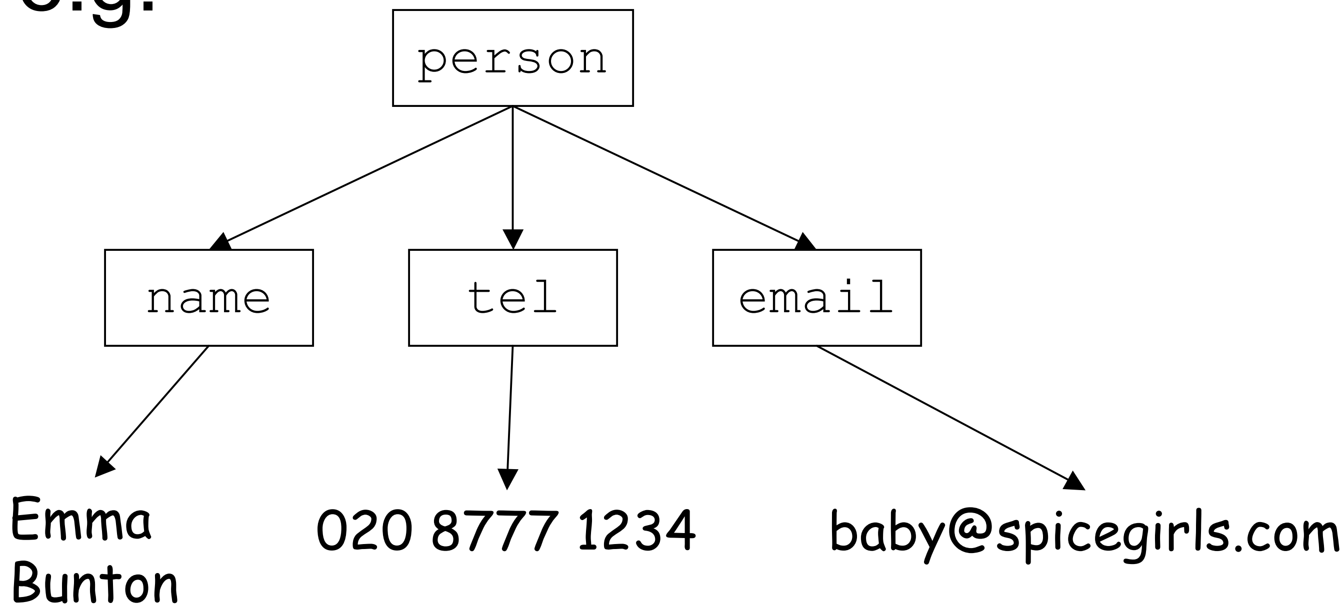
XML structure cont.

- Join avoiding:

```
<bank2>
 <cust>
   <name>Britney Spears</name>
   <address>Florida</address>
   <acc>
     <accno>BS001</accno>
     <branch>Florida High Street</branch>
     <balance>10,000,000</balance>
   </acc>
 </cust>
 …
</bank2>
```

XML and trees

- One can visualise XML documents as trees, e.g.



Attributes

- In addition to elements we have **attributes**
- Attributes appear as `name=value` pairs in opening tags, e.g.
  - `<acc type="deposit"> … </acc>`
  - `<acc type="saving" status="closed"> … </acc>`

- (Aside: An element with no body can be abbreviated from `<foo></foo>` to `<foo/>`)

DTDs

- XML documents can be created without any schema
- XML documents can contain a **document type definition** (**DTD**), which is similar to a schema

Example DTD

```
<!DOCTYPE bank [
  <!ELEMENT bank    ((acc|cust|saver)+)>
  <!ELEMENT acc     (accno branch balance)>
  <!ELEMENT cust    (name address)>
  <!ELEMENT saver   (sname saccno)>
  <!ELEMENT accno   (#PCDATA)>
  <!ELEMENT branch  (#PCDATA)>
  <!ELEMENT balance(#PCDATA)>
  <!ELEMENT name    (#PCDATA)>
  <!ELEMENT address(#PCDATA)>
  <!ELEMENT sname   (#PCDATA)>
  <!ELEMENT saccno  (#PCDATA)>
]>
```

DTD details

- ‘|’ denotes alternative, ‘+’ denotes one or more, and ‘*’ denotes zero or more
- ‘#PCDATA’ (Parsed Character Data) means any text!
- We can also specify attributes, e.g.
- <!ATTLIST acc acctype CDATA “deposit”>

Element

Attribute name

Attribute Type (String of characters)

Default value

Attributes

- An attribute of type **ID** provides a unique identifier for the element
- An attribute of type **IDREF** is a reference to an element
- Example:

```
<!ATTLIST account number ID      #REQUIRED
                  owners IDREFS #REQUIRED>

<account number="A001" owners="C001 C007">
…</account>
```

Using DTDs

- DTDs are placed at the start of an XML document
- A document that conforms to its DTD is said to be **valid**
- Alternatively you can give a URL for a DTD, e.g.

```
<!DOCTYPE mybank SYSTEM
          “http://www.hsbc.com/mybank.dtd”>
<mybank>
…
</mybank>
```

Aside on DTDs

- Wouldn't it be better in ML?

```
datatype bank      = BANK of bankitem list
   and   bankitem = ACC of accno*branch*balance
                  | CUST of name*address
                  | SAVER of sname*saccno;
type accno   = string;
type branch  = string;
type balance = string; (*could be int!*)
type name    = string;
type address = string;
type sname   = string;
type saccno  = string;
```

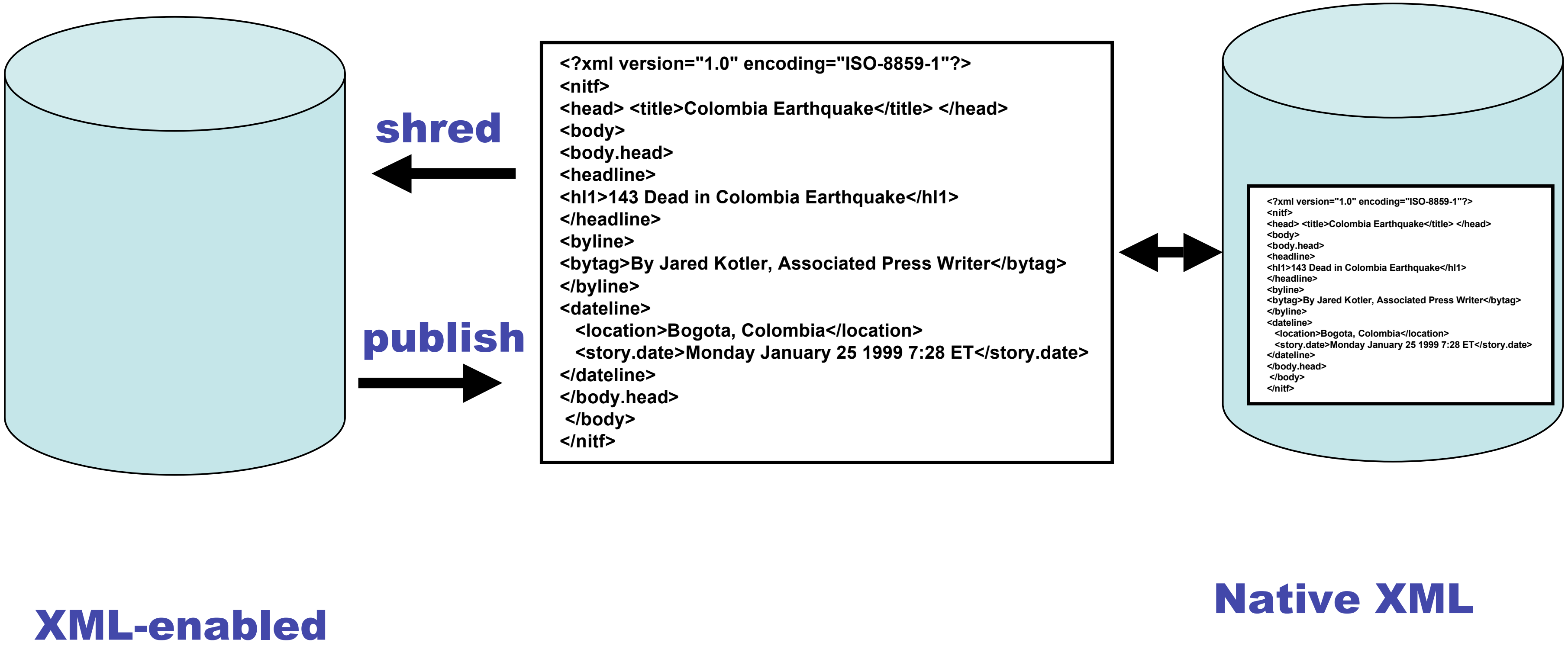
Schema

- You'll have noticed weaknesses with DTDs from a database schema point of view
  - Individual text elements and attributes can't be typed further
  - We don't need ordered sub-elements in database world
  - There is a lack of typing in IDs and IDREFs
- An effort to address these problems has led to a better schema language: **XML schema**

Domain specific DTDs

- There are now lots of DTDs that have been agreed by groups, including
  - WML: Wireless markup language (WAP)
  - OFX: Open financial exchange
  - CML: Chemical markup language
  - AML: Astronomical markup language
  - MathML: Mathematics markup language
  - SMIL: Synchronised Multimedia Integration Language
  - ThML: Theological markup language ☺

Native XML Databases



Documents vs databases

- But this is a document, which is quite different from our world of databases

Document world	**Database world**
Lots of small documents	A few large databases
Static (normally)	Dynamic
Implicit structure	Explicit structure (schema)
Tagging	Records
Human friendly ☺	Machine friendly
Meta data: Author, title, date	Meta data: schema
Editing	Updating
Retrieval (IR)	Querying