Introduction to Database Systems

Fundamental Concepts

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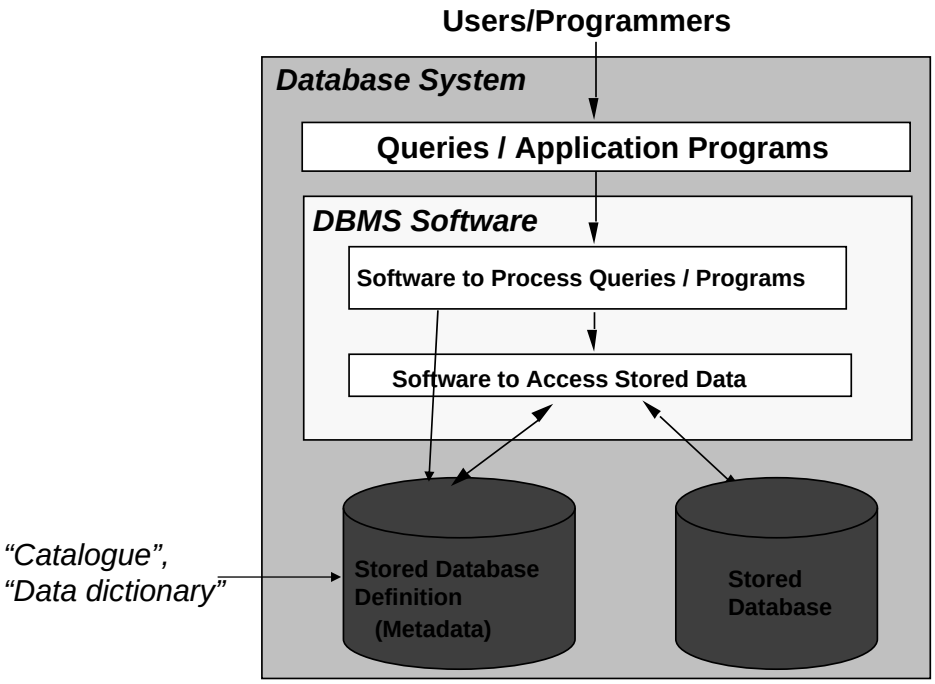
Characteristics of the DB Approach

- *Insulation* of application programs and data from each other
- Use of a *catalogue* to store the schema
- Support of *multiple user views*

➔ *How can one realise these principles?*

A DBMS Presents Programmers and Users with a Simplified Environment



Data Model, Schema and Instance

Data Model

- A set of concepts that can be used to describe the *structure* of a database: the data types, relationships, constraints, semantics and operational behaviour
- Hides details of data storage

Schema

- A formal definition that fixes all the *relevant features* of those parts of the real world that are of interest to the users of the database
- The schema of a db is held in the *data dictionary*

Schema (in relational data model) → **`Student(studno,name,address)`** **`Course(courseno,lecturer)`**

Instance → **`Student(123,Egger,Bozen)`** **`Course(CS321,Nutt)`**

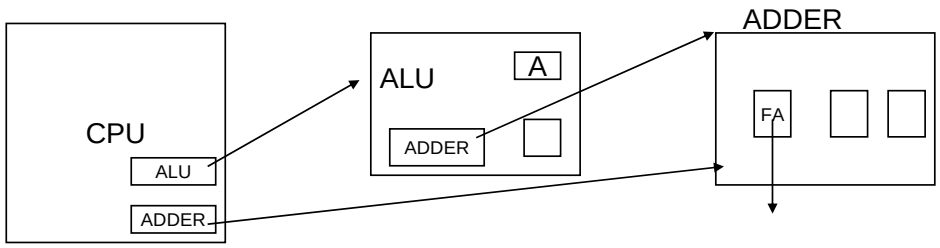
Other Data Models

Relational model is good for:

- Large amounts of data and simple operations
- Limited navigation, touching only small numbers of relations/tables

Difficult applications for relational model:

- VLSI design (CAD in general)



- CASE
- Graphical data
- Bill of materials, transitive closure

Object Data Models

Where number of “relations” is large, relationships are complex

- Object Data Model
- “Knowledge Data Model” (= Objects + Deductive Rules)

Object Data Model (Principles)

1. Complex Objects –
   Nested Structure (pointers or references)
2. Encapsulation, set of methods/access functions
3. Object Identity
4. Inheritance – Defining new classes like old classes

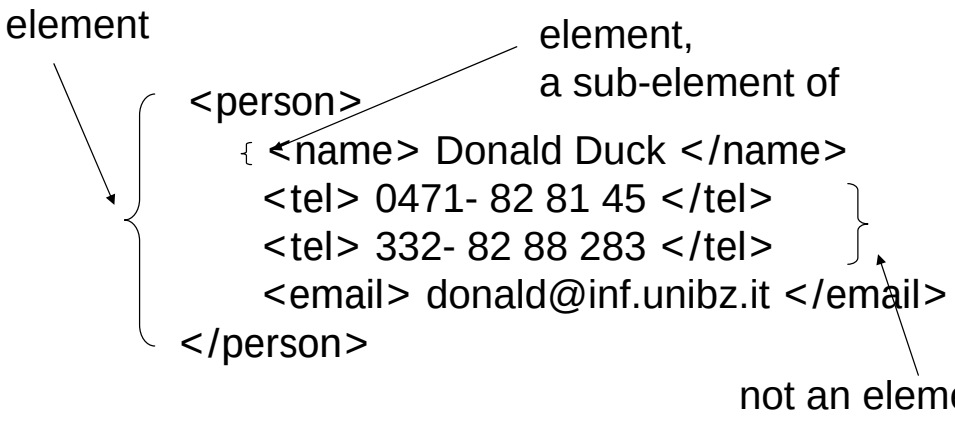
Object model: usually, objects are found via explicit navigation.
Also query language in some systems.

XML Documents

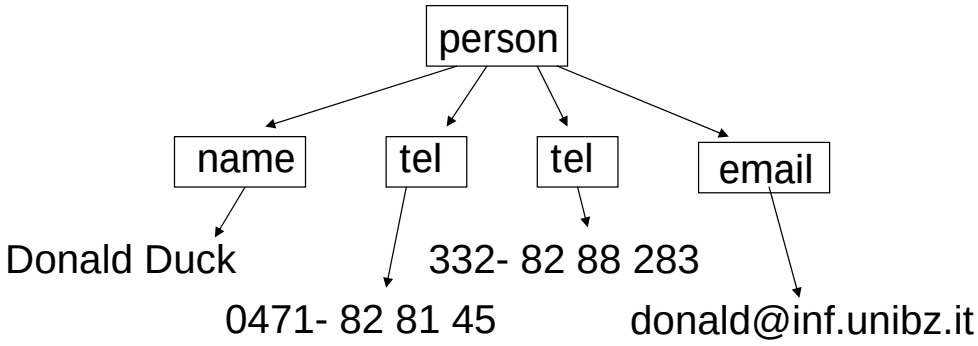
```
<addresses>
        <person>
                <name>Donald Duck</name>
                <tel> 0471- 82 81 45 </tel>
                <tel> 332- 82 88 283 </tel>
                <email> donald@inf.unibz.it </email>
        </person>
        <person>
                <name>Mickey Mouse</name>
                <tel> 0473 – 42 61 14 </tel>
        </person>
</addresses>
```


XML Terminology

The segment of an XML document
between an opening and a corresponding closing tag
is called an element



XML Documents are Trees



- XML documents are abstractly modeled as trees, as reflected by their nesting


```
<?xml version="1.0" encoding="ISO-8859-1"?>
    <catalog>
        <cd country="UK">
          <title>Dark Side of the Moon</title>
          <artist>Pink Floyd</artist>
          <price>10.90</price>
        </cd>
        <cd country="UK">
            <title>Space Oddity</title>
            <artist>David Bowie</artist>
            <price>9.90</price>
        </cd>
        <cd country="USA">
            <title>Aretha: Lady Soul</title>
            <artist>Aretha Franklin</artist>
            <price>9.90</price>
       </cd>
</catalog>
```

An XML document

Document Type Definition (DTD)

DTDs specify the format of documents

```
<!DOCTYPE catalog [
  <!ELEMENT catalog (cd*)>
  <!ELEMENT cd  (title, artist, price)>
  <!ELEMENT title   (#PCDATA)>
  <!ELEMENT artist   (#PCDATA)>
  <!ELEMENT price   (#PCDATA)>
  <!ATTLIST person
                country     CDATA    ID   #IMPLIED>
]>
```

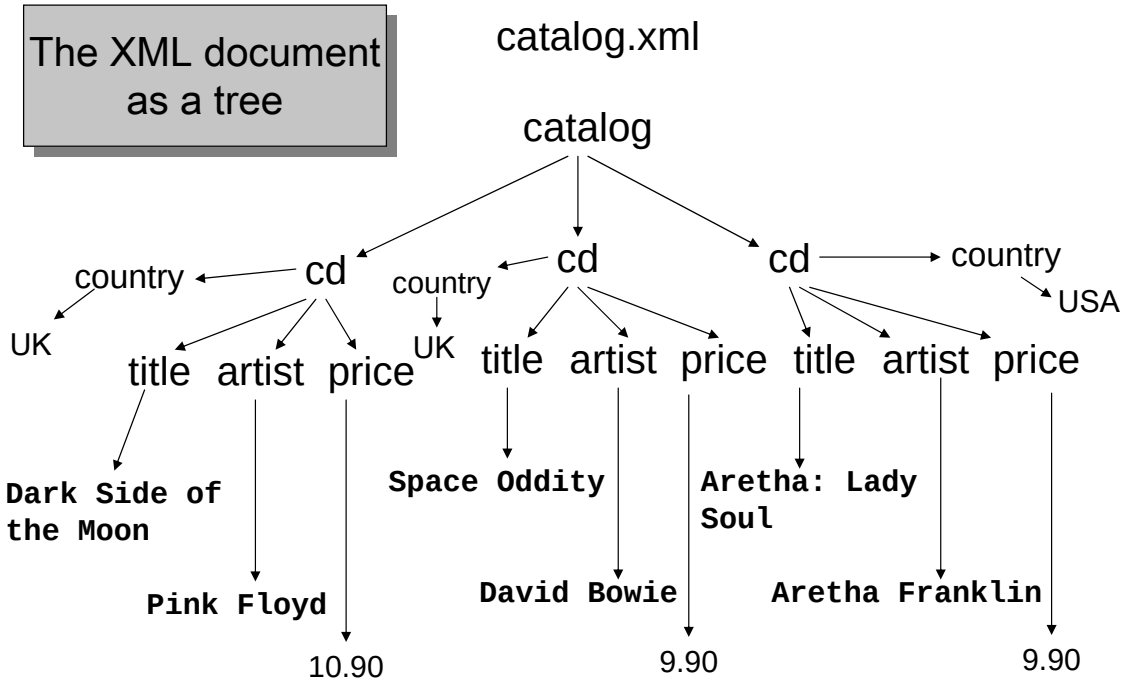
an arbitrary number of CDs

a title, followed by an artist, followed by a price

title, artist, and price contain parsable character data

A person element can have an (optional) country attribute

The XML document as a tree

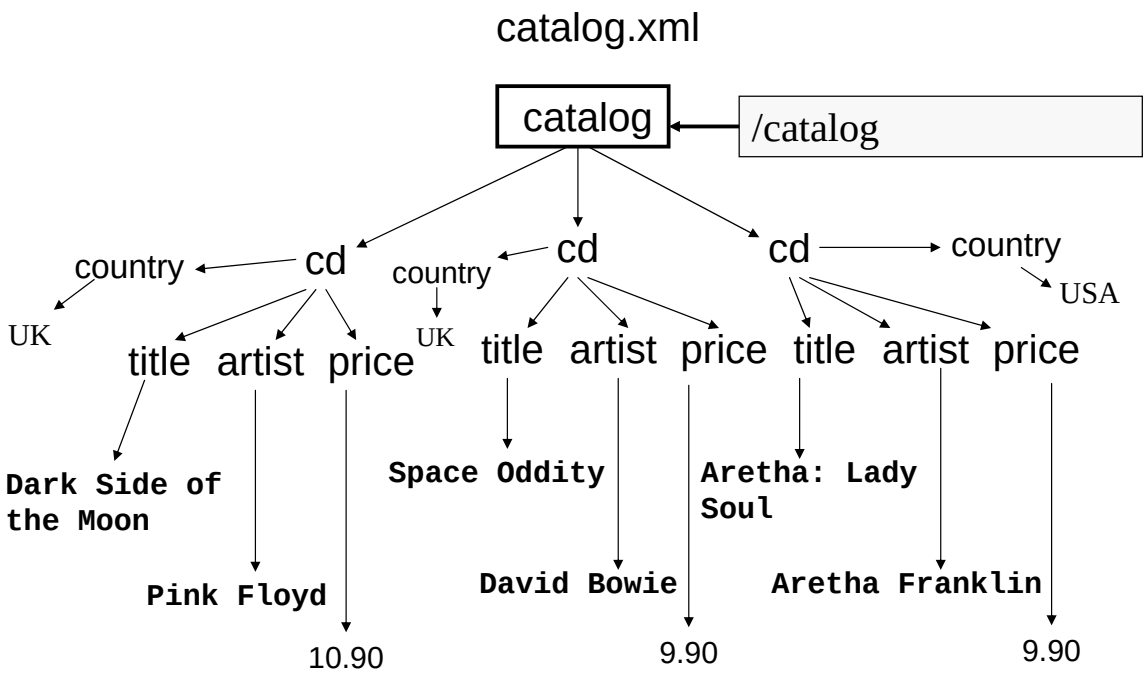


XPath: an XML Query Language

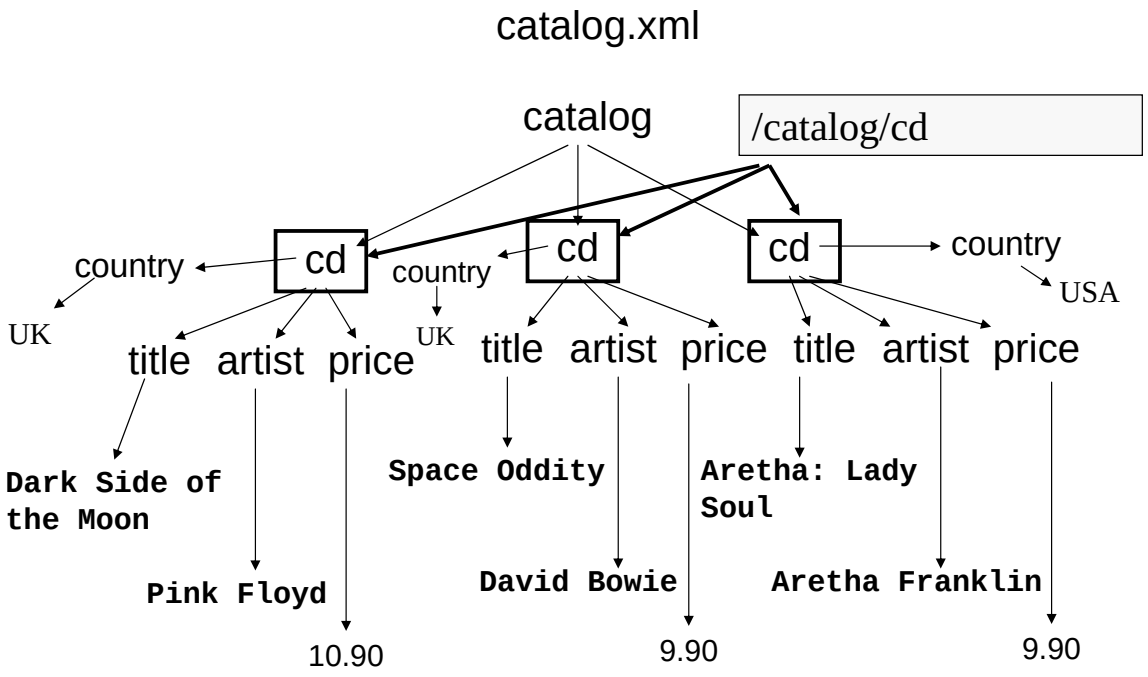
- XPath expressions are evaluated over documents
- XPath operates on the *abstract tree document* structure
- Documents are trees with several *types of nodes*, such as
  - element nodes
  - attribute nodes
  - text nodes

XPath: Path Expressions are Main Element of Syntax

- / at the beginning of an XPath expression represents the root of the document
- / between element names represents a parent-child relationship
- // represents an ancestor-descendent relationship
- @ marks an attribute
- [condition] specifies a condition

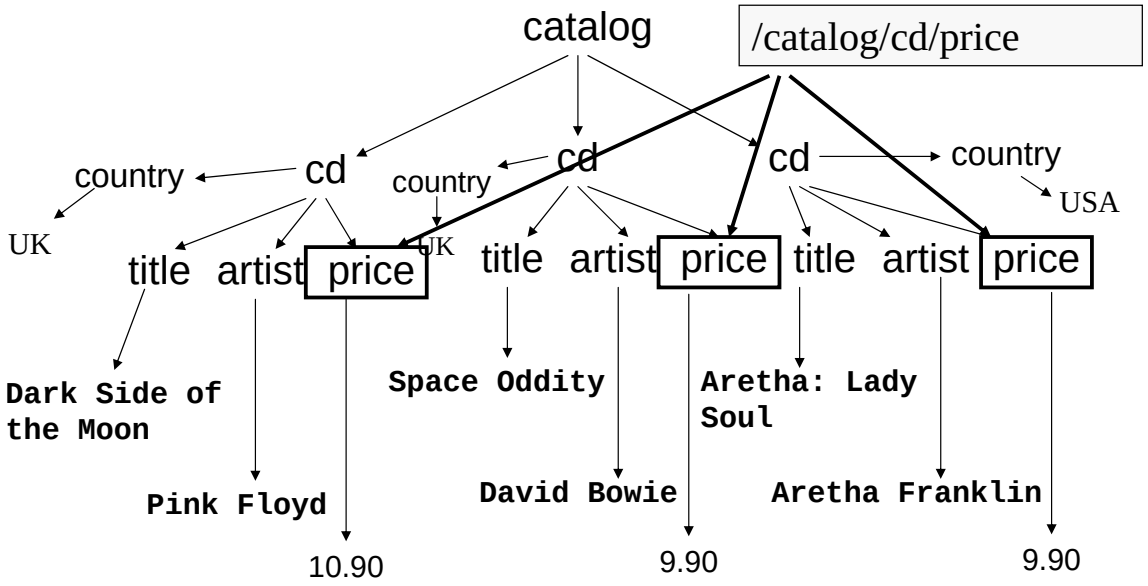


Getting the root element of the document



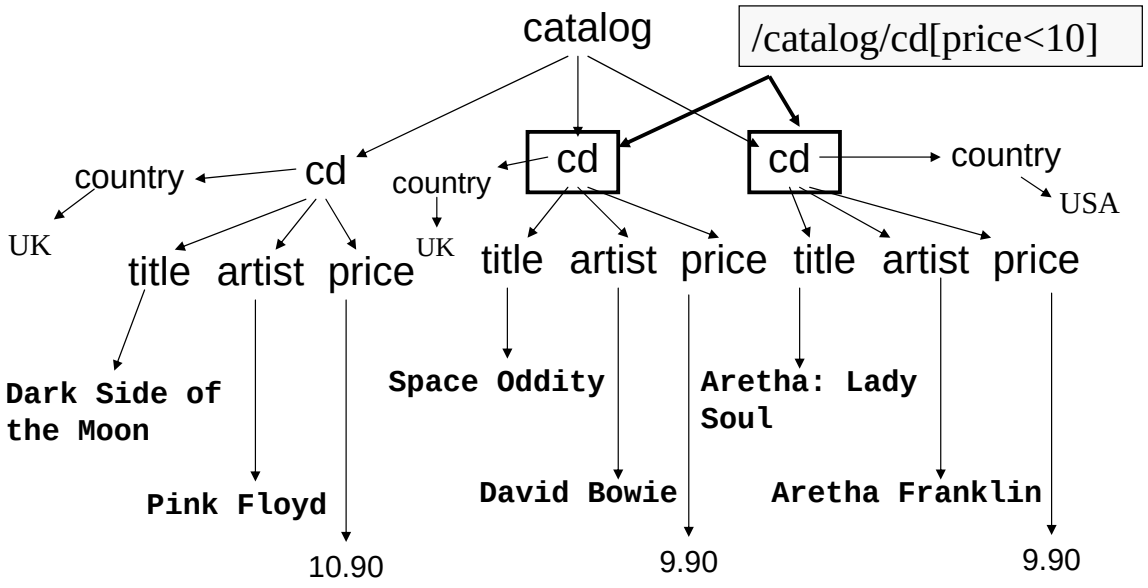
Finding child nodes

catalog.xml

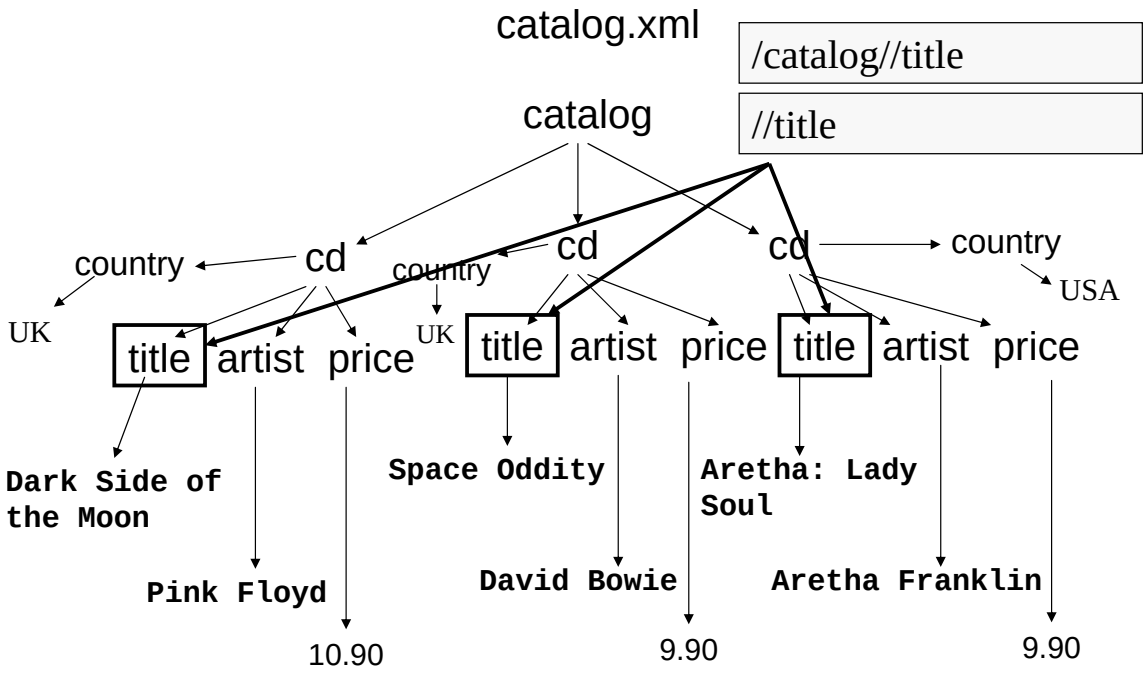


Finding descendant nodes

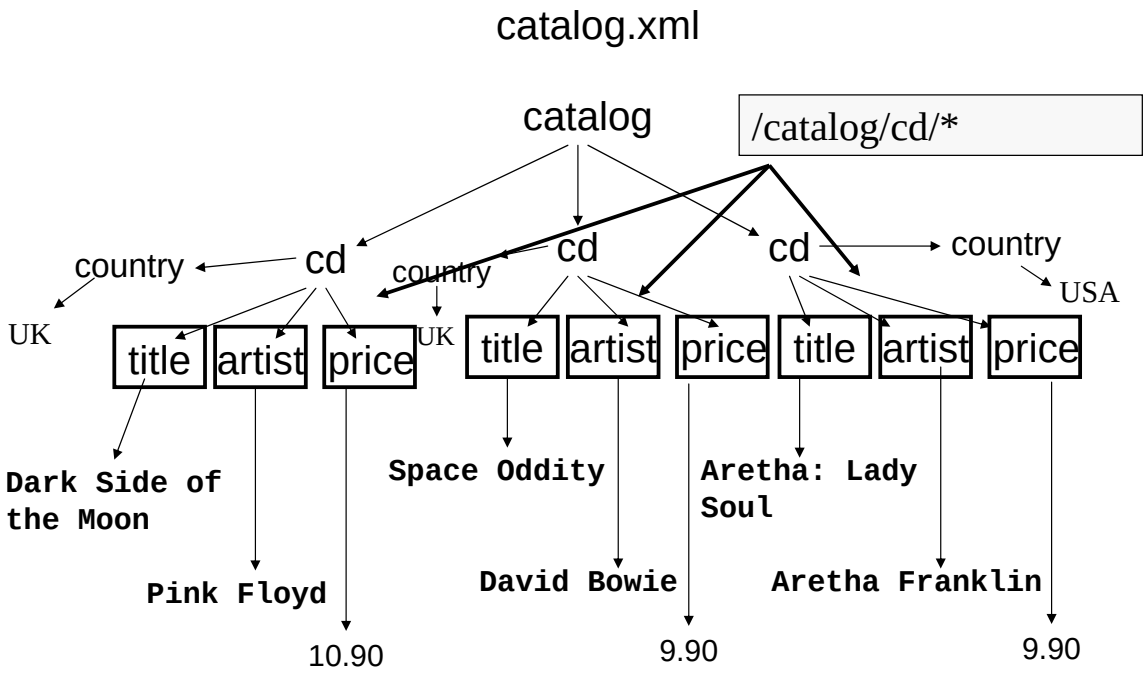
catalog.xml



Condition on elements

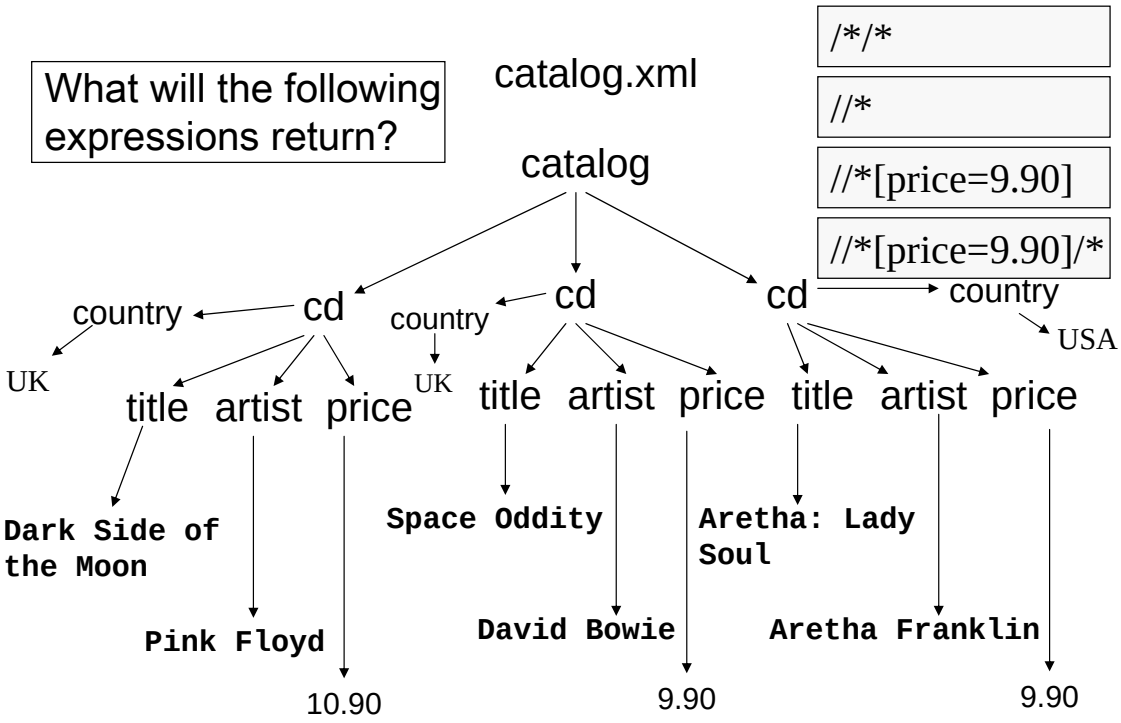


// represents any directed path in the document



* represents any element name in the document

What will the following expressions return?



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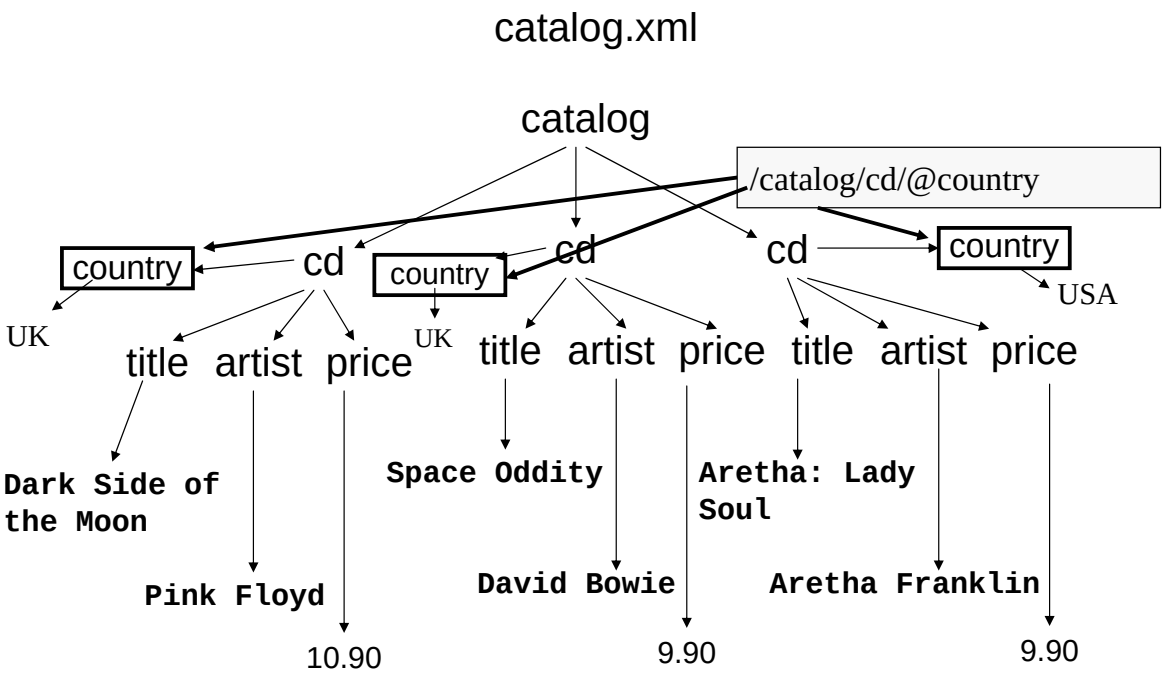
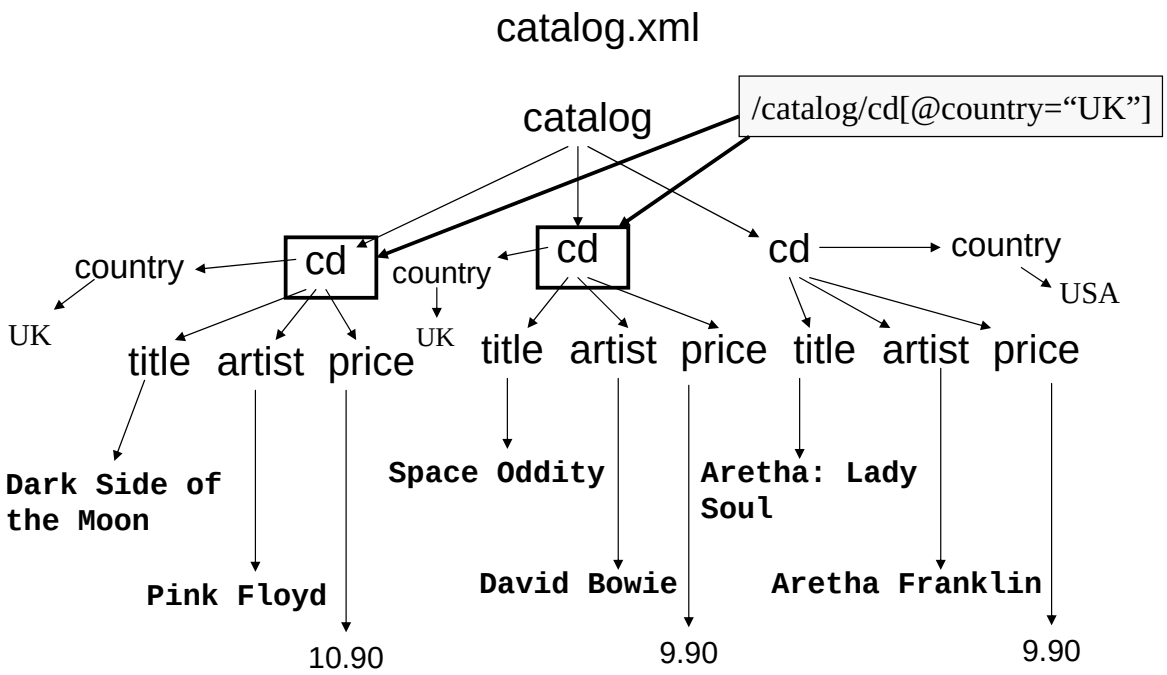
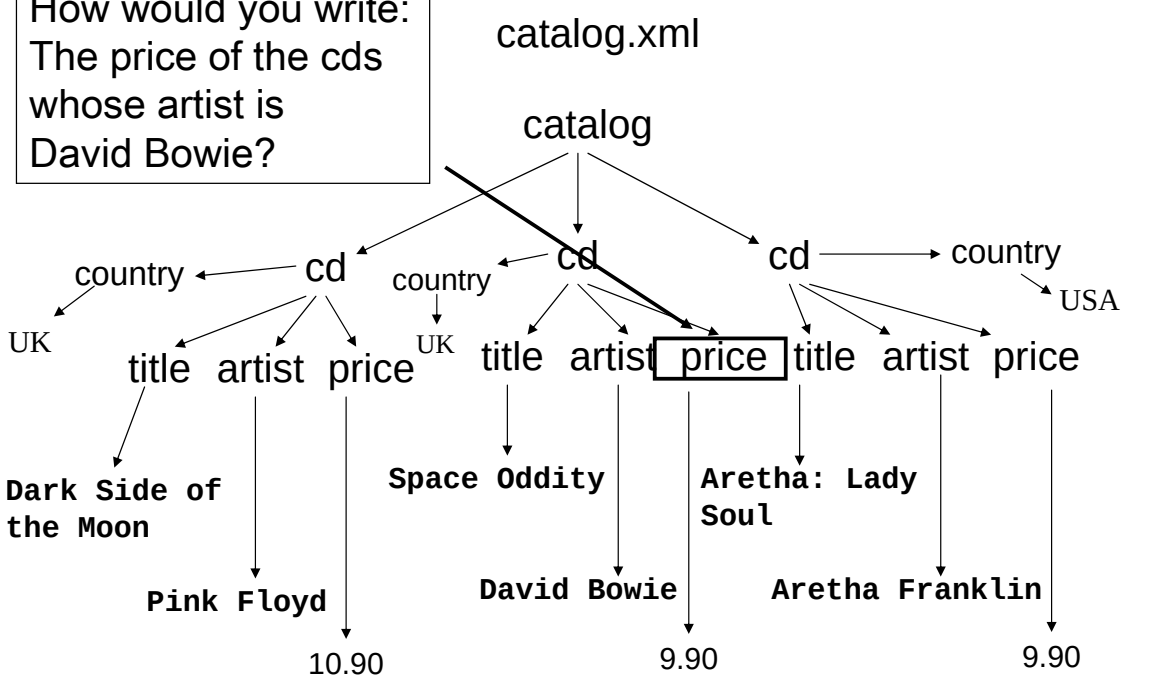


@ marks attributes



@ marks attributes

How would you write: The price of the cds whose artist is David Bowie?



Data Models

60's — Hierarchical; Network

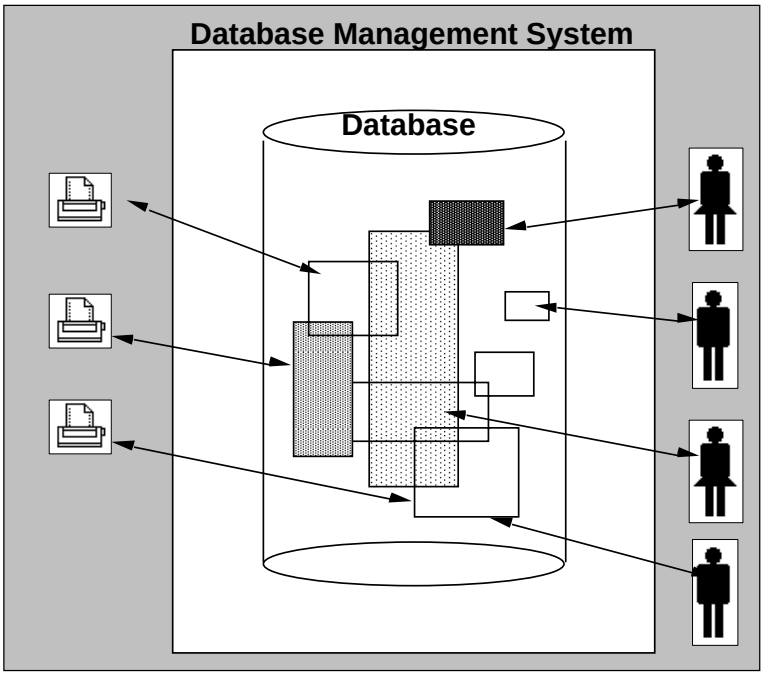
70's — Relational

80's — *Choice for most applications today*

90's — Object Models; Knowledge Bases, Rules

00's — Semistructured Data, XML; Semantic Web, RDF

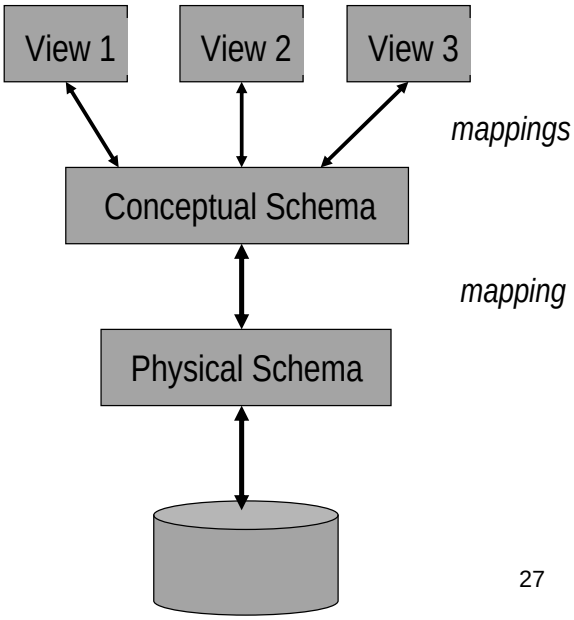
Sharing—Multiple *views* of data



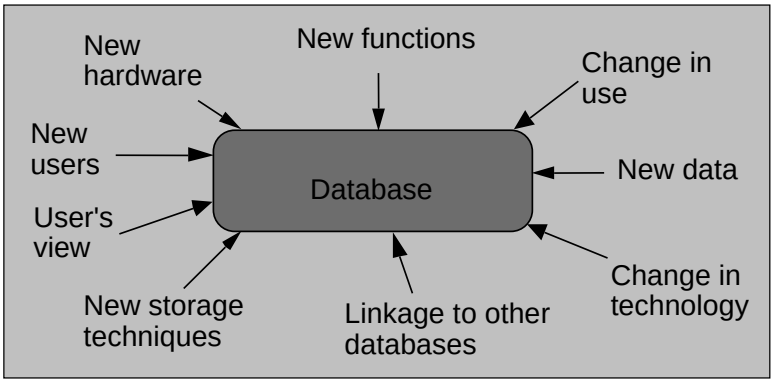
Three Levels of Abstraction

ANSI/SPARC architecture for DBMSs (1978):

- Many *external views*
- One *conceptual* (= logical) *schema*
- One *physical* (= internal) *schema*
  - Views describe how users see the data
  - Conceptual schema defines logical structure
  - Physical schema describes the files and indexes used



Data Independence



- **Logical** data independence
  - change the logical schema without having to change the external schemas
- **Physical** data independence
  - change the internal schema without having to change the logical schema

Change the mapping, not the schema!

Database Languages

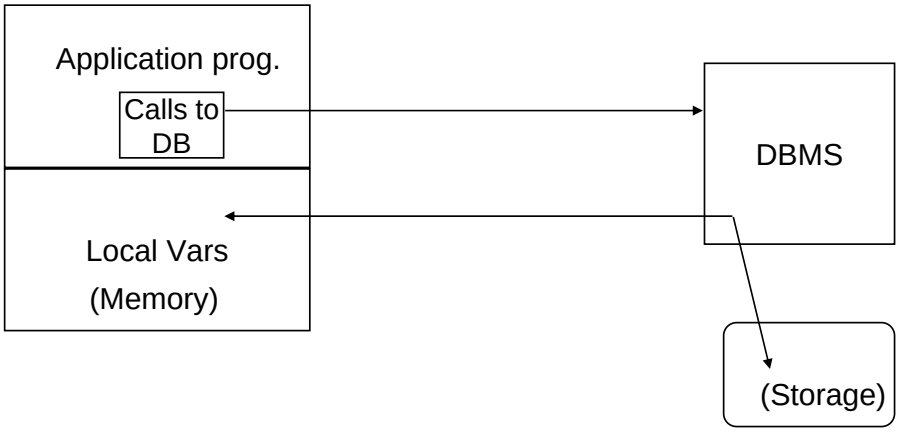
- Data Definition Language (DDL)
  - Commands for setting up the schema of a database
  - The process of designing a schema can be complex, may use a design methodology and/or tool
- Data Manipulation Language (DML)
  - Commands to manipulate data in database:

    `RETRIEVE, INSERT, DELETE, MODIFY`

  - Also called “query language”

Host Languages

C, C++, Fortran, Lisp, Java, Perl, Python, …

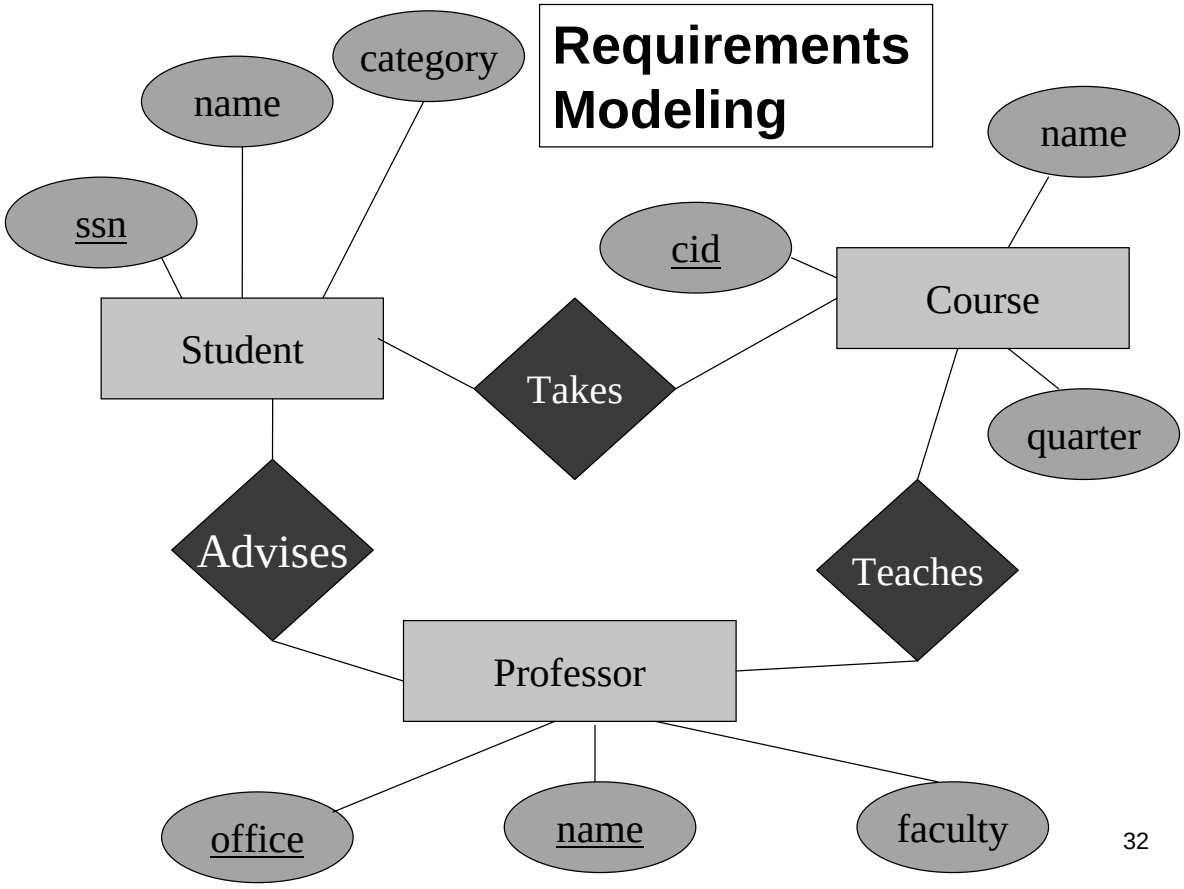


Host language is completely general (Turing complete) but gives no support for data manipulation

Query language—less general, “non procedural” and optimizable

Building an Application with a DBMS

- Requirements gathering (natural language, pictures)
- Requirements modeling (conceptual data model, ER)
  - Decide what *entities* should be part of the application and how they should be *related*
- Schema design and implementation
  - Decide on a set of *tables*, *attributes*
  - Create the tables in the database system
  - Populate database (insert records/tuples)
- Write application programs using the DBMS
  - … a lot easier now that the data management is taken care of



Schema Design and Implementation

- Tables:

Student:

SSN	Name	Category
123-45-6789	Charles	undergrad
234-56-7890	Dan	grad
	...	...

Takes:

SSN	CID
123-45-6789	CSE444
123-45-6789	CSE444
234-56-7890	CSE142
	...

Course:

CID	Name	Quarter
CSE444	Databases	fall
CSE541	Operating systems	winter

- The logical schema separates the logical view from the physical view of the data.

Querying a Database

- *"Find all courses that Mary takes"*
- **S**(tructured) **Q**(uery) **L**(anguage)

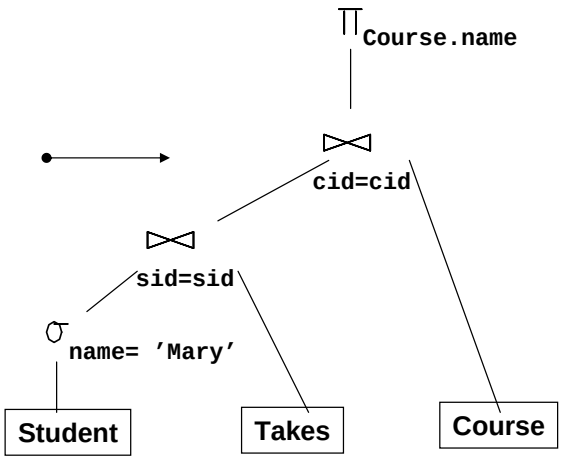
```
select c.name
from   Student s, Takes t,
       Course c
where  s.name = 'Mary' and
       s.ssn  = t.ssn and
       t.cid  = c.cid
```

- The query processor figures out how to answer the query efficiently

Query Optimization

Goal: *Declarative SQL query* → *Query execution plan*

```
select c.name
from   Student s, Takes t,
       Course c
where  s.name = 'Mary' and
       s.ssn  = t.ssn and
       t.cid  = c.cid
```



Plan: Tree of relational algebra operators, choice of algorithm for each operator

Ideally: Find best plan Practically: Avoid worst plans!

Traditional and Novel Data Management Issues

- Traditional Data Management:
  - Relational data for enterprise applications
  - Storage
  - Query processing/optimization
  - Transaction processing
- Novel Data Management:
  - Integration of data from multiple databases, warehousing
  - Data management for decision support, data mining
  - Managing documents, audio, and visual data
  - Exchange of data on the web: XML
  - Data Streams
  - Querying data on the Web: RDF