# XML

Lecture 3:

Tree Structurtured Data –

Set Theoretic Query Languages

XML,

Document Type Definitions (DTDs), XML Schema.

2023

# Web Data

- 1. not hard-wired as input data set for a browser/ program [ not as at Stage 1, or thru client-server prog.]

- 2. not accessed thru a database schema as in case of a DBMS [ not as at Stage 2 ]
- 3. Web Data is – (i) Document and objects
- (ii) Objects have description tags; Documents have tags and follow a DOM
- (iii) Software agents : gmail, live objects, browser,
- 4. Communication medium → Semi-structured data (schema + data ) → html, xml, JSON, ….

# DOM: Tree-structured Data

- Web: Document ( Data ) → DOM (Tree)

- Database ( Relations ) → Tree
- Rooted, Acyclic with unique path
  (from root to leaf node) → Tree

→Searching: Breadth first / Depth first

**Example:** root [IIT_DB] Find **name** at node (Teacher) where sub-node (Course)="COV888"

→ (Answer – "**Bhalla**")

# DOM: Tree Structured Data

= Data in Tree form

XML → root (tree)

→{tree} ;     level 1 [ ];     level 2 (); ….

→ {..[( ) ()] [ () ] ..} Proper Nesting

→A)rooted Tree

→B) Unique path from root

→C) No cycle (tree has no cycle)

# Data in XML: Object Model

- 1. Data (example) → **Web Programming**

- 2. xml → Element; Sub-element; Attribute

<**name-of-book**> Web Programming </**name-of-book**>

- Tag→ <**name-of-book** > .. </name-of-book>

- ( Opening ) Tag can include an attribute →

<**name-of-book** Type=“text-book” >

# Data in XML → meaning of Data

<bookstore>

- <**book** Category = “basic” >

  <**title** lang = “Italian” > Everday Italian</**title**>

  <author> Giada De Laurentiis </author>

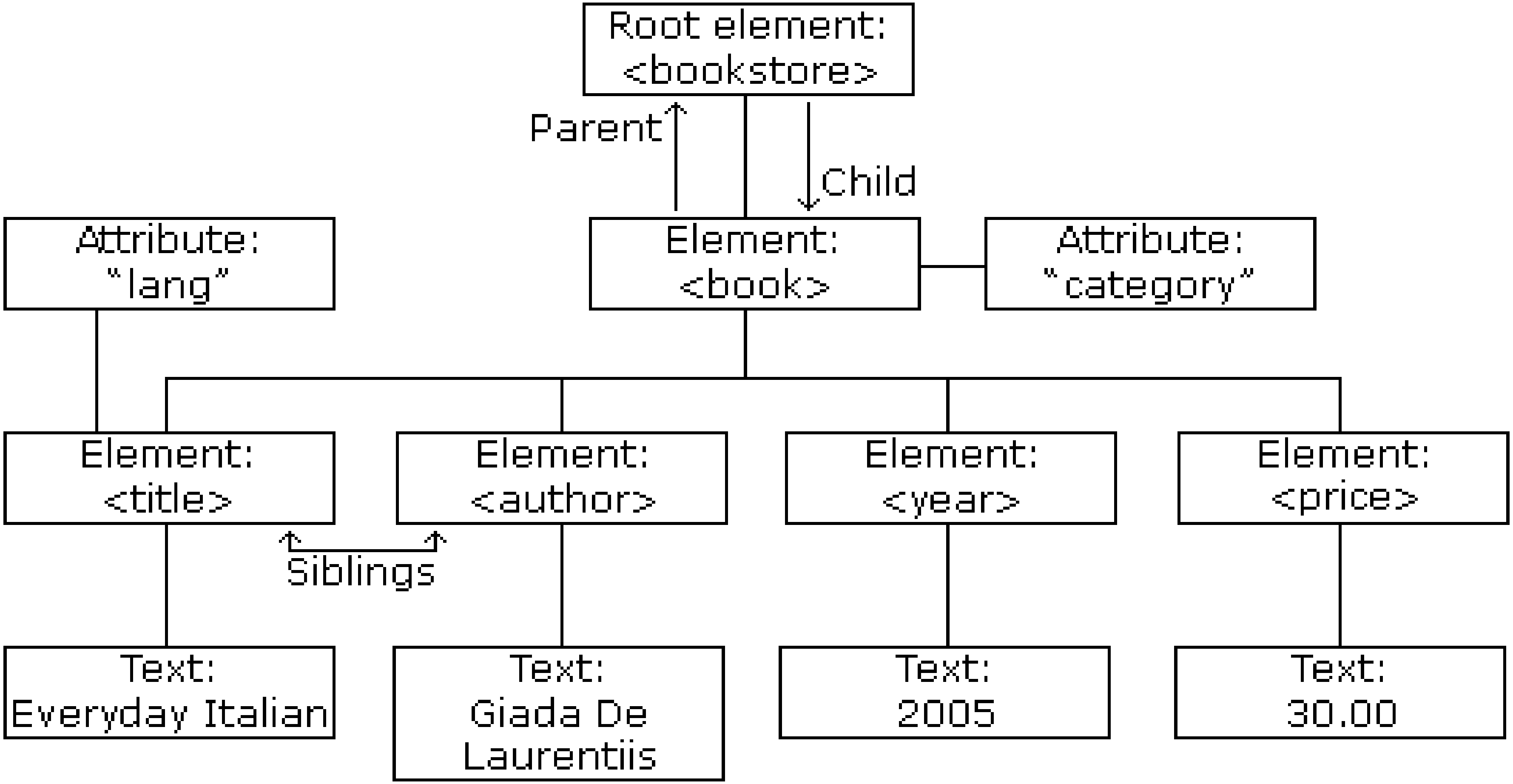
  <year> 2005 </year>

  <price> 3000 </price>

- </**book**>
- <**book**> .. .. </**book**>
- . . . .. </bookstore>

# Document Object Model (DOM)
# http://www.w3schools.com/

Graph:  rooted,  unique path from root to leaf,  acyclic



# Lecture 1

- **Documents**: Book Chapter, Report, Book, ..

- **Web** → Document
- Documents → have **Object Model**

- Example: Book → **Title, Index, Chapter heading**
- All Books: DOM (Document Object Model) → Title, index, Chapter 1,2 .., back index.

- Programming: a) Client-side – ( DOM Document display)

  HTML, XML, XHTML, CSS, JavaScript, ..

  b) Server-side- ( Prepare DOM Document)

  PHP, Java/JSP, Javascript,...

# Complex Data: Table – Set/bag (represent as Tree)

| company | section | employee |
|---|---|---|
| c1 | s1 | e1 |
| c1 | s1 | e2 |
| c1 | s2 | e3 |

```
<company id="c1">
    <section id="s1">
        <employee id="e1"/>
        <employee id="e2"/>
    </section>
    <section id="s2">
        <employee id="e3"/>
    </section>
</company>
```

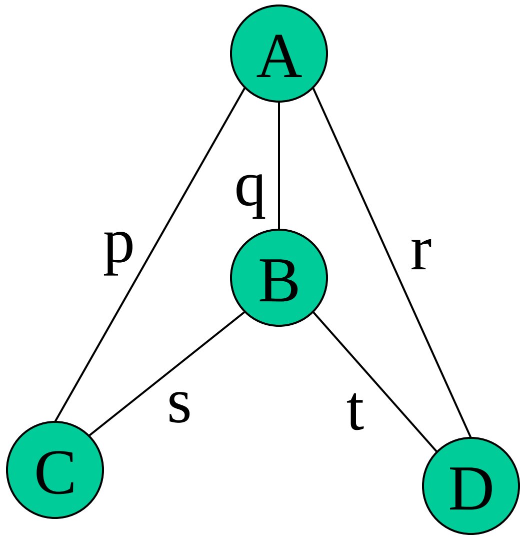
# Data in Tree ( Examples )

```
<sectionList>
  <section id="s1">
    <company id="c1"/>
      <employee id="e1"/>
      <employee id="e2"/>
  </section>
  <section id="s2">
    <company id="c1"/>
      <employee id="e3"/>
  </section>
</sectionList>
```

```
<employeeList>
  <employee id="e1">
    <company id="c1"/>
      <section id="s1"/>
  </employee>
  <employee id="e2">
    <company id="c1"/>
      <section id="s1"/>
  </employee>
  <employee id="e3">
    <company id="c1"/>
      <section id="s2"/>
  </employee>
</employeeList>
```

# Complex Data (case 1) Storing Graph Data → set

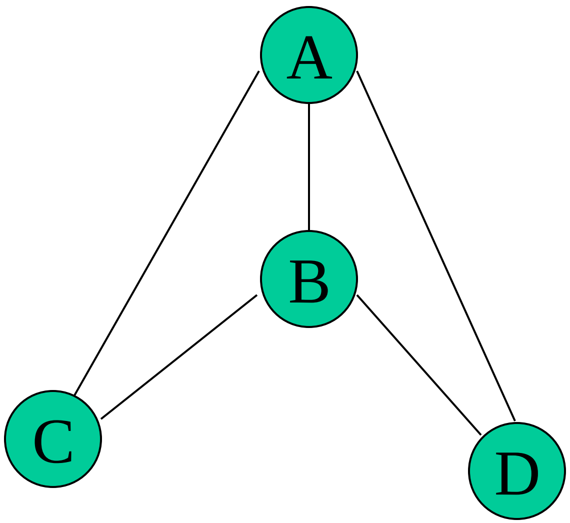
Attributed Relational Graphs (ARGs)




| | | |
|---|---|---|
| A | B | q |
| B | C | s |
| B | D | t |
| A | C | p |
| A | D | r |

# 1. Storing Graph Data in XML → **Tree** (rooted tree,acyclic, unique path from root)

- <node id=“A”>
-     <node id=“B”>
-         <node id=“C”>
-         </node>
-         <node id=“D”>
-         </node>
-     </node>
-     <node id=“C”>
-     </node>
-     <node id=“D”>
-     </node>
- </node>



# Tree Structure Data

- Element nodes for “C” and “D” (Duplicate)
- rooted tree, acyclic,
  unique path (root → node)

- Subelement nodes → Parent-Child

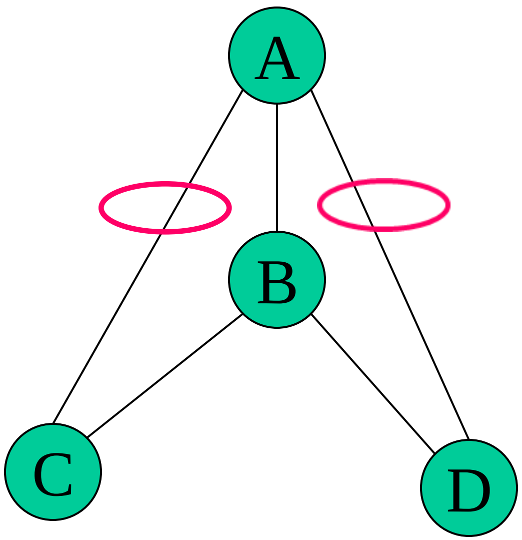
- Tree Structure →

A → B, C, D

B → C, D

# 2. Storing Graph Data in XML (Tree) (case 2)

XML with IDs and IDREFS:




```
<node id="A", adj="C D">
        <node id="B">
                <node id="C">
                </node>
                <node id="D">
                </node>
        </node>
</node>
```

# Tree Structured Data (case 2)

- Element nodes for “C” and “D” ( Not Duplicate )
- rooted tree, acyclic, unique path (root → node)

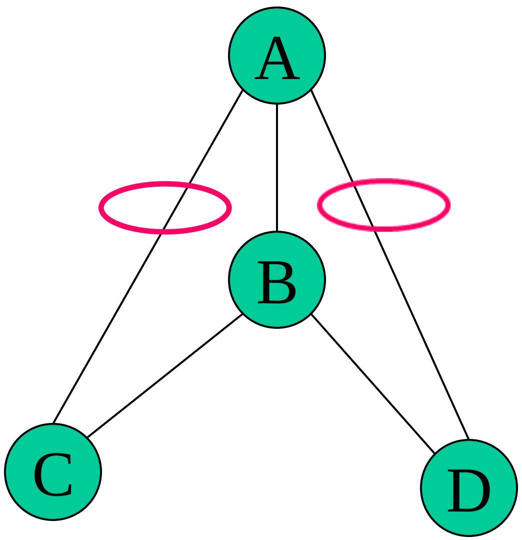
- Subelement nodes: Parent → Child
- Node Attributes: Parent → Child
- Tree Structure →

A → B, C, D

B → C, D

# 2. Storing Graph Data in XML (Tree) (case 3)

XML with IDs and IDREFS:

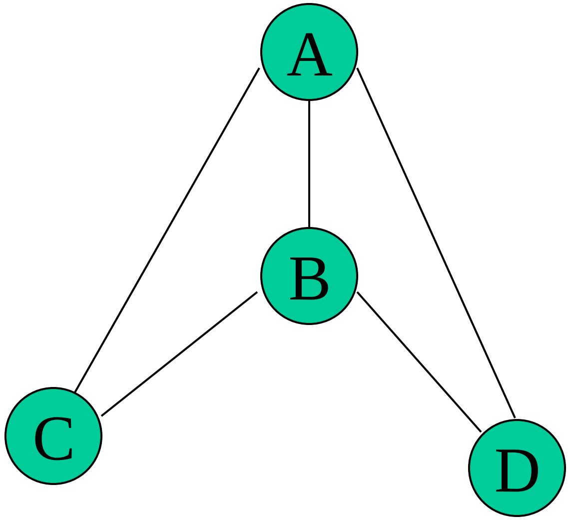



<node id="A" adj="c","D" >
<node id="B">
<node id="C", adj="A">
</node>
<node id="D", adj="A">
</node>
</node>
</node>

Forward and Backward Pointers

# 1. Storing Graph Data in XML → **Graph** (**case 2**)
# (rooted tree, acyclic, unique path from root)

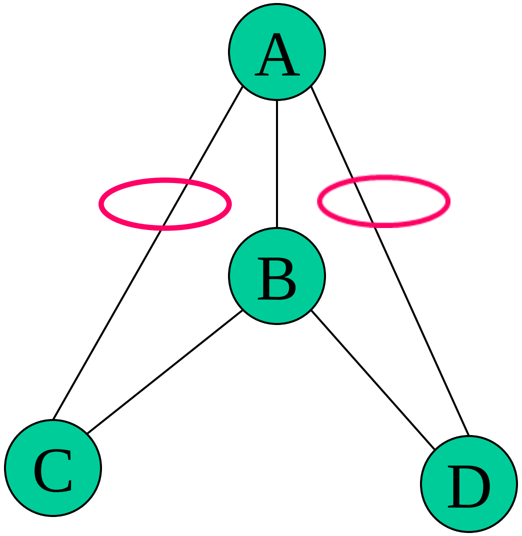
- <node id="A">
-         <node id="B">
-                 <node id="C">
-                 </node>
-                 <node id="D">
-                 </node>
-         </node>
-         <node id="C", adj = "A, B">
-         </node>
-         <node id="D", adj="A, B">
-         </node>
- </node>




with Backward pointers

# 2. Storing Graph Data in XML (Graph) (case 2)

XML with IDs and IDREFS:




<node id=“A”, adj=“C D”>
<node id=“B”>
<node id=“C”, adj=“A”>
</node>
<node id=“D”, adj=“A”>
</node>
</node>
</node>

# Tree structured Data + Graph

- Element nodes ( No Duplicates )
-  Element → subelement

  rooted tree, acyclic,

  unique path  (root → node)
- Subelement nodes: Parent → Child
- Node Attributes: Parent → Child; Child →
- Data is Arbitrary Graph Structure Data→

A → B, C, D  ;  C → A, B  ; D → A, B

B → C, D

# Storing Graph Data → as graph

- XML (with or without IDREFS )
  - Reduces graph database to an XML base
  - Use XPath / XQuery engines for attribute queries and structural queries
  - Widely supported by a variety of XML parsers

  - Costly structure/sub-structure matching
  - Needs distinction between-

(i) IDREF edges (attribute) and

(ii) hierarchy edges (subelement)

.

# Note: Other Graph Database Models

- "**Schema-less**" collection of graphs
  - Example: **GraphGrep, Daylight ACD, gIndex**
- **Database** as a graph
  - Example: SUBDUE
- Database with schema and views
  - Example: **GRACE**

# XML: Well-Formed and Valid XML

- *1. **Well-Formed** XML*

→**has no schema.**

→It allows you to invent your own tags.

- *2. **Valid XML***

→**Has a schema**

→ DTD (Document Type Definition).

DTD → XML file

# XML Vocabularies

- Web applications → agree to share common vocabulary (schema), → Banks, Air-line, ..

→ to communicate and collaborate

- Many businesses use common (specialized schema)
  - mathematics (MathML)
  - bioinformatics (BSML)
  - human resources (HRML)
  - …

# The XML Language

An XML document consists of

- a **prolog**
- a number of **elements**
- an optional epilog (not discussed)

# Prolog of an XML Document

The prolog consists of

- an XML declaration and
- an optional reference to external structuring documents

**<?xml version="1.0" encoding="UTF-16"?>**

**<!DOCTYPE book SYSTEM "book.dtd">**

# XML Elements

- The “Document” objects (data Content)
  - E.g. **books**, authors, publishers
- An element consists of:
  - an opening tag
  - the content
  - a closing tag  [ May have sub-elements before it ]

**<**lecturer**>**   **David Billington**    **</**lecturer**>**

# XML Elements (2)

- RULES
- **Tag names** can be chosen freely.
- The **first character** must be a -

→ **letter, an underscore, or a colon**

- **No** name may begin with the string “xml” in any combination of cases
  - E.g. “**Xml”, “xML**”

# Well-Formed XML

- Start the document with a *declaration*, surrounded by <?xml … ?> .
- Normal declaration is:

```
<?xml version = ”1.0”
  standalone = ”yes” ?>
```

  - “standalone” = “no DTD provided.”
- Balance of document is a *root tag* surrounding nested tags.

- No DTD → traverse tree to find nodes, structure, attributes . . . .

# Tags

- Tags are normally matched pairs, as <FOO> … </FOO>.
- Unmatched tags also allowed, as

<FOO … />

- Tags may be nested arbitrarily, with proper nesting.
- XML tags are case-sensitive.

# Example: Well-Formed XML

```
<?xml version = "1.0" standalone = "yes" ?>
<BARS>
  <BAR><NAME>Joe's Bar</NAME>
    <BEER><NAME>Bud</NAME>
        <PRICE>2.50</PRICE></BEER>
    <BEER><NAME>Miller</NAME>
        <PRICE>3.00</PRICE></BEER>
  </BAR>
  <BAR> …
</BARS>
```

A NAME subelement

Root tag

A BEER subelement

Tags surrounding a BEER element

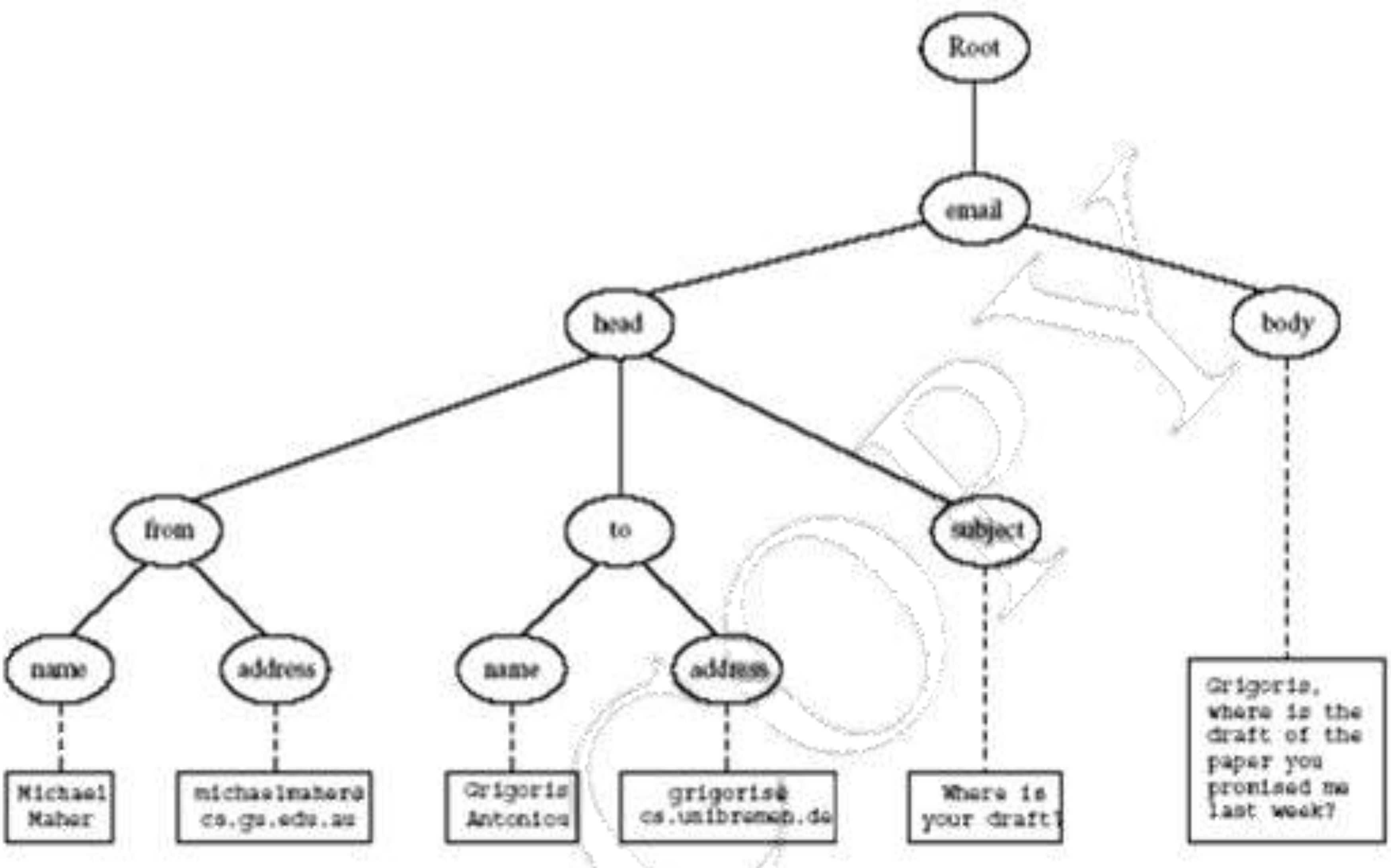
# Well-Formed XML Documents

- Syntactically correct documents
- Rules:
  - Only one outermost element
    (called root element)
  - Each element→ an opening and closing tag
  - Tags may not overlap
    - **<author><name>Lee Hong</author></name>**
  - Attributes within an element have unique names
  - Element and tag names must be permissible

# The Tree Model of XML Documents: An Example

```
<email>
    <head>
        <from name="Michael Maher"
                address="michaelmaher@cs.gu.edu.au"/>
        <to name="Grigoris Antoniou"
                address="grigoris@cs.unibremen.de"/>
        <subject>Where is your draft?</subject>
    </head>
    <body>
        Grigoris, where is the draft of the paper you promised me
        last week?
    </body>
</email>
```

# The Tree Model of XML Documents: An Example (2)



# The Tree Model of XML Docs

- The tree representation of an XML document is an ordered labeled tree:
- 
  - There is only **one root**
  - There are **no cycles**
  - Each **non-root node** has exactly one parent
  - Each node has a **label.**
  - The **order** of elements is important
  - … but the *order of attributes* is not important

# DTD Structure

**DTD** contains → (a) Tree structure: Element – Sub-element; (b) Attributes; (c ) details of elements, (d) occurances

**Style** →

<!DOCTYPE <root tag> [

<!ELEMENT <name>(<components>)>

. . . more elements . . .

]>

# Pupose of DTD

- Define → element and attribute names that may be used
- Define → the structure
  - what **values** an attribute may take
  - Tree elements and their sub-elements
  - 
- With a DTD → the document can be **validated**

# DTD Elements

- Description of an element →

  Name (tag), and a parenthesized description of any nested tags.

  - Includes order of sub-tags and their multiplicity.

- Leaves (text elements) have #PCDATA (*Parsed Character DATA*) in place of nested tags.

# Example: DTD

```
<!DOCTYPE BARS [
  <!ELEMENT BARS (BAR*)>
  <!ELEMENT BAR (NAME, BEER+)>
  <!ELEMENT NAME (#PCDATA)>
  <!ELEMENT BEER (NAME, PRICE)>
  <!ELEMENT PRICE (#PCDATA)>
]>
```

A BARS object has zero or more BAR's nested within.

A BAR has one NAME and one or more BEER subobjects.

A BEER has a NAME and a PRICE.

NAME and PRICE are text.

# Element Descriptions

- Subtags must appear in order shown.
- A tag may be followed by a symbol to indicate its multiplicity.
  - * = zero or more.
  - + = one or more.
  - ? = zero or one.
- Symbol | can connect alternative sequences of tags.

# Example: Element Description

- A name is an optional title (e.g., “Prof.”), a first name, and a last name, in that order, or it is an IP address:

```
<!ELEMENT NAME (
  (TITLE?, FIRST, LAST) | IPADDR
)>
```

# Use of DTD’s

1. Set standalone = “no”.
2. Either:
   a) Include the DTD as a preamble of the XML document, or
   b) Follow DOCTYPE and the <root tag> by SYSTEM and a path to the file

   (where the DTD can be found → file address or a web url link).

# Example: (a)

```
<?xml version = "1.0" standalone = "no" ?>
<!DOCTYPE BARS [
    <!ELEMENT BARS (BAR*)>
    <!ELEMENT BAR (NAME, BEER+)>
    <!ELEMENT NAME (#PCDATA)>
    <!ELEMENT BEER (NAME, PRICE)>
    <!ELEMENT PRICE (#PCDATA)>
]>
<BARS>
    <BAR><NAME>Joe's Bar</NAME>
        <BEER><NAME>Bud</NAME> <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME> <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> …
</BARS>
```

The DTD

The document

# Example: (b)

- Assume the BARS DTD is in file bar.dtd.

```
<?xml version = "1.0" standalone = "no" ?>
<!DOCTYPE BARS SYSTEM "bar.dtd">
<BARS>
    <BAR><NAME>Joe's Bar</NAME>
        <BEER><NAME>Bud</NAME>
            <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME>
            <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> …
</BARS>
```

Get the DTD from the file bar.dtd or a URL

# Attributes

- Opening tags in XML can have *attributes*.
- In a DTD,

`<!ATTLIST` *E* `...>`

declares attributes for element *E*, along with its datatype.

# Example: Attributes

- Bars can have an attribute `kind`, a character string describing the bar.

```
<!ELEMENT BAR (NAME BEER*)>
  <!ATTLIST BAR kind CDATA
    #IMPLIED>
```

Character string type; no tags

Attribute is optional
opposite: #REQUIRED

# Example: Attribute Use

- In a document that allows BAR tags, we might see:

```
<BAR kind = ”sushi”>
  <NAME>Homma’s</NAME>
  <BEER><NAME>Sapporo</NAME>
         <PRICE>5.00</PRICE></BEER>
  ...
</BAR>
```

# ID’s and IDREF’s

- Attributes can be pointers from one object to another.
  - Compare to HTML’s NAME = ”foo” and HREF = ”#foo”.
- Allows the structure of an XML document to be a general graph, rather than just a tree.

# Creating ID's

- Give an element *E* an attribute *A* of type ID.
- When using tag <*E* > in an XML document, give its attribute *A* a unique value.
- Example:

```
<E  A = "xyz">
```

# Creating IDREF's

- To allow elements of type *F* to refer to another element with an ID attribute, give *F* an attribute of type IDREF.
- Or, let the attribute have type IDREFS, so the *F*-element can refer to any number of other elements.

# Example: ID's and IDREF's

- A new BARS DTD includes both BAR and BEER subelements.
- BARS and BEERS have ID attributes `name`.
- BARS have SELLS subelements, consisting of a number (the price of one beer) and an IDREF `theBeer` leading to that beer.
- BEERS have attribute `soldBy`, which is an IDREFS leading to all the bars that sell it.

# The DTD

Bar elements have name as an ID attribute and have one or more SELLS subelements.

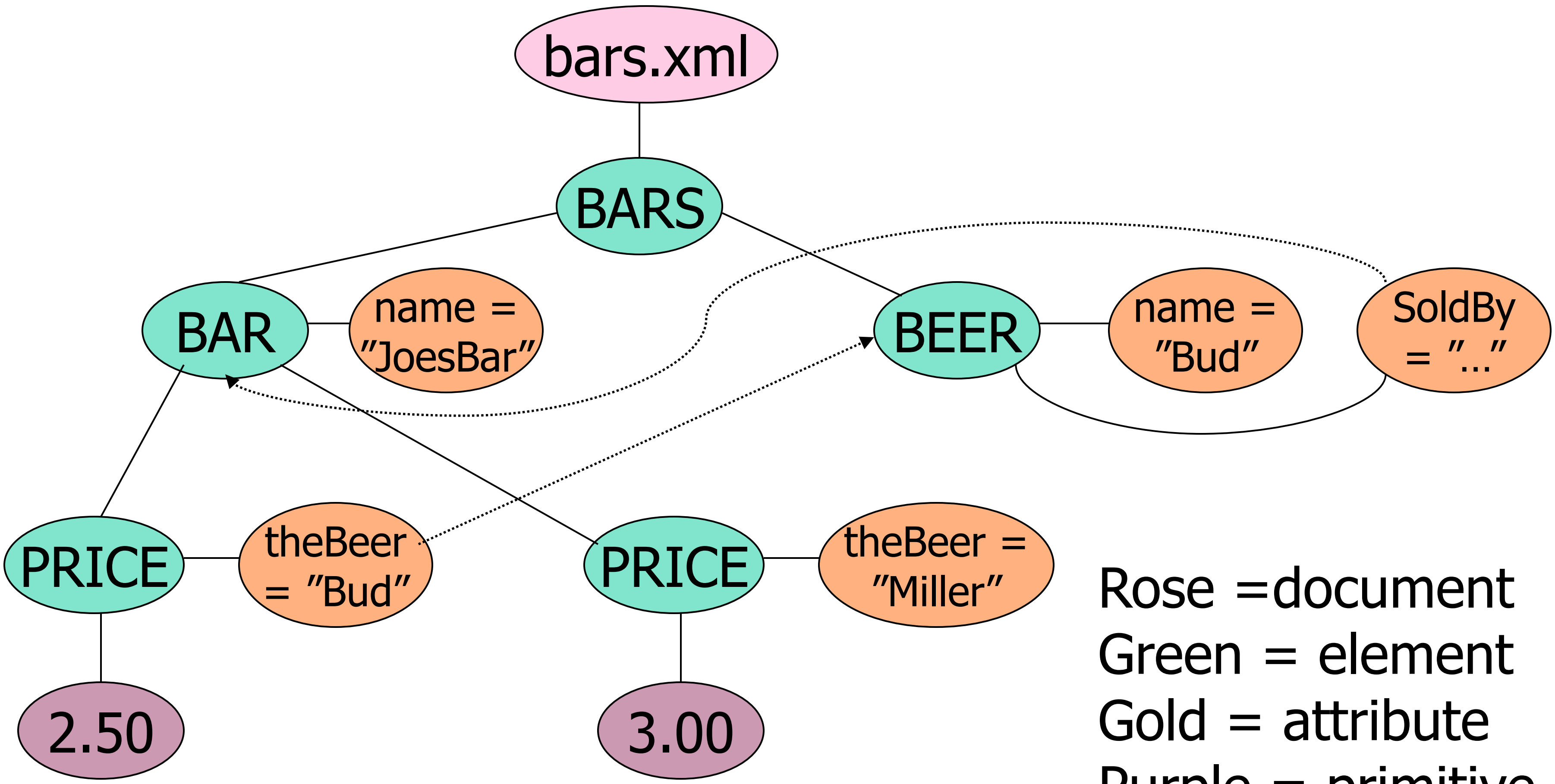
```
<!DOCTYPE BARS [
  <!ELEMENT BARS (BAR*, BEER*)>
  <!ELEMENT BAR (SELLS+)>
     <!ATTLIST BAR name ID #REQUIRED>
  <!ELEMENT SELLS (#PCDATA)>
     <!ATTLIST SELLS theBeer IDREF #REQUIRED>
  <!ELEMENT BEER EMPTY>
     <!ATTLIST BEER name ID #REQUIRED>
     <!ATTLIST BEER soldBy IDREFS #IMPLIED>
]>
```

SELLS elements have a number (the price) and one reference to a beer.

Explained next

Beer elements have an ID attribute called name, and a soldBy attribute that is a set of Bar names.

# Nodes as Semistructured Data




Rose =document
Green = element
Gold = attribute
Purple = primitive value

# Example: A Document

```
<BARS>
   <BAR name = ”JoesBar”>
      <SELLS theBeer = ”Bud”>2.50</SELLS>
      <SELLS theBeer = ”Miller”>3.00</SELLS>
   </BAR> …
   <BEER name = ”Bud” soldBy = ”JoesBar
      SuesBar …” /> …
   </BARS>
```

Find - IDs and IDREFs

# Empty Elements

- We can do all the work of an element in its attributes.
  - Like BEER in previous example.
- Another example: SELLS elements could have attribute `price` rather than a value that is a price.

# Example: Empty Element

- In the DTD, declare:

<!ELEMENT SELLS EMPTY>

<!ATTLIST SELLS theBeer IDREF #REQUIRED>

<!ATTLIST SELLS price CDATA #REQUIRED>

- Example use:

<SELLS theBeer = ”Bud” price = ”2.50” />

Note exception to “matching tags” rule

# Alternative Method for DTD
# XML Schema

- A more powerful way to describe the structure of XML documents.

- XML-Schema declarations are themselves XML documents.
  - They describe "elements" and the things doing the describing are also "elements."

# Structure of an XML-Schema Document

```
<? xml version = … ?>
<xs:schema xmlns:xs =
  "http://www.w3.org/2001/XMLschema">
                . . .
</xs:schema>
```

So uses of "xs" within the schema element refer to tags from this namespace.

Defines "xs" to be the *namespace* described in the URL shown. Any string in place of "xs" is OK.

# The xs:element Element

- Has attributes:
  1. name = the tag-name of the element being defined.
  2. type = the type of the element.
     - Could be an XML-Schema type, e.g., xs:string.
     - Or the name of a type defined in the document itself.

# Example: xs:element

```
<xs:element name = ”NAME”
    type = ”xs:string” />
```

- Describes elements such as

  <NAME>Joe’s Bar</NAME>

# Complex Types

- To describe elements that consist of subelements, we use xs:complexType.
  - Attribute name gives a name to the type.
- Typical subelement of a complex type is xs:sequence, which itself has a sequence of xs:element subelements.
  - Use minOccurs and maxOccurs attributes to control the number of occurrences of an xs:element.

# Example: a Type for Beers

```
<xs:complexType name = ”beerType”>
  <xs:sequence>
    <xs:element name = ”NAME”
      type = ”xs:string”
      minOccurs = ”1” maxOccurs = ”1” />
    <xs:element name = ”PRICE”
      type = ”xs:float”
      minOccurs = ”0” maxOccurs = ”1” />
  </xs:sequence>
</xs:complexType>
```

Exactly one occurrence

Like ? in a DTD

# An Element of Type beerType

```
<xxx>
  <NAME>Bud</NAME>
  <PRICE>2.50</PRICE>
</xxx>
```

We don't know the name of the element of this type.

# Example: a Type for Bars

```
<xs:complexType name = ”barType”>
  <xs:sequence>
    <xs:element name = ”NAME”
      type = ”xs:string”
      minOccurs = ”1” maxOccurs = ”1” />
    <xs:element name = ”BEER”
      type = ”beerType”
      minOccurs = ”0” maxOccurs =
         ”unbounded” />
  </xs:sequence>
</xs:complexType>
```

Like * in a DTD

# xs:attribute

- xs:attribute elements can be used within a complex type to indicate attributes of elements of that type.
- attributes of xs:attribute:
  - name and type as for xs.element.
  - use = ”required” or ”optional”.

# Example: xs:attribute

```
<xs:complexType name = ”beerType”>
  <xs:attribute name = ”name”
    type = ”xs:string”
    use = ”required” />
  <xs:attribute name = ”price”
    type = ”xs:float”
    use = ”optional” />
</xs:complexType>
```

# An Element of This New Type beerType

```
<xxx name = ”Bud”
  price = ”2.50” />
```

We still don’t know the element name.

The element is empty, since there are no declared subelements.

# Restricted Simple Types

- xs:simpleType can describe enumerations and range-restricted base types.
- name is an attribute
- xs:restriction is a subelement.

# Restrictions

- Attribute base gives the simple type to be restricted, e.g., xs:integer.
- xs:{min, max}{Inclusive, Exclusive} are four attributes that can give a lower or upper bound on a numerical range.
- xs:enumeration is a subelement with attribute value that allows enumerated types.

# Example: license Attribute for BAR

```
<xs:simpleType name = ”license”>
  <xs:restriction base = ”xs:string”>
    <xs:enumeration value = ”Full” />
    <xs:enumeration value = ”Beer only” />
    <xs:enumeration value = ”Sushi” />
  </xs:restriction>
</xs:simpleType>
```

# Example: Prices in Range [1,5)

```
<xs:simpleType name = ”price”>
  <xs:restriction
     base = ”xs:float”
     minInclusive = ”1.00”
     maxExclusive = ”5.00” />
</xs:simpleType>
```

# Keys in XML Schema

- An xs:element can have an xs:key subelement.
- Meaning: within this element, all subelements reached by a certain *selector* path will have unique values for a certain combination of *fields*.
- Example: within one BAR element, the name attribute of a BEER element is unique.

# Example: Key

```
<xs:element name = "BAR" … >
    . . .
  <xs:key name = "barKey">
    <xs:selector xpath = "BEER" />
    <xs:field xpath = "@name" />
  </xs:key>
    . . .
</xs:element>
```

And @ indicates an attribute rather than a tag.

XPath is a query language for XML. All we need to know here is that a path is a sequence of tags separated by /.

# Foreign Keys

- An xs:keyref subelement within an xs:element says that within this element, certain values (defined by selector and field(s), as for keys) must appear as values of a certain key.

# Example: Foreign Key

- Suppose that we have declared that subelement NAME of BAR is a key for BARS.
  - The name of the key is barKey.
- We wish to declare DRINKER elements that have FREQ subelements. An attribute bar of FREQ is a foreign key, referring to the NAME of a BAR.

# Example: Foreign Key in XML Schema

```
<xs:element name = ”DRINKERS”
      . . .
  <xs:keyref name = ”barRef”
      refers = ”barKey”
      <xs:selector xpath =
          ”DRINKER/FREQ” />
      <xs:field xpath = ”@bar” />
  </xs:keyref>
</xs:element>
```

# Summary

- Use data from Web Documents and Databases
- Complex data → Tree or graph
- XML is flexible →
- Tags are user defined ( extensible ) Markup for tree and graphs

# The XPath/XQuery Data Model

- Corresponding to the fundamental "relation" of the relational model is: *sequence of items*.
- An *item* is either:
  1. A primitive value, e.g., integer or string.
  2. A *node* (defined next).

# Principal Kinds of Nodes

1. *Document nodes* represent entire documents.
2. *Elements* are pieces of a document consisting of some opening tag, its matching closing tag (if any), and everything in between.
3. *Attributes* names that are given values inside opening tags.

# Document Nodes

- Formed by doc(URL) or document(URL).
- Example: doc(/usr/class/cs145/bars.xml)
- All XPath (and XQuery) queries refer to a doc node, either explicitly or implicitly.
  - Example: key definitions in XML Schema have Xpath expressions that refer to the document described by the schema.

# DTD for Running Example

```
<!DOCTYPE BARS [
   <!ELEMENT BARS (BAR*, BEER*)>
   <!ELEMENT BAR (PRICE+)>
        <!ATTLIST BAR name ID #REQUIRED>
   <!ELEMENT PRICE (#PCDATA)>
        <!ATTLIST PRICE theBeer IDREF #REQUIRED>
   <!ELEMENT BEER EMPTY>
        <!ATTLIST BEER name ID #REQUIRED>
        <!ATTLIST BEER soldBy IDREFS #IMPLIED>
]>
```

# Example Document

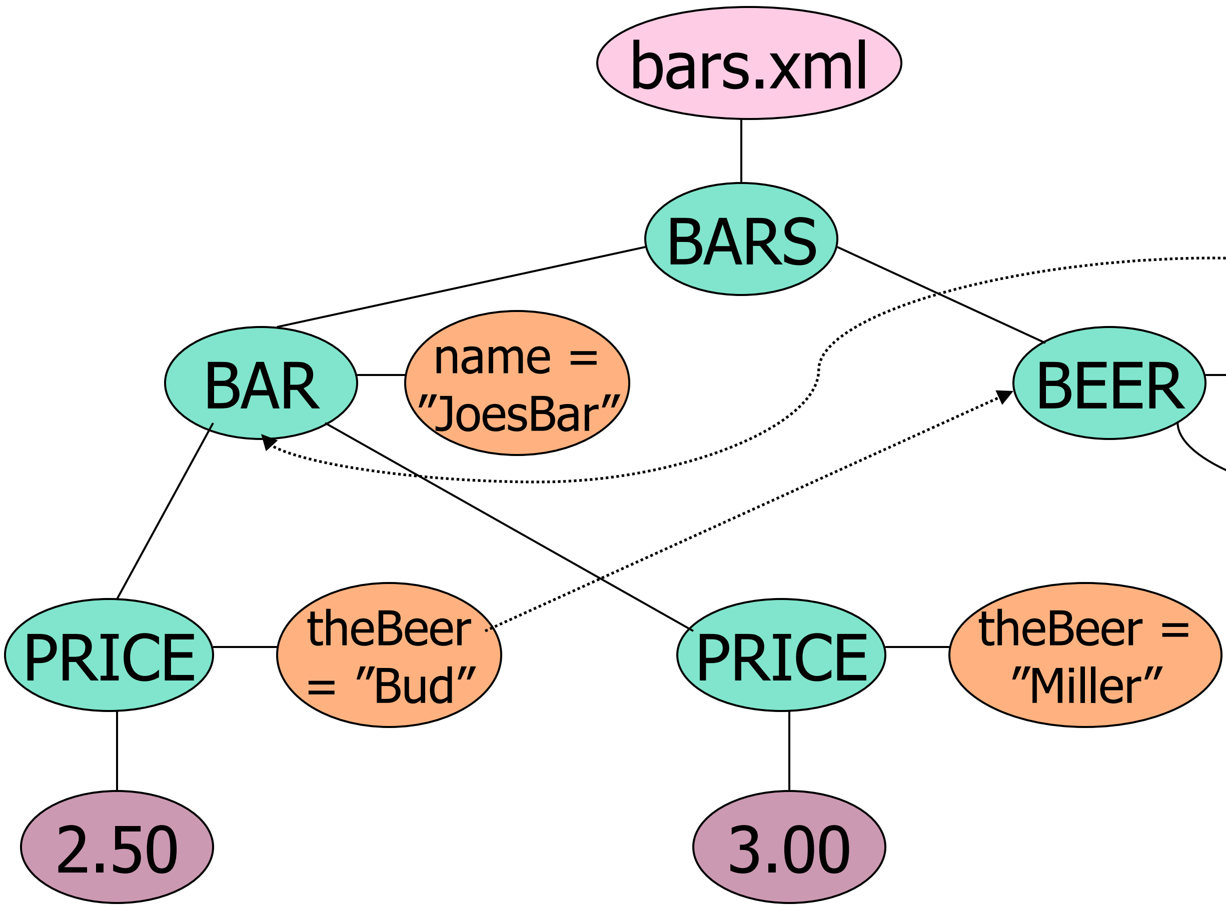
An element node

```
<BARS>
  <BAR name = ”JoesBar”>
    <PRICE theBeer = ”Bud”>2.50</PRICE>
    <PRICE theBeer = ”Miller”>3.00</PRICE>
  </BAR> …
  <BEER name = ”Bud” soldBy = ”JoesBar
    SuesBar … ”/> …
</BARS>
```

An attribute node

Document node is all of this, plus the header ( <? xml version… ).

# Nodes as Semistructured Data




Rose =document
Green = element
Gold = attribute
Purple = primitive value

# Paths in XML Documents

- XPath is a language for describing paths in XML documents.
- The result of the described path is a sequence of items.

# Path Expressions

- Simple path expressions are sequences of slashes (/) and tags, starting with /.
  - Example: /BARS/BAR/PRICE
- Construct the result by starting with just the doc node and processing each tag from the left.

# Evaluating a Path Expression

- Assume the first tag is the root.
  - Processing the doc node by this tag results in a sequence consisting of only the root element.
- Suppose we have a sequence of items, and the next tag is *X*.
  - For each item that is an element node, replace the element by the subelements with tag *X*.

# Example: /BARS

```
<BARS>
  <BAR name = ”JoesBar”>
      <PRICE theBeer = ”Bud”>2.50</PRICE>
      <PRICE theBeer = ”Miller”>3.00</PRICE>
  </BAR> …
  <BEER name = ”Bud” soldBy = ”JoesBar
      SuesBar … ”/> …
</BARS>
```

One item, the BARS element

# Example: /BARS/BAR

<BARS>

<BAR name = "JoesBar">

<PRICE theBeer ="Bud">2.50</PRICE>

<PRICE theBeer = "Miller">3.00</PRICE>

</BAR> …

<BEER name = "Bud" soldBy = "JoesBar

SuesBar …"/> …

</BARS>

This BAR element followed by all the other BAR elements

# Example: /BARS/BAR/PRICE

<BARS>

<BAR name = ”JoesBar”>

<PRICE theBeer =”Bud”>2.50</PRICE>

<PRICE theBeer = ”Miller”>3.00</PRICE>

</BAR> …

<BEER name = ”Bud” soldBy = ”JoesBar

SuesBar …”/> …

</BARS>

These PRICE elements followed by the PRICE elements of all the other bars.

# Attributes in Paths

- Instead of going to subelements with a given tag, you can go to an attribute of the elements you already have.
- An attribute is indicated by putting @ in front of its name.

# Example: /BARS/BAR/PRICE/@theBeer

```
<BARS>
  <BAR name = ”JoesBar”>
      <PRICE theBeer = ”Bud”>2.50</PRICE>
      <PRICE theBeer = ”Miller”>3.00</PRICE>
  </BAR> …
  <BEER name = ”Bud” soldBy = ”JoesBar
      SuesBar …”/> …
</BARS>
```

These attributes contribute ”Bud” ”Miller” to the result, followed by other theBeer values.

# Remember: Item Sequences

- Until now, all item sequences have been sequences of elements.
- When a path expression ends in an attribute, the result is typically a sequence of values of primitive type, such as strings in the previous example.

# Paths that Begin Anywhere

- If the path starts from the document node and begins with *//X*, then the first step can begin at the root or any subelement of the root, as long as the tag is *X*.

# Example: //PRICE

<BARS>

<BAR name = ”JoesBar”>

<PRICE theBeer =”Bud”>2.50</PRICE>

<PRICE theBeer = ”Miller”>3.00</PRICE>

</BAR> …

<BEER name = ”Bud” soldBy = ”JoesBar

SuesBar …”/> …

</BARS>

These PRICE elements and any other PRICE elements in the entire document

# Wild-Card *

- A star (*) in place of a tag represents any one tag.
- Example: /*/*/PRICE represents all price objects at the third level of nesting.

# Example: /BARS/*

This BAR element, all other BAR elements, the BEER element, all other BEER elements

<BARS>

<BAR name = "JoesBar">

<PRICE theBeer = "Bud">2.50</PRICE>

<PRICE theBeer = "Miller">3.00</PRICE>

</BAR> …

<BEER name = "Bud" soldBy = "JoesBar SuesBar … "/> …

</BARS>

# Selection Conditions

- A condition inside [...] may follow a tag.
- If so, then only paths that have that tag and also satisfy the condition are included in the result of a path expression.

# Example: Selection Condition

- /BARS/BAR/PRICE[. < 2.75]

<BARS>

<BAR name = ”JoesBar”>

<PRICE theBeer = ”Bud”>2.50</PRICE>

<PRICE theBeer = ”Miller”>3.00</PRICE>

</BAR> …

The current element.

The condition that the PRICE be < $2.75 makes this price but not the Miller price part of the result.

# Example: Attribute in Selection

- /BARS/BAR/PRICE[@theBeer = ”Miller”]

<BARS>

<BAR name = ”JoesBar”>

<PRICE theBeer = ”Bud”>2.50</PRICE>

<PRICE theBeer = ”Miller”>3.00</PRICE>

</BAR> …

Now, this PRICE element is selected, along with any other prices for Miller.

# Axes

- In general, path expressions allow us to start at the root and execute steps to find a sequence of nodes at each step.
- At each step, we may follow any one of several *axes*.
- The default axis is child:: --- go to all the children of the current set of nodes.

# Example: Axes

- /BARS/BEER is really shorthand for /BARS/child::BEER .
- @ is really shorthand for the attribute:: axis.
  - Thus, /BARS/BEER[@name = ”Bud” ] is shorthand for

    /BARS/BEER[attribute::name = ”Bud”]

# More Axes

- Some other useful axes are:
  1. parent:: = parent(s) of the current node(s).
  2. descendant-or-self:: = the current node(s) and all descendants.
     - Note: // is really  shorthand for this axis.
  3. ancestor::, ancestor-or-self, etc.
  4. self (the dot).

# Summary

- Data on the web – shared by Applications and browsers
- Semi-structured → DTD + tagged contents
- Volume → Documents and Databases
- Storage and Query Systems