Lecture 6
XML/Xpath/XQuery

Wednesday, November 3, 2010

Announcements

Due to popular demand, take-home final dates have moved as follows:

- Posted: Friday, 10/10, 11:59pm
- Due: Sunday, 10/12, 11:59pm

HW 4 due next week

HW 5 posted today, due in two weeks

XML Outline

- XML
  - Syntax
  - Semistructured data
  - DTDs
- Xpath
- XQuery

Additional Readings on XML

- http://www.w3.org/XML/
  - Main source on XML, but hard to read

- http://www.w3.org/TR/xquery/
  - Authority on Xquery

Reading: textbook chapters 27.6, 27.7, 27.8

XML

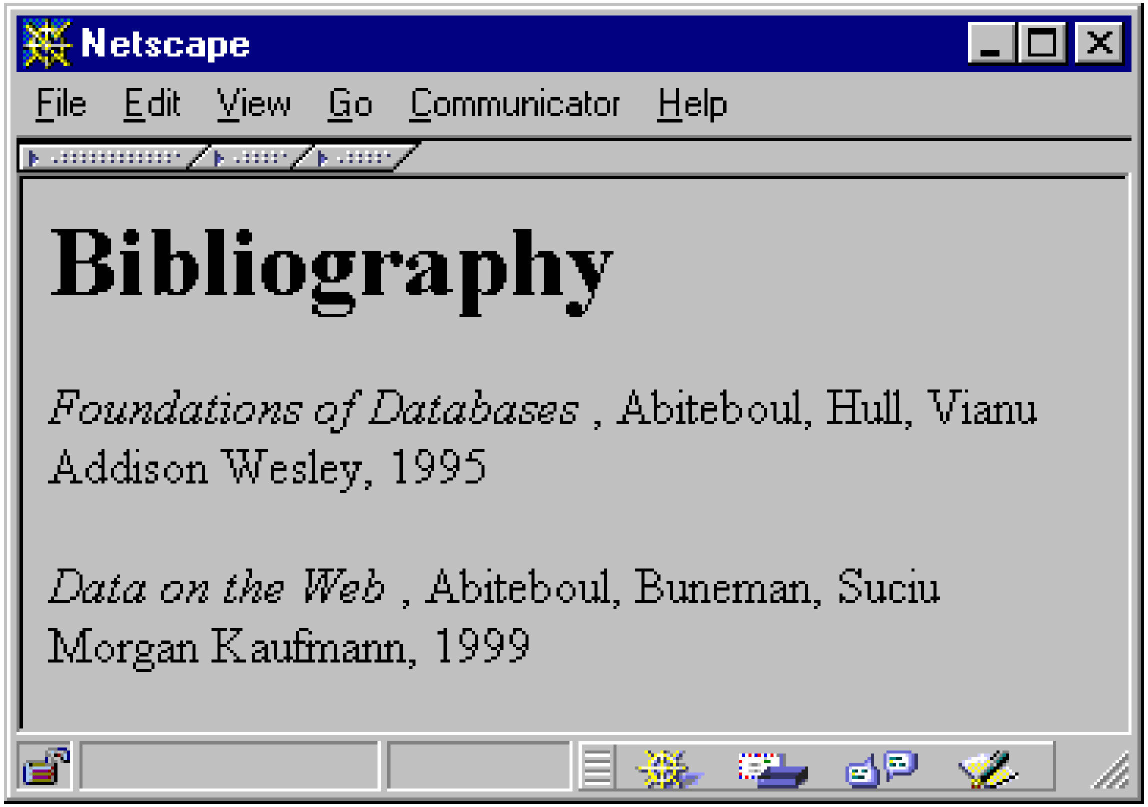
- A flexible syntax for data
- Used in:
  - Configuration files, e.g. Web.Config
  - Replacement for binary formats (MS Word)
  - Document markup: e.g. XHTML
  - Data: data exchange, semistructured data
- Roots: SGML - a very nasty language

We will study only XML as data

XML as Semistructured Data

- Relational databases have rigid schema
  - Schema evolution is costly
- XML is flexible: semistructured data
  - Store data in XML
- Warning: not normal form ! Not even 1NF

From HTML to XML



Bibliography

Foundations of Databases , Abiteboul, Hull, Vianu
Addison Wesley, 1995

Data on the Web , Abiteboul, Buneman, Suciu
Morgan Kaufmann, 1999

HTML describes the presentation

HTML

```
<h1> Bibliography </h1>
<p> <i> Foundations of Databases </i>
        Abiteboul, Hull, Vianu
        <br> Addison Wesley, 1995
<p> <i> Data on the Web </i>
        Abiteoul, Buneman, Suciu
        <br> Morgan Kaufmann, 1999
```

XML Syntax

```
<bibliography>
     <book>    <title> Foundations… </title>
               <author> Abiteboul </author>
               <author> Hull </author>
               <author> Vianu </author>
               <publisher> Addison Wesley </publisher>
               <year> 1995 </year>
     </book>
     …
</bibliography>
```

XML describes the content

XML Terminology

- tags: book, title, author, …
- start tag: <book>, end tag: </book>
- elements: <book>…</book>,<author>…</author>
- elements are nested
- empty element: <red></red> abbrv. <red/>
- an XML document: single *root element*

well formed XML document: if it has matching tags

More XML: Attributes

```
<book price = “55” currency = “USD”>
   <title> Foundations of Databases </title>
   <author> Abiteboul </author>
    …
   <year> 1995 </year>
</book>
```

Attributes v.s. Elements

```
<book price = “55” currency = “USD”>
   <title> Foundations of DBs </title>
   <author> Abiteboul </author>
    …
   <year> 1995 </year>
</book>
```

```
<book>
  <title> Foundations of DBs </title>
   <author> Abiteboul </author>
    …
   <year> 1995 </year>
   <price> 55 </price>
   <currency> USD </currency>
</book>
```

attributes are alternative ways to represent data

Comparison

Elements	**Attributes**
Ordered	Unordered
May be repeated	Must be unique
May be nested	Must be atomic

XML v.s. HTML

- What are the differences between XML and HTML ?

  In class

That’s All !

- That’s all you ever need to know about XML *syntax*
  - – Optional type information can be given in the DTD or XSchema (later)
  - – We’ll discuss some additional syntax in the next few slides, but that’s not essential
- What is important for you to know: XML’s *semantics*

More Syntax: Oids and References

```
<person id=“o555”>
      <name> Jane </name>
</person>

<person id=“o456”>
      <name> Mary </name>
      <mother idref=“o555”/>
</person>
```

Are just keys/ foreign keys design by someone who didn’t take 444

Don’t use them: use your own foreign keys instead.

oids and references in XML are just syntax

More Syntax: CDATA Section

- Syntax: <![CDATA[.....any text here...]]>

- Example:

```
<example>
   <![CDATA[ some text here </notAtag> <>]]>
</example>
```

More Syntax: Entity References

- Syntax: &entityname;
- Example:
  <element> this is less than < </element>
- Some entities:

<	<
>	>
&	&
'	‘
"	“
&	Unicode char

More Syntax: Comments

- Syntax <!-- .... Comment text... -->
- Yes, they are part of the data model !!!

XML Namespaces

- name ::= [prefix:]localpart

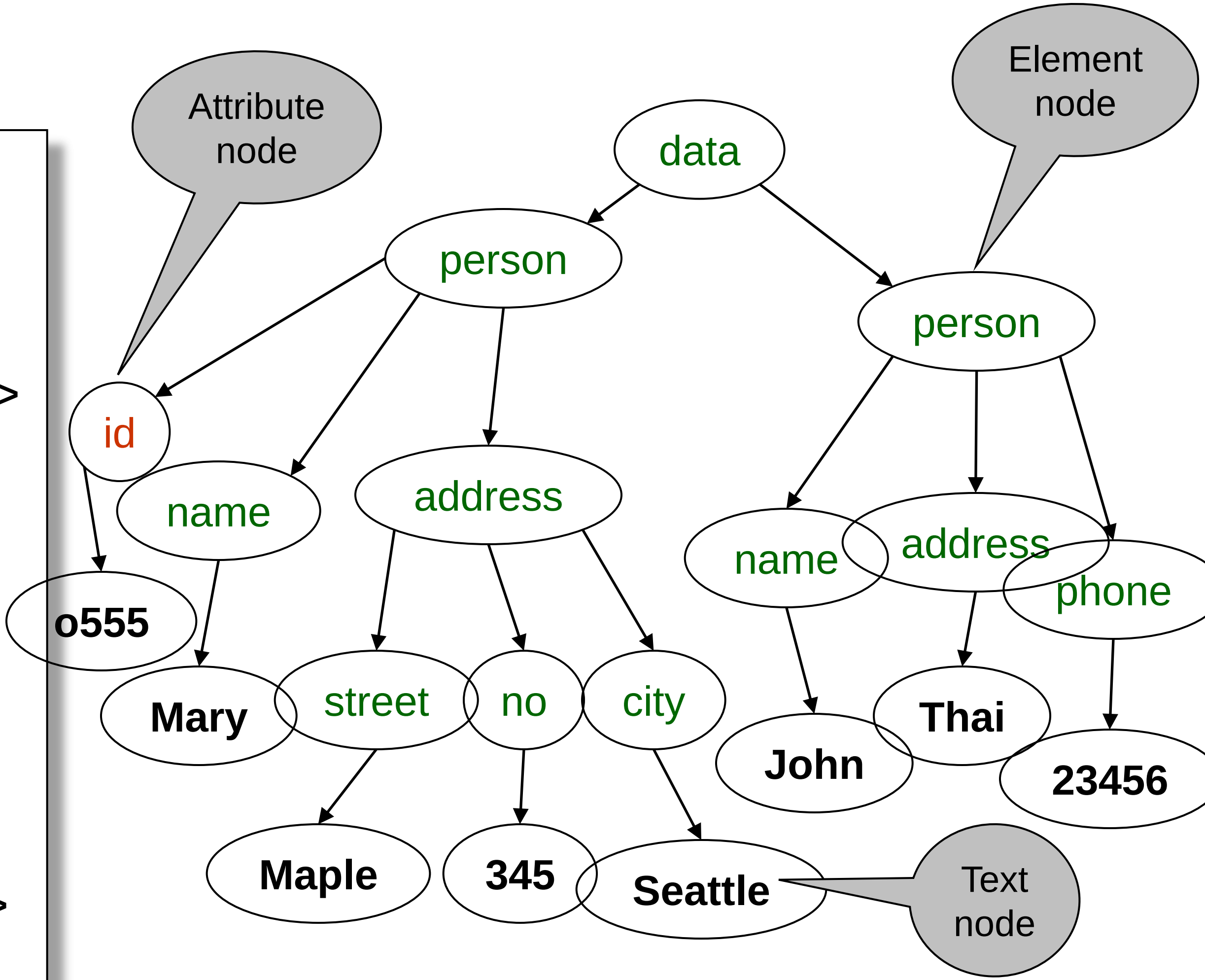
a unique name

```
<book xmlns:bookStandard=“www.isbn-org.org/def”>
      <bookStandard:title> … </bookStandard:title>
      <bookStandard:publisher> . . .</bookStandard:publisher>


</book>
```

XML Semantics: a Tree !

```
<data>
  <person id="o555" >
    <name> Mary </name>
    <address>
      <street>Maple</street>
      <no> 345 </no>
      <city> Seattle </city>
    </address>
  </person>
  <person>
    <name> John </name>
    <address>Thailand
    </address>
    <phone>23456</phone>
  </person>
</data>
```



Order matters !!!

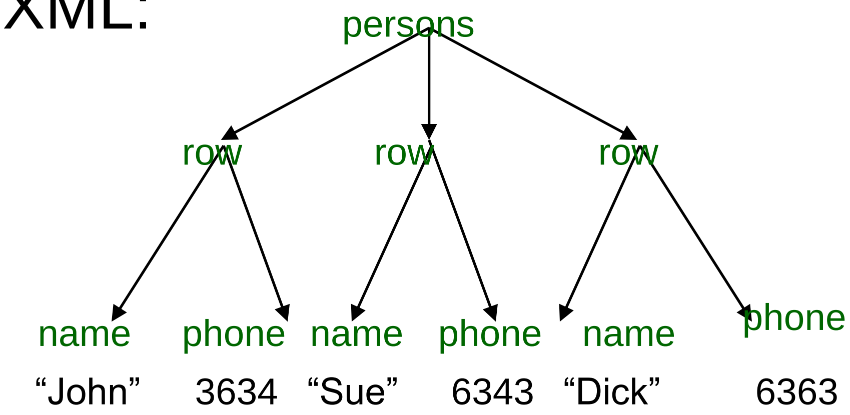
XML as *Data*

- XML is self-describing
- Schema elements become part of the data
  - Reational schema: persons(name,phone)
  - In XML <persons>, <name>, <phone> are part of the data, and are repeated many times
- Consequence: XML is much more flexible
- XML = semistructured data

Mapping Relational Data to XML

The canonical mapping:

XML:



Persons

Name	Phone
John	3634
Sue	6343
Dick	6363

```
<persons>
      <row> <name>John</name>
                 <phone> 3634</phone></row>
       <row> <name>Sue</name>
                   <phone> 6343</phone>
       <row> <name>Dick</name>
                   <phone> 6363</phone></row>
</persons>
```

Mapping Relational Data to XML

Natural mapping

Persons

Name	Phone
John	3634
Sue	6343

Orders

PersonName	Date	Product
John	2002	Gizmo
John	2004	Gadget
Sue	2002	Gadget

XML

```
<persons>
  <person>
      <name> John </name>
      <phone> 3634 </phone>
      <order>  <date> 2002 </date>
               <product> Gizmo </product>
       </order>
       <order> <date> 2004 </date>
               <product> Gadget </product>
       </order>
  </person>
 <person>
      <name> Sue </name>
      <phone> 6343 </phone>
      <order>  <date> 2004 </date>
               <product> Gadget </product>
       </order>
  </person>
</persons>
```

XML is Semi-structured Data

- Missing attributes:

```
<person>   <name> John</name>
           <phone>1234</phone>
 </person>

<person>  <name>Joe</name>
</person>
```

no phone !

- Could represent in a table with nulls

name	phone
John	1234
Joe	-

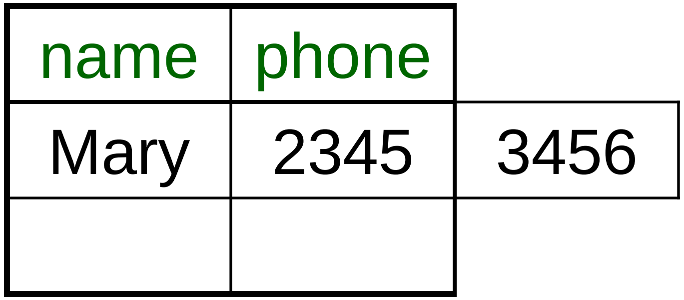
XML is Semi-structured Data

- Repeated attributes

```
<person> <name> Mary</name>
              <phone>2345</phone>
              <phone>3456</phone>
</person>
```

Two phones !

- Impossible in tables:



name	phone	
Mary	2345	3456

???

XML is Semi-structured Data

- Attributes with different types in different objects

```
<person> <name>  <first> John </first>
                  <last> Smith </last>
         </name>
         <phone>1234</phone>
</person>
```

Structured name !

- Nested collections (no 1NF)
- Heterogeneous collections:
  - <db> contains both <book>s and <publisher>s

Document Type Definitions DTD

- part of the original XML specification
- an XML document may have a DTD
- XML document:

  Well-formed = if tags are correctly closed

  Valid = if it has a DTD and conforms to it

- validation is useful in data exchange

DTD

Goals:

- Define what tags and attributes are allowed
- Define how they are nested
- Define how they are ordered

Superseded by XML Schema

- Very complex: DTDs still used widely

Very Simple DTD

```
<!DOCTYPE company [
  <!ELEMENT company   ((person|product)*)>
  <!ELEMENT person  (ssn, name, office, phone?)>
  <!ELEMENT ssn         (#PCDATA)>
  <!ELEMENT name      (#PCDATA)>
  <!ELEMENT office     (#PCDATA)>
  <!ELEMENT phone     (#PCDATA)>
  <!ELEMENT product  (pid, name, description?)>
  <!ELEMENT pid    (#PCDATA)>
  <!ELEMENT description    (#PCDATA)>
]>
```

Very Simple DTD

Example of valid XML document:

```
<company>
   <person>  <ssn> 123456789 </ssn>
              <name> John </name>
              <office> B432 </office>
              <phone> 1234 </phone>
   </person>
   <person>  <ssn> 987654321 </ssn>
              <name> Jim </name>
              <office> B123 </office>
   </person>
   <product> ...  </product>
   ...
</company>
```

DTD: The Content Model

<!ELEMENT tag (*CONTENT*)>

content model

- Content model:
  - Complex = a regular expression over other elements
  - Text-only = #PCDATA
  - Empty = EMPTY
  - Any = ANY
  - Mixed content = (#PCDATA | A | B | C)*

DTD: Regular Expressions

DTD

XML

sequence

```
<!ELEMENT name
               (firstName, lastName))>
```

optional

```
<!ELEMENT name  (firstName?, lastName))>
```

Kleene star

```
<!ELEMENT person   (name, phone*))>
```

alternation

```
<!ELEMENT person   (name, (phone|email)))>
```

DTD: Regular Expressions

DTD

XML

sequence

```
<!ELEMENT name
              (firstName, lastName))>
```

```
<name>
   <firstName>  . . . . . </firstName>
   <lastName>  . . . . . </lastName>
</name>
```

optional

```
<!ELEMENT name  (firstName?, lastName))>
```

Kleene star

```
<!ELEMENT person   (name, phone*))>
```

alternation

```
<!ELEMENT person   (name, (phone|email)))>
```

DTD: Regular Expressions

DTD

sequence

```
<!ELEMENT name
                 (firstName, lastName))>
```

XML

```
<name>
   <firstName>  . . . . . </firstName>
   <lastName>  . . . . . </lastName>
</name>
```

optional

```
<!ELEMENT name  (firstName?, lastName))>
```

Kleene star

```
<!ELEMENT person   (name, phone*))>
```

```
<person>
   <name>  . . . . . </name>
   <phone>  . . . . . </phone>
   <phone>  . . . . . </phone>
   <phone>  . . . . . </phone>
   . . . . . . .
</person>
```

alternation

```
<!ELEMENT person   (name, (phone|email)))>
```

Begin Optional Material

XSchema

- Generalizes DTDs
- Uses XML syntax
- Two parts: structure and datatypes
- Very complex
  - criticized
  - alternative proposals: Relax NG

DTD v.s. XML Schemas

DTD:

```
<!ELEMENT paper (title,author*,year, (journal|conference))>
```

XML Schema:

```
<xs:element name=“paper” type=“paperType”/>
<xs:complexType name=“paperType”>
    <xs:sequence>
          <xs:element name=“title” type=“xs:string”/>
          <xs:element name=“author” minOccurs=“0”/>
          <xs:element name=“year”/>
          <xs: choice> < xs:element name=“journal”/>
                     <xs:element name=“conference”/>
          </xs:choice>
    </xs:sequence>
</xs:element>
```

Example

A valid XML Document:

```
<paper>
  <title> The Essence of XML </title>
  <author> Simeon</author>
  <author> Wadler</author>
  <year>2003</year>
  <conference> POPL</conference>
</paper>
```

Elements v.s. Types

```
<xs:element name=“person”>
  <xs:complexType>
    <xs:sequence>
      <xs:element name=“name”
                      type=“xs:string”/>
      <xs:element name=“address”
                      type=“xs:string”/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

```
<xs:element name=“person”
                      type=“ttt”>
<xs:complexType name=“ttt”>
  <xs:sequence>
    <xs:element name=“name”
                      type=“xs:string”/>
    <xs:element name=“address”
                      type=“xs:string”/>
  </xs:sequence>
</xs:complexType>
```

Both say the same thing; in DTD:

```
<!ELEMENT person (name,address)>
```

- Types:
  - Simple types (integers, strings, ...)
  - Complex types (regular expressions, like in DTDs)

- Element-type Alternation:
  - An **element** has a **type**
  - A **type** is a regular expression of **elements**

Local v.s. Global Types

- Local type:

```
<xs:element name=“person”>
        [define locally the person’s type]
</xs:element>
```

- Global type:

```
<xs:element name=“person” type=“ttt”/>

<xs:complexType name=“ttt”>
        [define here the type ttt]
</xs:complexType>
```

Global types: can be reused in other elements

Local v.s. Global Elements

- Local element:

```
 <xs:complexType name=“ttt”>
     <xs:sequence>
          <xs:element name=“address” type=“...”/>...
     </xs:sequence>
 </xs:complexType>
```

- Global element:

```
  <xs:element name=“address” type=“...”/>

  <xs:complexType name=“ttt”>
      <xs:sequence>
        <xs:element ref=“address”/>  ...
     </xs:sequence>
  </xs:complexType>
```

Global elements: like in DTDs

Regular Expressions

Recall the element-type-element alternation:

```
<xs:complexType name=“....”>
        [regular expression on elements]
 </xs:complexType>
```

Regular expressions:

- <xs:sequence> A B C </...>   = A B C
- <xs:choice> A B C </...>   = A | B | C
- <xs:group> A B C </...>   = (A B C)
- <xs:... minOccurs=“0” maxOccurs=“unbounded”> ..</...>   = (...)*
- <xs:... minOccurs=“0” maxOccurs=“1”> ..</...>   = (...)?

Local Names

name has different meanings in **person** and in **product**

```
<xs:element name=“person”>
  <xs:complexType>
        . . . . .
      <xs:element name=“name”>
              <xs:complexType>
                    <xs:sequence>
                         <xs:element name=“firstname” type=“xs:string”/>
                         <xs:element name=“lastname” type=“xs:string”/>
              </xs:sequence>
      </xs:element>
       .   . . .
 </xs:complexType>
</xs:element>


<xs:element name=“product”>
  <xs:complexType>
        . . . . .
      <xs:element name=“name”   type=“xs:string”/>

  </xs:complexType>
</xs:element>
```

Subtle Use of Local Names

```
<xs:element name=“A” type=“oneB”/>


<xs:complexType name=“onlyAs”>
  <xs:choice>
      <xs:sequence>
          <xs:element name=“A” type=“onlyAs”/>
          <xs:element name=“A” type=“onlyAs”/>
      </xs:sequence>
      <xs:element name=“A” type=“xs:string”/>
  </xs:choice>
</xs:complexType>
```

```
<xs:complexType name=“oneB”>
  <xs:choice>
      <xs:element name=“B” type=“xs:string”/>
      <xs:sequence>
          <xs:element name=“A” type=“onlyAs”/>
          <xs:element name=“A” type=“oneB”/>
      </xs:sequence>
      <xs:sequence>
          <xs:element name=“A” type=“oneB”/>
          <xs:element name=“A” type=“onlyAs”/>
      </xs:sequence>
 </xs:choice>
</xs:complexType>
```

Arbitrary deep binary tree with A elements, and a single B element

Note: this example is not legal in XML Schema (why ?)
Hence they cannot express all regular tree languages

Attributes in XML Schema

```
<xs:element name=“paper” type=“papertype”>
  <xs:complexType name=“papertype”>
      <xs:sequence>
            <xs:element name=“title” type=“xs:string”/>
            . . . . . . .
      </xs:sequence>
      <xs:attribute name=“language" type="xs:NMTOKEN" fixed=“English"/>
  </xs:complexType>
</xs:element>
```

Attributes are associated to the *type*, not to the element

Only to *complex types*; more trouble if we want to add attributes to *simple types*.

“Mixed” Content, “Any” Type

```
<xs:complexType mixed="true">
 . . . .
```

- Better than in DTDs: can still enforce the type, but now may have text between any elements

```
<xs:element name="anything" type="xs:anyType"/>
  . . . .
```

- Means anything is permitted there

“All” Group

```
<xs:complexType name="PurchaseOrderType">
  <xs:all>  <xs:element name="shipTo" type="USAddress"/>
               <xs:element name="billTo" type="USAddress"/>
               <xs:element ref="comment" minOccurs="0"/>
               <xs:element name="items"  type="Items"/>
  </xs:all>
  <xs:attribute name="orderDate" type="xs:date"/>
</xs:complexType>
```

- A restricted form of & in SGML
- Restrictions:
  - Only at top level
  - Has only elements
  - Each element occurs at most once
- E.g. “comment” occurs 0 or 1 times

Derived Types by Extensions

```
<complexType name="Address">
      <sequence>  <element name="street" type="string"/>
                       <element name="city"   type="string"/>
      </sequence>
 </complexType>

 <complexType name="USAddress">
    <complexContent>
         <extension base="ipo:Address">
             <sequence>  <element name="state" type="ipo:USState"/>
                              <element name="zip"   type="positiveInteger"/>
             </sequence>
         </extension>
    </complexContent>
</complexType>
```

Corresponds to inheritance

Derived Types by Restrictions

```
<complexContent>
    <restriction base="ipo:Items“>
     … [rewrite the entire content, with restrictions]...
    </restriction>
 </complexContent>
```

- (*): may restrict cardinalities, e.g. (0,infty) to (1,1); may restrict choices; other restrictions…

Corresponds to set inclusion

Simple Types

- String
- Token
- Byte
- unsignedByte
- Integer
- positiveInteger
- Int (larger than integer)
- unsignedInt
- Long
- Short
- ...

- Time
- dateTime
- Duration
- Date
- ID
- IDREF
- IDREFS

Facets of Simple Types

Facets = additional properties restricting a simple type

15 facets defined by XML Schema

Examples

- length
- minLength
- maxLength
- pattern
- enumeration
- whiteSpace

- maxInclusive
- maxExclusive
- minInclusive
- minExclusive
- totalDigits
- fractionDigits

Facets of Simple Types

- Can further restrict a simple type by changing some facets
- Restriction = subset

Not so Simple Types

- List types:

```
<xs:simpleType name="listOfMyIntType">
  <xs:list itemType="myInteger"/>
</xs:simpleType>
```

```
<listOfMyInt>20003 15037 95977 95945</listOfMyInt>
```

- Union types
- Restriction types

End Optional Material

Typical XML Applications

- Data exchange
  - – Take the data, don't worry about schema
- Property lists
  - – Many attributes, most are NULL
- Evolving schema
  - – Add quickly a new attribute

Approaches to XML Processing

- Via API
  - – Called DOM
  - – Navigate, update the XML arbitrarily
  - – BUT: memory bound
- Via some query language:
  - – Xpath or Xquery
  - – Stand-alone processor OR embedded in SQL

Querying XML Data

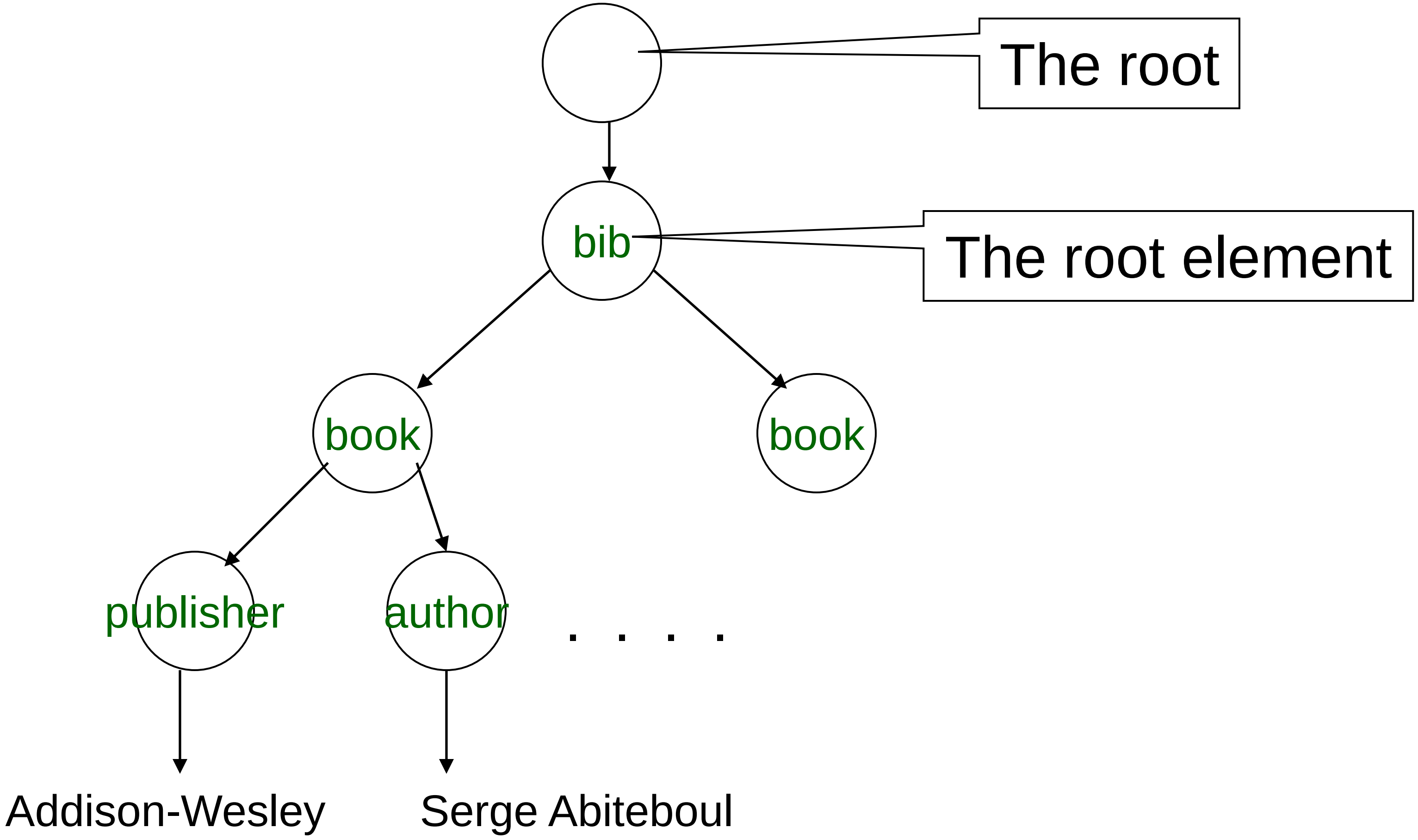
Will discuss next:

- XPath = simple navigation on the tree
- XQuery = “the SQL of XML”

Sample Data for Queries

```
<bib>
    <book>  <publisher> Addison-Wesley </publisher>
            <author> Serge Abiteboul </author>
            <author> <first-name> Rick </first-name>
                     <last-name> Hull </last-name>
            </author>
            <author> Victor Vianu </author>
            <title> Foundations of Databases </title>
            <year> 1995 </year>
    </book>
    <book price="55">
           <publisher> Freeman </publisher>
            <author> Jeffrey D. Ullman </author>
            <title> Principles of Database and Knowledge Base Systems </title>
            <year> 1998 </year>
    </book>
</bib>
```

Data Model for XPath



The root

bib

The root element

book

book

publisher

author

. . . .

Addison-Wesley

Serge Abiteboul

XPath: Simple Expressions

/bib/book/year

Result: <year> 1995 </year>
<year> 1998 </year>

/bib/paper/year

Result: empty (there were no papers)

/bib

What's the difference ?

/

XPath: Restricted Kleene Closure

//author

```
Result:<author> Serge Abiteboul </author>
          <author> <first-name> Rick </first-name>
                      <last-name> Hull </last-name>
          </author>
          <author> Victor Vianu </author>
          <author> Jeffrey D. Ullman </author>
```

```
Result:  <first-name> Rick </first-name>
```

/bib//first-name

Xpath: Attribute Nodes

`/bib/book/@price`

Result: should be “55”, but XPath can’t print (WHY ?)

@price means that price is has to be an attribute

Xpath: Wildcard

`//author/*`

Result: <first-name> Rick </first-name>
<last-name> Hull </last-name>

* Matches any element

@* Matches any attribute

Xpath: Text Nodes

`/bib/book/author/text()`

Result: Serge Abiteboul
Victor Vianu
Jeffrey D. Ullman

Rick Hull doesn’t appear because he has firstname, lastname

Functions in XPath:

- text() = matches the text value
- node() = matches any node (= * or @* or text())
- name() = returns the name of the current tag

Xpath: Predicates

```
/bib/book/author[first-name]
```

Result:
```
<author> <first-name> Rick </first-name>
         <last-name> Hull </last-name>
</author>
```

Xpath: More Predicates

```
/bib/book/author[first-name][address[.//zip][city]]/last-name
```

Explain how this is evaluated !

Xpath: More Predicates

```
/bib/book/author[first-name][address[.//zip][city]]/last-name
```

Result: <lastname> … </lastname>

<lastname> … </lastname>

How do we read this ?

First remove all qualifiers (predicates):

```
/bib/book/author/last-name
```

Then add them one by one:

```
/bib/book/author[first-name][address]/last-name
```

Xpath: More Predicates

```
/bib/book[@price < 60]
```

```
/bib/book[author/@age < 25]
```

```
/bib/book[author/text()]
```

Xpath: More Axes

. means *current node* `/bib/book[.//review]`

`/bib/book[./review]` Same as `/bib/book[review]`

`/bib/book/. /author` Same as `/bib/book/author`

Xpath: More Axes

.. means *parent node*

`/bib/book/author/../author`

Same as

`/bib/book/author`

`/bib/book/author[./first-name/../last-name]`

Same as `/bib/book/author[first-name][last-name]`

Xpath: Brief Summary

bib	matches a bib element
*	matches any element
/	matches the root element
/bib	matches a bib element under root
bib/paper	matches a paper in bib
bib//paper	matches a paper in bib, at any depth
//paper	matches a paper at any depth
paper|book	matches a paper or a book
@price	matches a price attribute
bib/book/@price	matches price attribute in book, in bib
bib/book[@price<“55”]/author/lastname	matches…

XQuery

- Based on Quilt, which is based on XML-QL

- Uses XPath to express more complex queries

FLWR (“Flower”) Expressions

FOR ...

LET...

WHERE...

RETURN...

FOR-WHERE-RETURN

Find all book titles published after 1995:

```
for $x in document("bib.xml")/bib/book

where $x/year/text() > 1995

return $x/title
```

Result:

```
  <title> abc </title>
  <title> def </title>
  <title> ghi </title>
```

FOR-WHERE-RETURN

Equivalently (perhaps more geekish)

```
for $x in document("bib.xml")/bib/book[year/text() > 1995] /title
return $x
```

And even shorter:

```
document("bib.xml")/bib/book[year/text() > 1995] /title
```

FOR-WHERE-RETURN

- Find all book titles and the year when they were published:

```
for $x in document("bib.xml")/ bib/book
return <answer>
                <title> { $x/title/text() } </title>
                <year>{ $x/year/text() } </year>
            </answer>
```

Result:

```
<answer> <title> abc </title>  <year> 1995 </year > </answer>
<answer> <title> def </title>  <year>  2002 </year > </answer>
<answer> <title> ghk </title>  <year> 1980 </year > </answer>
```

FOR-WHERE-RETURN

- Notice the use of “{“ and “}”
- What is the result without them ?

```
for $x in document("bib.xml")/ bib/book
return <answer>
                    <title>  $x/title/text() </title>
                    <year> $x/year/text() </year>
               </answer>
```

FOR-WHERE-RETURN

- Notice the use of “{“ and “}”
- What is the result without them ?

```
for $x in document("bib.xml")/bib/book
return <answer>
                      <title>  $x/title/text() </title>
                      <year> $x/year/text() </year>
                 </answer>
```

```
<answer>  <title>  $x/title/text() </title>  <year> $x/year/text() </year> </answer>
<answer>  <title>  $x/title/text() </title>  <year> $x/year/text() </year> </answer>
<answer>  <title>  $x/title/text() </title>  <year> $x/year/text() </year> </answer>
```

Nesting

For each author of a book published in 1995, list all books she published:

```
for $b in document(“bib.xml”)/bib,
       $a in $b/book[year/text()=1995]/author
return <result>
                { $a,
                  for $t in $b/book[author/text()=$a/text()]/title
                  return $t
                }
             </result>
```

In the RETURN clause comma concatenates XML fragments

Result

```
<result>
          <author>Jones</author>
          <title> abc </title>
          <title> def </title>
   </result>
   <result>
           <author> Smith </author>
           <title> ghi </title>
   </result>
```

Aggregates

Find all books with more than 3 authors:

```
for $x in document("bib.xml")/bib/book
where count($x/author)>3
return $x
```

count = a function that counts
avg = computes the average
sum = computes the sum
distinct-values = eliminates duplicates

Aggregates

Same thing:

```
for $x in document("bib.xml")/bib/book[count(author)>3]
return  $x
```

Aggregates

Print all authors who published more than 3 books

```
for $b in document("bib.xml")/bib,
        $a in distinct-values($b/book/author/text())
where count($b/book[author/text()=$a])>3
return <author> { $a } </author>
```

Flattening

- “Flatten” the authors, i.e. return a list of (author, title) pairs

```
for $b in document("bib.xml")/bib/book,
       $x in $b/title/text(),
       $y in $b/author/text()
return <answer>
              <title> { $x } </title>
              <author> { $y } </author>
           </answer>
```

Result:

```
<answer>
   <title> abc </title>
   <author> efg </author>
</answer>
<answer>
   <title> abc </title>
   <author> hkj </author>
</answer>
```

Re-grouping

- For each author, return all titles of her/his books

```
for $b in document("bib.xml")/bib
let $a:=distinct-values($b/book/author/text())
for $x in $a
return
  <answer>
    <author> { $x } </author>
    { for $y in $b/book[author/text()=$x]/title
       return $y }
  </answer>
```

Result:

```
<answer>
   <author> efg </author>
    <title> abc </title>
    <title> klm </title>
     . . . .
</answer>
```

Re-grouping

- Same thing:

```
for $b in document("bib.xml")/bib,
         $x in distinct-values($b/book/author/text())
return
  <answer>
     <author> { $x } </author>
     { for $y in $b/book[author/text()=$x]/title
        return $y }
  </answer>
```

SQL and XQuery Side-by-side

Product(pid, name, maker, price)

Find all product names, prices,
sort by price

```
SELECT x.name,
            x.price
FROM Product x
ORDER BY x.price
```

SQL

SQL and XQuery Side-by-side

Product(pid, name, maker, price)

Find all product names, prices, sort by price

```
SELECT x.name,
            x.price
FROM Product x
ORDER BY x.price
```

```
for $x in document(“db.xml”)/db/product/row
order by $x/price/text()
return <answer>
                  { $x/name,  $x/price }
               </answer>
```

SQL

XQuery

Xquery’s Answer

```
 <answer>
        <name>  abc  </name>
        <price>  7 </price>
</answer>
 <answer>
        <name>  def  </name>
        <price>  23 </price>
</answer>
  . . . .
```

SQL and XQuery Side-by-side

Product(pid, name, maker, price)

Company(cid, name, city, revenues)

Find all products made in Seattle

```
SELECT x.name
FROM Product x, Company y
WHERE x.maker=y.cid
        and y.city=“Seattle”
```

SQL

SQL and XQuery Side-by-side

Product(pid, name, maker, price)
Company(cid, name, city, revenues)

Find all products made in Seattle

```
SELECT x.name
FROM Product x, Company y
WHERE x.maker=y.cid
        and y.city=“Seattle”
```

SQL

```
for $r in document(“db.xml”)/db,
         $x in $r/product/row,
         $y in $r/company/row
where
    $x/maker/text()=$y/cid/text()
    and  $y/city/text() = “seattle”
return { $x/name }
```

XQuery

SQL and XQuery Side-by-side

Product(pid, name, maker, price)
Company(cid, name, city, revenues)

Find all products made in Seattle

SQL

```
SELECT x.name
FROM Product x, Company y
WHERE x.maker=y.cid
        and y.city=“Seattle”
```

XQuery

```
for $r in document(“db.xml”)/db,
        $x in $r/product/row,
        $y in $r/company/row
where
    $x/maker/text()=$y/cid/text()
    and  $y/city/text() = “seattle”
return { $x/name }
```

Cool XQuery

```
for $y in /db/company/row[city/text()=“seattle”],
        $x in /db/product/row[maker/text()=$y/cid/text()]
return { $x/name }
```

```
<product>
          <row> <pid> 123 </pid>
                      <name> abc </name>
                      <maker> efg </maker>
           </row>
           <row> …. </row>
           …
</product>
<product>
    . . .
</product>
. . . .
```

SQL and XQuery Side-by-side

For each company with revenues < 1M, count how many products with price > $100 they make

```
SELECT y.name, count(*)
FROM Product x, Company y
WHERE x.price > 100 and x.maker=y.cid and y.revenue < 1000000
GROUP BY y.cid, y.name
```

```
for $r in document(“db.xml”)/db,
        $y in $r/company/row[revenue/text()<1000000]
return
    <proudcompany>
        <companyname> { $y/name/text()  }  </companyname>
        <numberofexpensiveproducts>
          {count($r/product/row[maker/text()=$y/cid/text()][price/text()>100])}
        </numberofexpensiveproducts>
    </proudcompany>
```

SQL and XQuery Side-by-side

Find companies with at least 30 products, and their avg price

```
SELECT y.name, avg(x.price)
FROM Product x, Company y
WHERE x.maker=y.cid
GROUP BY y.cid, y.name
HAVING count(*) > 30
```

$r=element

```
for $r in document(“db.xml”)/db,
   $y in $r/company/row
let $p := $r/product/row[maker/text()=$y/cid/text()]
where count($p) > 30
return
    <thecompany>
        <companyname> { $y/name/text()  }
        </companyname>
        <avgprice> avg($p/price/text()) </avgprice>
    </thecompany>
```

$y=collection

FOR v.s. LET

FOR

- Binds *node variables* → iteration

LET

- Binds *collection variables* → one value

FOR v.s. LET

```
for $x in /bib/book
return <result> { $x } </result>
```

Returns:

```
 <result> <book>...</book></result>
<result> <book>...</book></result>
<result> <book>...</book></result>
...
```

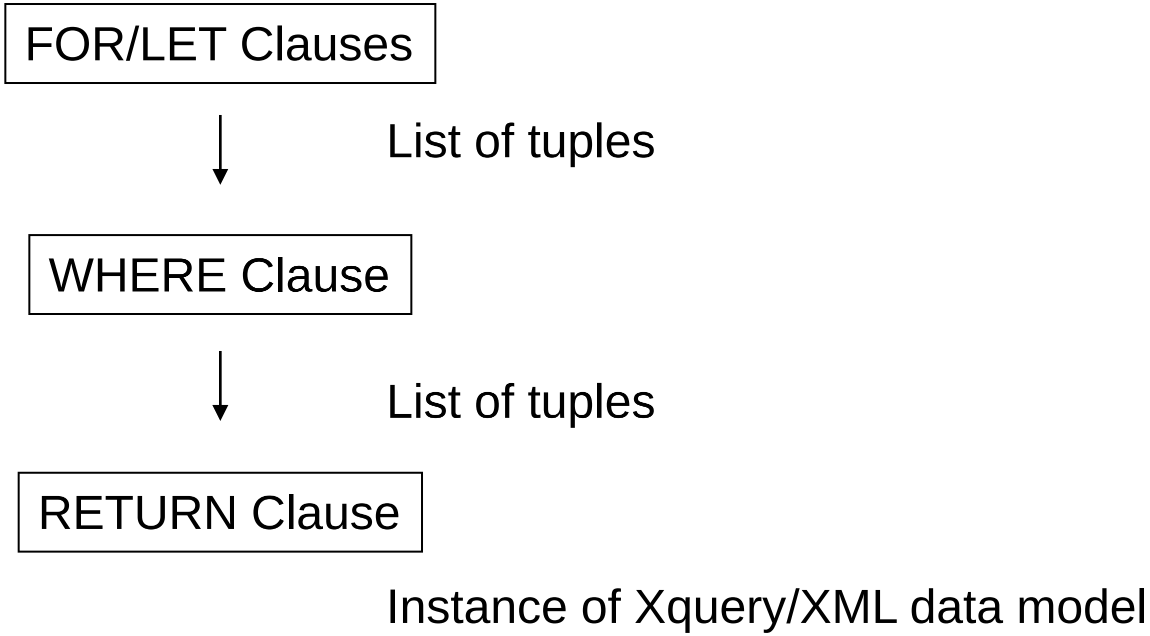
```
let $x := /bib/book
return <result> { $x } </result>
```

Returns:

```
 <result> <book>...</book>
          <book>...</book>
          <book>...</book>
          ...
</result>
```

Summary of XQuery

- FOR-LET-WHERE-RETURN = FLWR



FOR/LET Clauses

List of tuples

WHERE Clause

List of tuples

RETURN Clause

Instance of Xquery/XML data model

The Rest is Optional Material

XML in SQL Server

- Create tables with attributes of type XML
- Use Xquery in SQL queries
- Rest of the slides are from:

Shankar Pal et al., *Indexing XML data stored in a relational database*, VLDB'2004

```
CREATE TABLE DOCS (
        ID int primary key,
        XDOC xml)
```

```
SELECT ID, XDOC.query('
    for $s in  /BOOK[@ISBN= “1-55860-438-3”]//SECTION
    return <topic>{data($s/TITLE)} </topic>')
FROM DOCS
```

XML Methods in SQL

- Query() = returns XML data type
- Value() = extracts scalar values
- Exist() = checks conditions on XML nodes
- Nodes() = returns a rowset of XML nodes that the Xquery expression evaluates to

Examples

- From here: http://msdn.microsoft.com/library/default.asp?url=/library/en-us/dnsql90/html/sql2k5xml.asp

XML Type

```
CREATE TABLE docs (
      pk INT PRIMARY KEY,
      xCol XML not null
)
```

Inserting an XML Value

```
INSERT INTO docs VALUES (2,
'<doc id="123">
    <sections>
   <section num="1"><title>XML Schema</title></section>
   <section num="3"><title>Benefits</title></section>
   <section num="4"><title>Features</title></section>
    </sections>
</doc>')
```

Query( )

```
SELECT pk, xCol.query('/doc[@id = 123]//section')
FROM   docs
```

Exists( )

```
SELECT xCol.query('/doc[@id = 123]//section')
FROM   docs
WHERE  xCol.exist ('/doc[@id = 123]') = 1
```

Value( )

```
SELECT xCol.value(
   'data((/doc//section[@num = 3]/title)[1])', 'nvarchar(max)')
FROM docs
```

Nodes( )

```
SELECT nref.value('first-name[1]', 'nvarchar(50)')
                    AS  FirstName,
       nref.value('last-name[1]', 'nvarchar(50)')
                    AS LastName
FROM   @xVar.nodes('//author') AS R(nref)
WHERE  nref.exist('.[first-name != "David"]') = 1
```

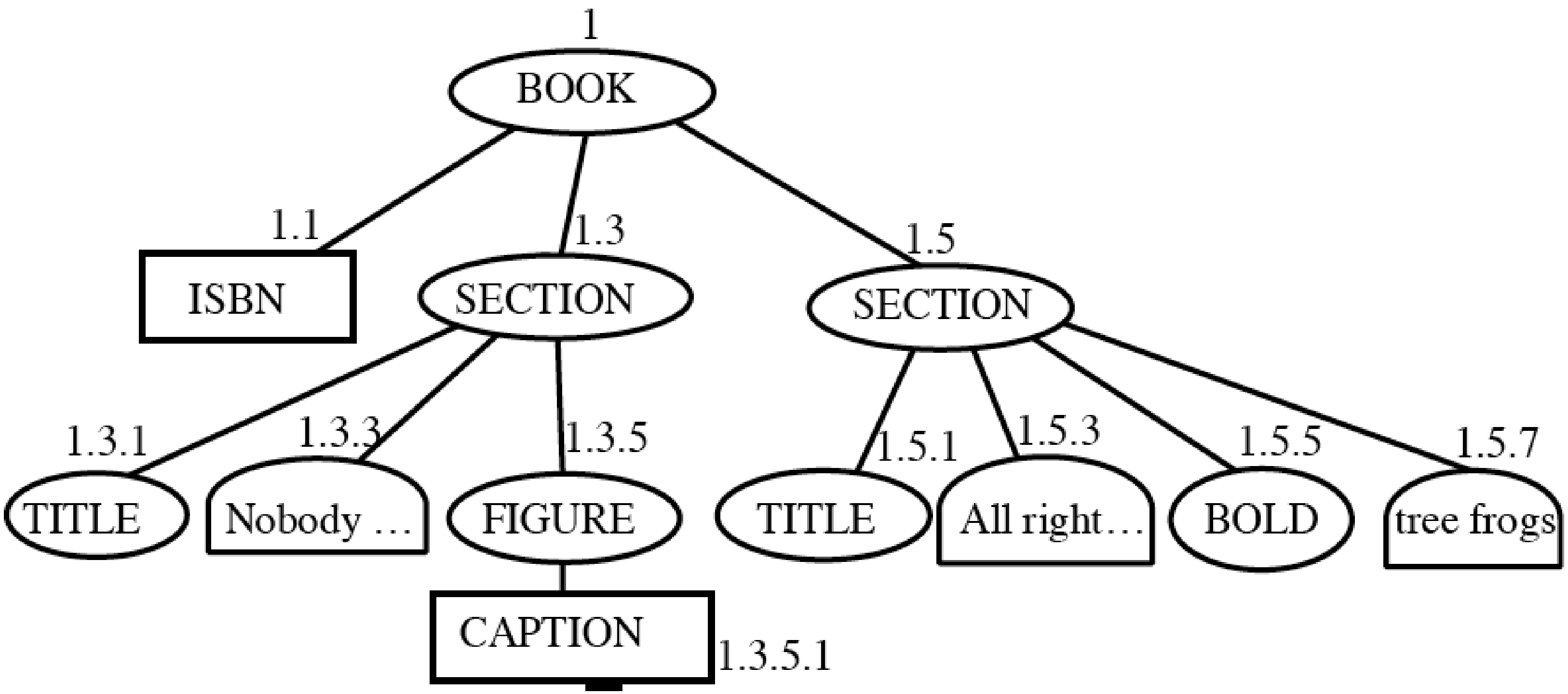
Nodes( )

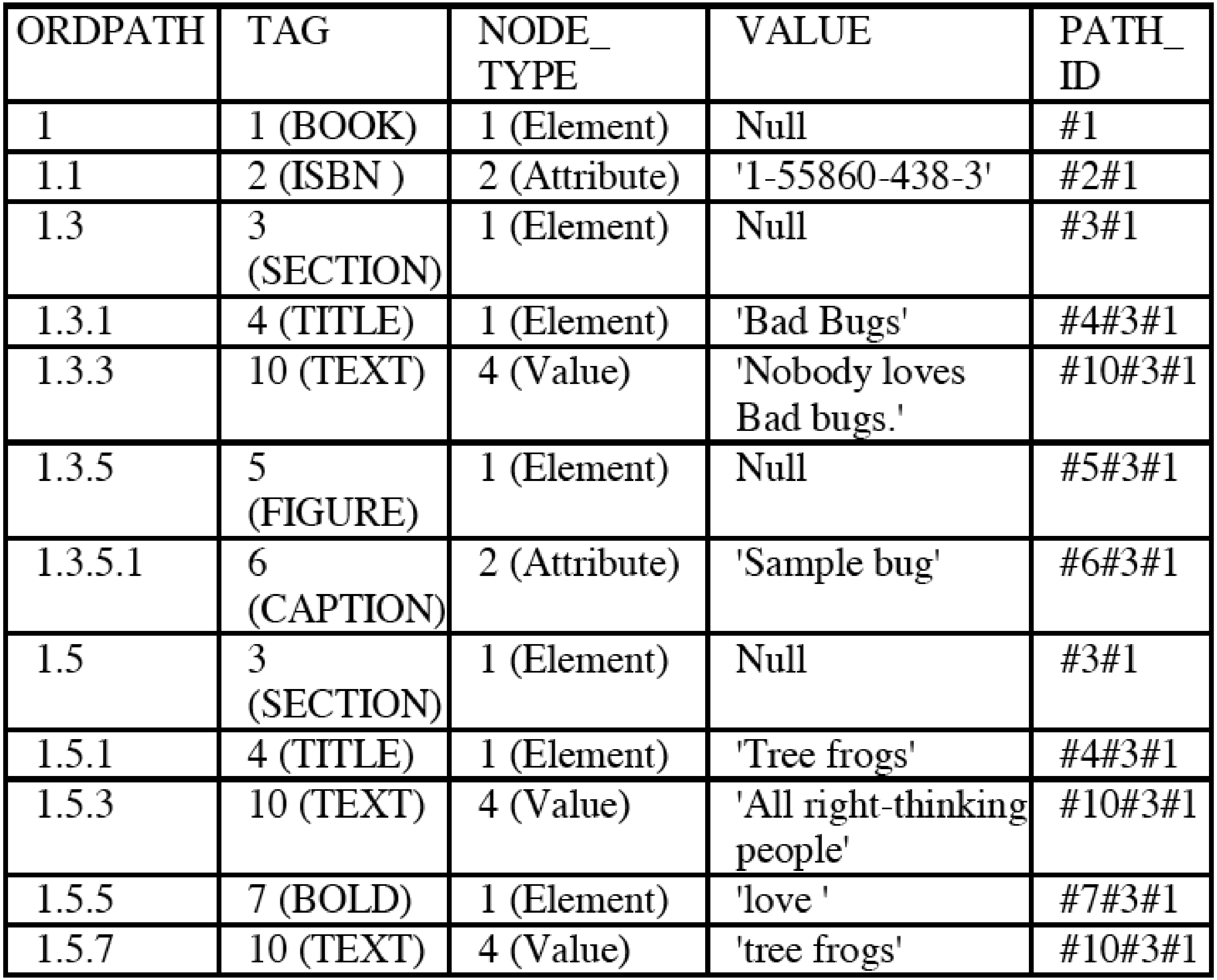
```
SELECT nref.value('@genre', 'varchar(max)') LastName
FROM docs CROSS APPLY xCol.nodes('//book') AS R(nref)
```

Internal Storage

- XML is “shredded” as a table
- A few important ideas:
  - Dewey decimal numbering of nodes; store in clustered B-tree indes
  - Use only odd numbers to allow insertions
  - Reverse PATH-ID encoding, for efficient processing of postfix expressions like //a/b/c
  - Add more indexes, e.g. on data values

```
<BOOK ISBN=“1-55860-438-3”>
  <SECTION>
    <TITLE>Bad Bugs</TITLE>
    Nobody loves bad bugs.
    <FIGURE CAPTION=“Sample bug”/>
  </SECTION>
  <SECTION>
   <TITLE>Tree Frogs</TITLE>
   All right-thinking people
   <BOLD> love </BOLD>
   tree frogs.
  </SECTION>
</BOOK>
```


1
BOOK
1.1
ISBN
1.3
SECTION
1.5
SECTION
1.3.1
TITLE
1.3.3
Nobody …
1.3.5
FIGURE
CAPTION
1.3.5.1
1.5.1
TITLE
1.5.3
All right…
1.5.5
BOLD
1.5.7
tree frogs



ORDPATH	TAG	NODE_ TYPE	VALUE	PATH_ ID
1	1 (BOOK)	1 (Element)	Null	#1
1.1	2 (ISBN)	2 (Attribute)	'1-55860-438-3'	#2#1
1.3	3 (SECTION)	1 (Element)	Null	#3#1
1.3.1	4 (TITLE)	1 (Element)	'Bad Bugs'	#4#3#1
1.3.3	10 (TEXT)	4 (Value)	'Nobody loves Bad bugs.'	#10#3#1
1.3.5	5 (FIGURE)	1 (Element)	Null	#5#3#1
1.3.5.1	6 (CAPTION)	2 (Attribute)	'Sample bug'	#6#3#1
1.5	3 (SECTION)	1 (Element)	Null	#3#1
1.5.1	4 (TITLE)	1 (Element)	'Tree frogs'	#4#3#1
1.5.3	10 (TEXT)	4 (Value)	'All right-thinking people'	#10#3#1
1.5.5	7 (BOLD)	1 (Element)	'love '	#7#3#1
1.5.7	10 (TEXT)	4 (Value)	'tree frogs'	#10#3#1

Infoset Table

```
/BOOK[@ISBN = “1-55860-438-3”]/SECTION
```

```
SELECT SerializeXML (N2.ID, N2.ORDPATH)
FROM infosettab N1  JOIN infosettab N2 ON (N1.ID = N2.ID)
WHERE N1.PATH_ID = PATH_ID(/BOOK/@ISBN)
    AND N1.VALUE = '1-55860-438-3'
    AND N2.PATH_ID = PATH_ID(BOOK/SECTION)
    AND Parent (N1.ORDPATH) = Parent (N2.ORDPATH)
```