Query Languages for XML

- ✓ XPath
- ✓ XSLT
- ✓ XQuery

Common Querying Tasks

- ✓ Filter, select XML values
  - – Navigation, selection, extraction
- ✓ Merge, integrate values from multiple XML sources
  - – Joins, aggregation
- ✓ Transform XML values from one schema to another
  - – XML construction

Query Languages

- XPath
  - Common language for navigation, selection, extraction
  - Used in XSLT, XQuery, XML Schema, . . .
- XSLT: XML ⇒ XML, HTML, Text
  - Loosely-typed scripting language
  - Format XML in HTML for display in browser
  - Highly tolerant of variability/errors in data
- XQuery 1.0: XML ⇒ XML
  - Strongly-typed query language
  - Large-scale database access
  - Safety/correctness of operations on data

XML data: Running example

XML input: www.a.b/bib.xml

```
<book   year="1996">
    <title>  HTML </title>
    <author>  <last> Lee </last>  <first> T. </first></author>
    <author>  <last> Smith</last> <first>C.</first></author>
    <publisher>  Addison-Wesley </publisher>
    <price>  59.99 </price>
</book>
<book   year="2003">
    <title>  WMD </title>
    <author>  <last> Bush</last>  <first> G.</first></author>
    <publisher> white house </publisher>
</book>
```

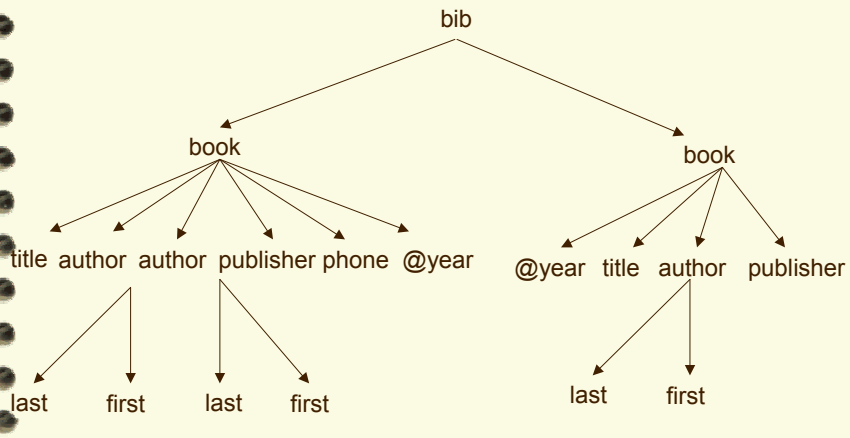
DTD

```
<!ELEMENT    bib      (book*) >
<!ELEMENT    book     (title, (author+  | editor+),
                       publisher?,  price?)  >
<!ATTLIST    book     year    CDATA      #required >
<!ELEMENT    author   (last, first)>
<!ELEMENT    editor   (last, first, affiliation)>

<!ELEMENT    publisher  (#PCDATA) >
….
```


Data model

Node-labeled, ordered tree



XPath

W3C standard: www.w3.org/TR/xpath

- ✓ Navigating an XML tree and finding parts of the tree (node selection and value extraction)

  Given an XML tree T and a context node n, an XPath query Q returns
  - the set of nodes reachable via Q from the node n in T – if Q is a unary query
  - truth value indicating whether Q is true at n in T – if Q is a Boolean query.
- ✓ Implementations: XALAN, SAXON, Berkeley DB XML – freeware, which you can play with
- ✓ A major element of XSLT, XQuery and XML Schema
- ✓ XPath 2.0 (Turing-Complete)

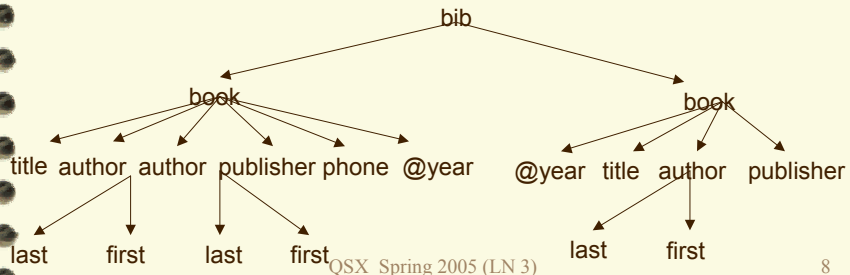
XPath constructs

XPath query Q:

- Tree traversal: downward, upward, sideways
- Relational/Boolean expressions: qualifiers (predicates)
- Functions: aggregation (e.g., count), string functions

//author[last="Bush"]

//book[author/last="Bush"]/title | //book[author/last="Blair"]/title



Downward traversal

Syntax:

Q ::= . | l | @l | Q/Q | Q | Q | //Q | /Q | Q[q]

q ::= Q | Q op c | q and q | q or q | not(q)

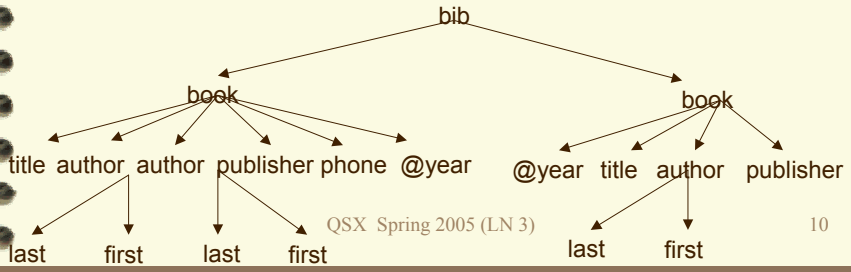
- .: self, the current node
- l: either a tag (label) or *: wildcard that matches any label
- @l: attribute
- /, |: concatenation (child), union
- //: descendants or self, “recursion”
- [q]: qualifier (filter, predicate)
  - op: =, !=, <=, <, >, >=, >
  - c: constant
  - and, or, not(): conjunction, disjunction, negation

Existential semantics: /bib/book[author/last=“Bush”]

Examples:

- parent/child: /bib/book
- ancestor//descendant: bib//last, //last
- wild card: bib/book/*
- attributes: bib/book/@year
- attributes with wild cards: //book/@*
- union: book/(editor | author)

Are book/(editor | author) and //(editor | author) “equivalent” at context nodes (1) root, (2) book, (3) author?



Filters (qualifiers)

- //book[price]/title -- titles of books with a price
- //book[@year > 1991]/title -- titles of books published after 1991
- //book[title and author and not(price)]/title
  titles of books with authors, title but no price
- //book[author/last = “Bush”]/title
  titles of books with an author whose last name is Bush
- //book[editor | author]/title
  titles of books with with either an author or an editor

What is /[//@id]? /[//[not(@id)]]? /[not(//[not(@id))]] ?

Upward traversal

Syntax:

Q ::= . . . | ../Q | ancestor ::Q | ancestor-or-self::Q

- ../: parent
- ancestor, ancestor-or-self: recursion

Example:

- //author[../title = “WMD”]/last
  find the last names of authors of books with the title “WMD”
- ancestor :: book[//last=“Bush”]
  find book ancestors with “Bush” as its last descendant

Are the following equivalent to each other (context node: a book)?

../book/author, ./author

Sideways

Syntax:

Q ::= . . . | following-sibling ::Q | preceding-sibling::Q

- following-sibling: the next sibling
- preceding-sibling: the previous sibling
- position function: e.g., //author[position( ) < 2]

Example:

- following-sibling :: book [//last="Bush"]
  find the next book written by Bush
- preceding-sibling :: book[//last="Bush"]
  find the last book written by Bush

Query Languages for XML

- XPath
- XSLT
- XQuery

XSL (eXtensible Stylesheet Language)

W3C recommendation www.w3.org/Style/XSL

- Two separate languages:
  - XSLT: transformation language, Turing complete
  - a formatting language
- Purpose: stylesheet specification language
  - displaying XML documents: XML -> HTML
  - transforming/querying XML data: XML -> XML
- Implementations: SAXON, XALAN, …

See http://www.oasis-open.org/cover/xsl.html for a number of implementations and demos.

XSL programs

XSL program: a collection of template rules

- template rule = pattern + template
- computation:
  - starts from the root
  - apply a pattern to each node. If it matches, execute the corresponding template (to construct XML/HTML), and apply templates recursively on its children.
- patterns:
  - match pattern: determine content – whether or not to apply the rule?
  - select pattern: identify nodes to be processed, set of nodes

An example XSLT program

Q1: Find titles and authors of all books published by Addison-Wesley after 1991.

```
<xsl:template      match="/bib/book[@year > 1991 and
                                publisher='Addison-Wesley']" >
    <result>
        <title> <xsl:value-of   select="title" /> </title>
        <xsl:for-each select="author" />
            <author><xsl:value-of /> </author>
        </xsl:for-each>
    </result>
</xsl:template>
```


Basic XSLT constructs

- a collection of templates: <xsl:template>
- match pattern: match="bib/book[@year > 1991 and publisher='Addison-Wesley']"
- select pattern: select="title", xsl:for-each select="author"
- value-of: string
- constructing XML data:

```
<result>
    <title> <xsl:value-of   select="title" /> </title>
    ...
</result>
```

Patterns

- match pattern: (downward) XPath
  - parent/child: bib/book
  - ancestor//descendant (_*): bib//last, //last, …
- select patterns: XPath

Example:

```
<xsl:template match="/bib/book/title >
    <result>
    <title> <xsl:value-of /> </title>
    <author> <xsl:value-of select="../author" ></author>
    </result>
</xsl:template>
```

note: first author only (without xsl:for-each)

Apply templates

Recursive processing:

```
<xsl:template match=XPath >
    . . .
    <xsl:apply-templates select=XPath/>
    . . .
</xsl:template>
```

- Compare each selected child (descendant) of the matched source element against the templates in your program
- If a match is found, output the template for the matched node
- One can use xsl:apply-templates instead of xsl:for-each
- If the select attribute is missing, all the children are selected
- When the match attribute is missing, the template matches every node:

```
<xsl:template> <xsl:apply-templates /> </xsl:template>
```

Rewriting Q1 with apply-templates

Selection and construction:

Q1: Find the titles and authors of all books published by Addison-Wesley after 1991.

```
<xsl:template      match="/bib/book[@year > 1991 and
                                publisher='Addison-Wesley']" >
    <result>
        <title> <xsl:value-of   select="title" /> </title>
        <xsl:apply-templates />
    </result>
</xsl:template>

<xsl:template   match="author" />
    <author><xsl:value-of    select="."/> </author>
</xsl:template>
```


Flow control in XSL

```
<xsl:template>
        <xsl:apply-templates />
</xsl:template>
<xsl:template      match="a" >
        <A> < xsl:apply-templates />  </A>
</xsl:template>
<xsl:template      match="b" >
        <B> < xsl:apply-templates />  <B>
</xsl:template>
<xsl:template      match="c" >
        <C> < xsl:value-of />  </C>
</xsl:template>
```

transformation

```
<a> <e> <b> <c> 1 </c>
                <c> 2  </c>
            </b>
        </e>
        <c>  4 </c>
</a>
```

⇒

```
<A> <B> <C> 1 </C>
            <C> 2 </C>
        </B>
        <C> 4 </C>
</A>
```


Divergence

XSL program may not terminate.

Add the following to the previous program:

```
<xsl:template      match="e" >
        < xsl:apply-templates   select="/" />
</xsl:template>
```

XSL default rules

Implicitly included in all style sheets

Default rule for element tree: it recursively descends the element tree and applies templates to the children of all elements

```
<xsl:template  match ="* | /" >
        <xsl:apply-templates />
</xsl:template>
```

* | /: for any element node and the root node

However, once an explicit rule for the parent of any element is present, this rule will not be activated for the element.

Optional elements

Q2: Find all book titles, and prices where available

```
<xsl:template      match="/bib/book[title]" >
    <result>
        <title> <xsl:value-of   select="title" /> </title>
        <xsl:if  test=".[price]">
          <price> <xsl:value-of  select="price"/> </price>
        </xsl:if>
    </result>
</xsl:template>
```

- ✓ conditional test: xsl:if
- ✓ .: current node, XPath

indexing

Q3: for each book, find its title and its first two authors, and returns <et-al/> if there are more than two authors

```
<xsl:template        match="/bib/book" >
    <result>
        <title> <xsl:value-of   select="title" /> </title>
        <xsl:apply-templates  select="author" />
    </result>
</xsl:template>
<xsl:template        match="author[position( ) < 2]" >
    <author> <xsl:value-of  /> </author>
</xsl:template>
<xsl:template        match="author[position( ) = 2]" >       <et-al />
</xsl:template>
```


sorting

Q4: find the titles of all books published by Addison-Wesley after 1991, and list them alphabetically.

```
<xsl:template      match="/bib/book[@year > 1991 and
                                publisher='Addison-Wesley']" >
        <title> <xsl:value-of   select="title" /> </title>
        <xsl:apply-templates>
                <xsl:sort   select="title" />
        </xsl:apply-templates>
</xsl:template>
```

- ✓ Key: title
- ✓ xsl:sort: used together with xsl:for-each or xsl:apply-templates

XML to HTML: display

Q5: generate a HTML document consisting of the titles and authors of all books.

```
<xsl:template    match="/">
    <html>
        <head> <title> Books  </title>   </head>
        <body> <ul> <xsl:apply-templates select="bib/book "></ul></body>
    </html>
</xsl:template>

<xsl:template     match="book">
    <li>  <b> <xsl:value-of   select="title" />,  </b>
        <xsl:for-each select="author" /> <em><xsl:value-of /> </em>
        </xsl:for-each> <br>
    </li>
</xsl:template>
```


Query Languages for XML

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XQuery

W3C working draft www.w3.org/TR/xquery

Functional, strongly typed query language: Turing-complete

- ✓ XQuery = XPath + …
  - for-let-where-return (FLWR) ~ SQL's SELECT-FROM-WHERE
    - Sort-by
  - XML construction (Transformation)
  - Operators on types (Compile & run-time type tests)
  - + User-defined functions
    - Modularize large queries
    - Process recursive data
  - + Strong typing
    - Enforced statically or dynamically
- ✓ Implementation: GALAX
  - http://www-db.research.bell-labs.com/galax/

FLWR Expressions

For, Let, Where, OrderBy, return

Q1: Find titles and authors of all books published by Addison-Wesley after 1991.

```
<answer>{
    for  $book  in /bib/book
    where $book/@year > 1991  and  $book/publisher='Addison-Wesley'
    return    <book>
                  <title>  {$book/title } </title>,
                   for  $author  in $book/author   return
                     <author>  {$author } </author>
              </book>
}</answer>
```

- ✓ for loop; $x: variable
- ✓ where: condition test; selection
- ✓ return: evaluate an expression and return its value

join

Find books that cost more at Amazon than at BN

```
<answer>{
    let  $amazon := doc("http://www.amozon.com/books.xml"),
         $bn  :=  doc("http://www.BN.com/books.xml")
    for    $a  in $amozon/books/book,
           $b  in $bn/books/book
    where    $a/isbn  = $b/isbn    and    $a/price > $b/price
    return   <book> {$a/title, $a/price, $b/price }  <book>
}</answer>
```

- ✓ let clause
- ✓ join: of two documents

Conditional expression

Q2: Find all book titles, and prices where available

```
<answer>{
    for  $book  in /bib/book
    return   <book>
                  <title>  {$book/title } </title>,
                   { if   $book[price]
                     then  <price> {$book/price } </price>
                     else   ( ) }
             </book>
}</answer>
```

Indexing

Q3: for each book, find its title and its first two authors, and returns <et-al/> if there are more than two authors

```
<answer>{
    for  $book  in /bib/book
    return   <book>
                  <title>  {$book/title } </title>,
                  { for  $author  in $book/author[position( ) <= 2]
                       return <author>  {$author } </author>  }
                  { if  (count($book/author) > 2
                    then <et-al/>
                    else  ( )
             </book>
}</answer>
```


Order by

Q4: find the titles of all books published by Addison-Wesley after 1991, and list them alphabetically.

```
<answer>{
    for  $book  in /bib/book
    where $book/@year > 1991  and  $book/publisher='Addison-Wesley'
    order  by  $book/title
    return
            <book>
                 <title>  {$book/title } </title>,
                  for  $author  in $book/author   return
                    <author>  {$author } </author>
             </book>
}</answer>
```

Grouping

Q5: For each author, find titles of books he/she has written

```
<answer>{
    for $author in distinct(/bib/book/author)
    return  <author  name="{$author}" >{
                for $book in /bib/book
                where  $book/author = $author
                return <title> {$book/title } </title>
            </author>
}</answer>
```

- ✓ Constructing attributes: <author name="{$author}" >
- ✓ Grouping: for $book in /bib/book …

Recursion

Consider a part DTD

```
<!ELEMENT  part  (part*)>
<!ATTLIST    part  name  CDATA  #required>
<!ATTLIST    part  cost   CDATA  #required>
```

part – subpart hierarchy

Given a part element, we want to find the total cost of the part – recursive computation that descends the part hierarchy

function

```
define   function   total  (element   part   $part)
returns   element  part {
          let   $subparts   :=
                    for   $s   in   $part/part    return   total($s)
          return {
              <part   name="$part/@name"
                    cost="$part/@cost + sum($subparts/@cost)">
               } </part>
}
```

- ✓ recursive function: it recursively descends the hierarchy of $part
- ✓ $subparts: a list
- ✓ $part: parameter

Summary and Review

Query languages for XML

- ✓ XPath: navigating an XML tree
- ✓ XSLT: XML transformations – can be used as a query language
- ✓ XQuery: XML query language

Very powerful (as opposed to relational algebra); however, query processing/optimization is hard – open issue!

Homework:

- ✓ Write queries on the school document you created, using XPath, XSLT and XQuery; display the query answers in HTML
- ✓ Find some queries in XPath, XSLT and XQuery that are not expressible in SQL, even when relational data is considered (i.e., relational data represented in a canonical form in XML)