XML, DTD, and XPath

CPS 116

Introduction to Database Systems

Announcements (October 18)

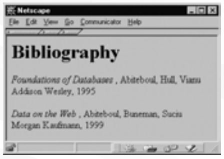
- Homework #3 will be assigned Thursday

… No news is good news…

From HTML to XML (eXtensible Markup Language)

- HTML describes the presentation of the content

```
<h1>Bibliography</h1>
<p><i>Foundations of Databases</i>
Abiteboul, Hull, and Vianu
<br>Addison Wesley, 1995
<p>…
```



Bibliography

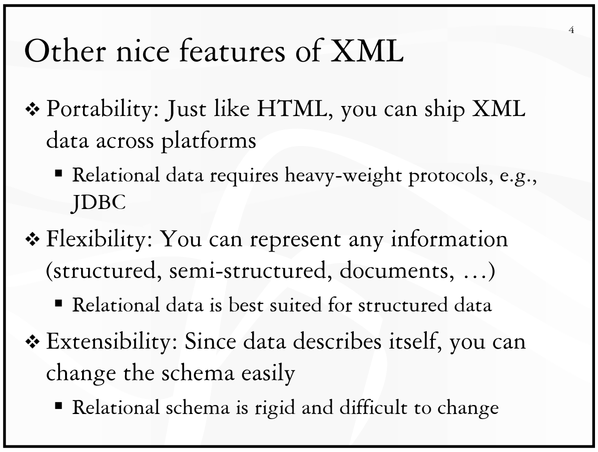
Foundations of Databases , Abiteboul, Hull, Vianu
Addison Wesley, 1995

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

- XML describes only the content

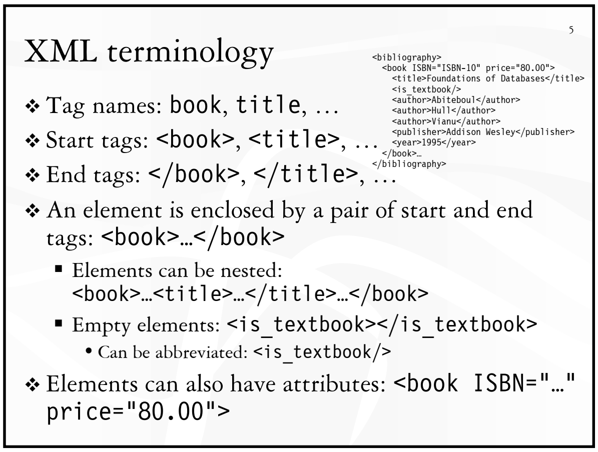
```
<bibliography>
  <book>
    <title>Foundations of Databases</title>
    <author>Abiteboul</author>
    <author>Hull</author>
    <author>Vianu</author>
    <publisher>Addison Wesley</publisher>
    <year>1995</year>
  </book>
  <book>…</book>
</bibliography>
```

☞ Separation of content from presentation simplifies content extraction and allows the same content to be presented easily in different looks



Other nice features of XML

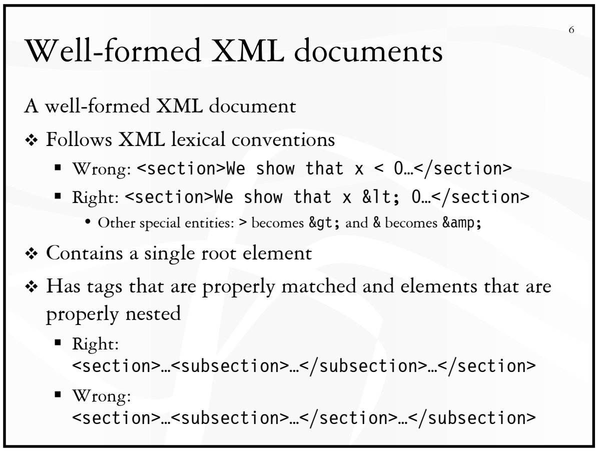
- ❖ Portability: Just like HTML, you can ship XML data across platforms
  - Relational data requires heavy-weight protocols, e.g., JDBC
- ❖ Flexibility: You can represent any information (structured, semi-structured, documents, …)
  - Relational data is best suited for structured data
- ❖ Extensibility: Since data describes itself, you can change the schema easily
  - Relational schema is rigid and difficult to change



XML terminology

```
<bibliography>
  <book ISBN="ISBN-10" price="80.00">
    <title>Foundations of Databases</title>
    <is_textbook/>
    <author>Abiteboul</author>
    <author>Hull</author>
    <author>Vianu</author>
    <publisher>Addison Wesley</publisher>
    <year>1995</year>
  </book>…
</bibliography>
```

- ❖ Tag names: `book`, `title`, …
- ❖ Start tags: `<book>`, `<title>`, …
- ❖ End tags: `</book>`, `</title>`, …
- ❖ An element is enclosed by a pair of start and end tags: `<book>…</book>`
  - Elements can be nested: `<book>…<title>…</title>…</book>`
  - Empty elements: `<is_textbook></is_textbook>`
    - Can be abbreviated: `<is_textbook/>`
- ❖ Elements can also have attributes: `<book ISBN="…" price="80.00">`



Well-formed XML documents

A well-formed XML document

- ❖ Follows XML lexical conventions
  - Wrong: `<section>We show that x < 0…</section>`
  - Right: `<section>We show that x &lt; 0…</section>`
    - Other special entities: > becomes `&gt;` and & becomes `&amp;`
- ❖ Contains a single root element
- ❖ Has tags that are properly matched and elements that are properly nested
  - Right: `<section>…<subsection>…</subsection>…</section>`
  - Wrong: `<section>…<subsection>…</section>…</subsection>`

More XML features

- ❖ Comments: `<!-- Comments here -->`
- ❖ CDATA: `<![CDATA[Tags: <book>,…]]>`
- ❖ ID's and references

```
<person id="o12"><name>Homer</name>…</person>
<person id="o34"><name>Marge</name>…</person>
<person id="o56" father="o12" mother="o34"><name>Bart</name>…</person>…
```

- ❖ Namespaces allow external schemas and qualified names

```
<book xmlns:myCitationStyle="http://…/mySchema">
  <myCitationStyle:title>…</myCitationStyle:title>
  <myCitationStyle:author>…</myCitationStyle:author>…
</book>
```

- ❖ Processing instructions for apps: `<?` …*java applet*… `?>`
- ❖ And more…

Valid XML documents

- ❖ A valid XML document conforms to a Document Type Definition (DTD)
  - ▪ A DTD is optional
- ❖ A DTD specifies
  - ▪ A grammar for the document
  - ▪ Constraints on structures and values of elements, attributes, etc.
- ❖ Example

```
<!DOCTYPE bibliography [
      <!ELEMENT bibliography (book+)>
      <!ELEMENT book (title, author*, publisher?, year?, section*)>
      <!ATTLIST book ISBN CDATA #REQUIRED>
      <!ATTLIST book price CDATA #IMPLIED>
      <!ELEMENT title (#PCDATA)>
      <!ELEMENT author (#PCDATA)>
      <!ELEMENT publisher (#PCDATA)>
      <!ELEMENT year (#PCDATA)>
      <!ELEMENT section (title, (#PCDATA)?, section*)>
]>
```

DTD explained

`<!DOCTYPE bibliography [`

↳ `bibliography` is the root element of the document

`<!ELEMENT bibliography (book+)>`

→ One or more

↳ `bibliography` consists of a sequence of one or more `book` elements

`<!ELEMENT book (title, author*, publisher?, year?, section*)>`

→ Zero or one

→ Zero or more

↳ `book` consists of a `title`, zero or more `author`s, an optional `publisher`, and zero or more `section`s, in sequence

`<!ATTLIST book ISBN ID #REQUIRED>`

↳ `book` has a required `ISBN` attribute which is a unique identifier

`<!ATTLIST book price CDATA #IMPLIED>`

↳ `book` has an optional (`#IMPLIED`) `price` attribute which contains character data

```
<bibliography>
  <book ISBN="ISBN-10" price="80.00">
    <title>Foundations of Databases</title>
    <author>Abiteboul</author>
    <author>Hull</author>
    <author>Vianu</author>
    <publisher>Addison Wesley</publisher>
    <year>1995</year>
  </book>…
</bibliography>
```

Other attribute types include `IDREF` (reference to an `ID`), `IDREFS` (space-separated list of references), enumerated list, etc.

DTD explained (cont'd)

```
<!ELEMENT title (#PCDATA)>
<!ELEMENT author (#PCDATA)>
<!ELEMENT publisher (#PCDATA)>
<!ELEMENT year (#PCDATA)>
```

PCDATA is text that will be parsed (<…> will be treated as a markup tag and &lt; etc. will be treated as entities); CDATA is unparsed character data

↳ `title`, `author`, `publisher`, and `year` all contain parsed character data (#PCDATA)

```
<!ELEMENT section (title, (#PCDATA)?, section*)>
```

↳ Each `section` starts with a `title`, followed by some optional text and then zero or more subsections

```
<section><title>Introduction</title>
  In this section we introduce XML and DTD…
  <section><title>XML</title>
    XML stands for…
  </section>
  <section><title>DTD</title>
    <section><title>Definition</title>
      DTD stands for…
    </section>
    <section><title>Usage</title>
      You can use DTD to…
    </section>
  </section>
</section>
```

```
]>
```

"Deterministic" content declaration

- Catch: the following declaration does not work:

  -
    ```
    <!ELEMENT pub-venue
      ( (name, address, month, year) |
        (name, volume, number, year) )>
    ```
  - Because when looking at `name`, the XML processor would not know which way to go without looking further ahead
- Requirement: content declaration must be "deterministic" (i.e., no look-ahead required)
- Can we rewrite the above declaration into an equivalent, but deterministic one?

Using DTD

- DTD can be included in the XML source file

  -
    ```
    <?xml version="1.0"?>
    <!DOCTYPE bibliography [
      … …
    ]>
    <bibliography>
    … …
    </bibliography>
    ```
- DTD can be external

  -
    ```
    <?xml version="1.0"?>
    <!DOCTYPE bibliography SYSTEM "../dtds/bib.dtd">
    <bibliography>
    … …
    </bibliography>
    ```

  -
    ```
    <?xml version="1.0"?>
    <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
                          "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
    <html>
    … …
    </html>
    ```

Why use DTD's?

- ❖ Benefits of not using DTD
  - ▪ Unstructured data is easy to represent
  - ▪ Overhead of DTD validation is avoided
- ❖ Benefits of using DTD
  - ▪ DTD can serve as a schema for the XML data
    - • Guards against errors
    - • Helps with processing
  - ▪ DTD facilitates information exchange
    - • People can agree to use a common DTD to exchange data (e.g., XHTML)

XML versus relational data

Relational data	XML data
❖ Schema is always fixed in advance and difficult to change	❖
❖ Simple, flat table structures	❖
❖ Ordering of rows and columns is unimportant	❖
❖ Data exchange is problematic	❖
❖ "Native" support in all serious commercial DBMS	❖

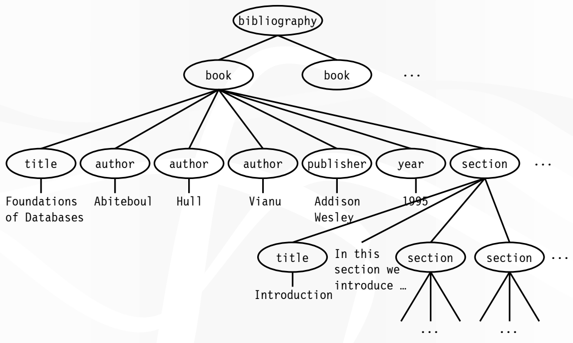
Query languages for XML

- ❖ XPath
  - ▪ Path expressions with conditions
  - ☞Building block of other standards (XQuery, XSLT, XLink, XPointer, etc.)
- ❖ XQuery
  - ▪ XPath + full-fledged SQL-like query language
- ❖ XSLT
  - ▪ XPath + transformation templates

Example DTD and XML

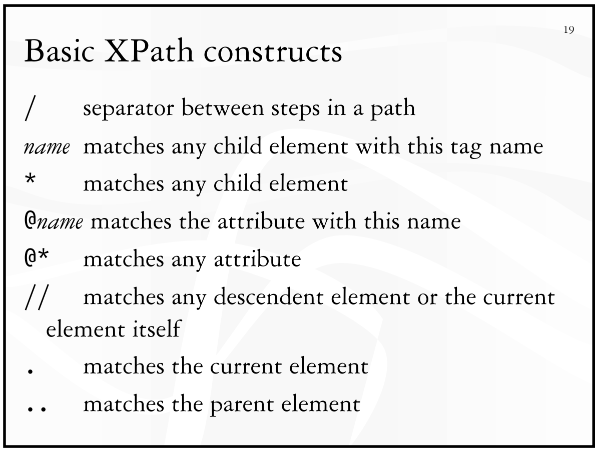
```
<?xml version="1.0">
<!DOCTYPE bibliography [
  <!ELEMENT bibliography (book+)>
  <!ELEMENT book (title, author*, publisher?, year?, section*)>
  <!ATTLIST book ISBN CDATA #REQUIRED>
  <!ATTLIST book price CDATA #IMPLIED>
  <!ELEMENT title (#PCDATA)>
  <!ELEMENT author (#PCDATA)>
  <!ELEMENT publisher (#PCDATA)>
  <!ELEMENT year (#PCDATA)>
  <!ELEMENT section (title, (#PCDATA)?, section*)>
]>
<bibliography>
  <book ISBN="ISBN-10" price="80.00">
    <title>Foundations of Databases</title>
    <author>Abiteboul</author>
    <author>Hull</author>
    <author>Vianu</author>
    <publisher>Addison Wesley</publisher>
    <year>1995</year>
    <section>…</section>…
  </book>
  …
</bibliography>
```

A tree representation



XPath

- XPath specifies path expressions that match XML data by navigating down (and occasionally up and across) the tree
- Example
  - Query: `/bibliography/book/author`
    - Like a UNIX path
  - Result: all author elements reachable from root via the path `/bibliography/book/author`



Basic XPath constructs

`/` separator between steps in a path

name matches any child element with this tag name

`*` matches any child element

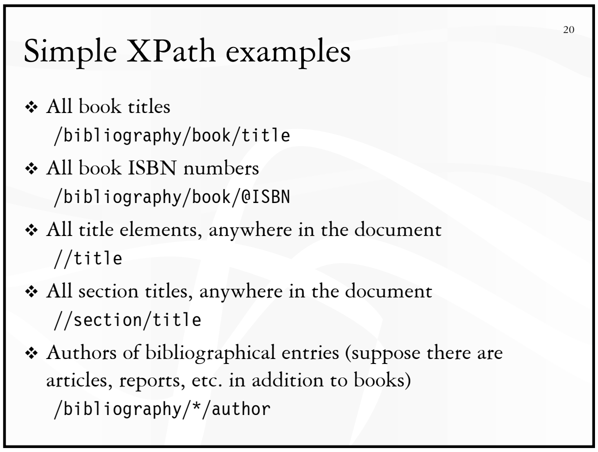
`@`*name* matches the attribute with this name

`@*` matches any attribute

`//` matches any descendent element or the current element itself

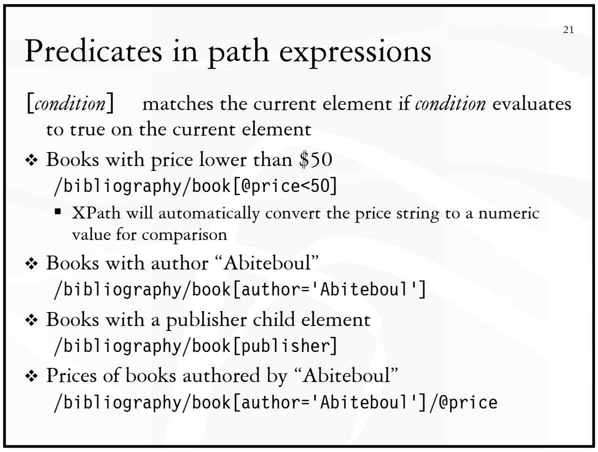
`.` matches the current element

`..` matches the parent element



Simple XPath examples

- All book titles
  `/bibliography/book/title`
- All book ISBN numbers
  `/bibliography/book/@ISBN`
- All title elements, anywhere in the document
  `//title`
- All section titles, anywhere in the document
  `//section/title`
- Authors of bibliographical entries (suppose there are articles, reports, etc. in addition to books)
  `/bibliography/*/author`



Predicates in path expressions

[*condition*] matches the current element if *condition* evaluates to true on the current element

- Books with price lower than $50
  `/bibliography/book[@price<50]`
  - XPath will automatically convert the price string to a numeric value for comparison
- Books with author "Abiteboul"
  `/bibliography/book[author='Abiteboul']`
- Books with a publisher child element
  `/bibliography/book[publisher]`
- Prices of books authored by "Abiteboul"
  `/bibliography/book[author='Abiteboul']/@price`

More complex predicates

Predicates can have `and`'s and `or`'s

- ❖ Books with price between $40 and $50

  `/bibliography/book[40<=@price and @price<=50]`

- ❖ Books authored by "Abiteboul" or those with price lower than $50

  ```
  /bibliography/book[author="Abiteboul" or
    @price<50]
  ```

Predicates involving node-sets

`/bibliography/book[author='Abiteboul']`

- ❖ There may be multiple authors, so `author` in general returns a node-set (in XPath terminology)
- ❖ The predicate evaluates to true as long as it evaluates true for at least one node in the node-set, i.e., at least one author is "Abiteboul"
- ❖ Tricky query

  ```
  /bibliography/book[author='Abiteboul' and
    author!='Abiteboul']
  ```

  - ▪ Will it return any books?

XPath operators and functions

Frequently used in conditions:

x + *y*, *x* − *y*, *x* * *y*, *x* `div` *y*, *x* `mod` *y*

`contains(`*x*`,` *y*`)` true if string *x* contains string *y*

`count(`*node-set*`)` counts the number nodes in *node-set*

`position()` returns the "context position" (roughly, the position of the current node in the node-set containing it)

`last()` returns the "context size" (roughly, the node-set containing the current node)

`name()` returns the tag name of the current element

More XPath examples

- All elements whose tag names contain "section" (e.g., "subsection")

  ```
  //*[contains(name(), 'section')]
  ```

- Title of the first section in each book

  ```
  /bibliography/book/section[position()=1]/title
  ```

  - A shorthand: `/bibliography/book/section[1]/title`

- Title of the last section in each book

  ```
  /bibliography/book/section[position()=last()]/title
  ```

- Books with fewer than 10 sections

  ```
  /bibliography/book[count(section)<10]
  ```

- All elements whose parent's tag name is not "book"

  ```
  //*[name()!='book']/*
  ```

A tricky example

- Suppose that `price` is a child element of `book`, and there may be multiple prices per book
- Books with some price in range [20, 50]
  - How about:

    ```
    /bibliography/book
    [price >= 20 and price <= 50]
    ```

  - Correct answer:

De-referencing IDREF's

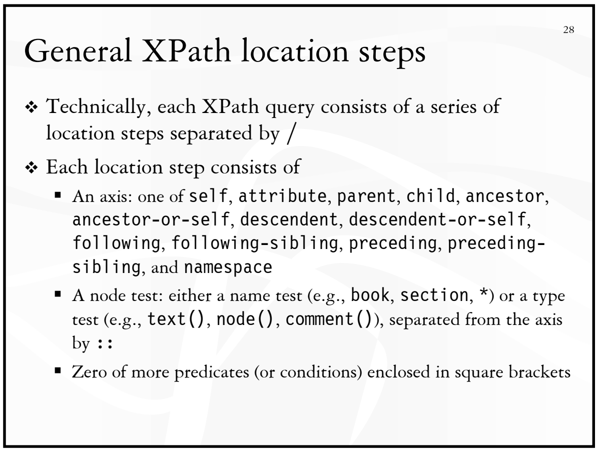
`id`(*identifier*) returns the element with the unique *identifier*

- Suppose that books can make references to other books

  ```
  <section><title>Introduction</title>
    XML is a hot topic these days; see <bookref
  ISBN="ISBN-10"/> for more details…
  </section>
  ```

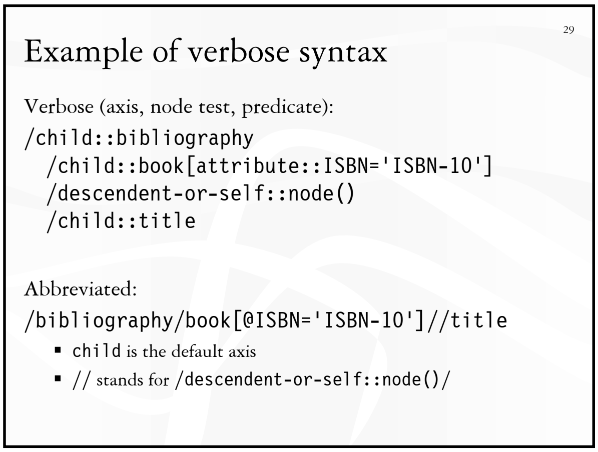
- Find all references to books written by "Abiteboul" in the book with "ISBN-10"

  ```
  /bibliography/book[@ISBN='ISBN-10']
    //bookref[id(@ISBN)/author='Abiteboul']
  ```



General XPath location steps

- ❖ Technically, each XPath query consists of a series of location steps separated by `/`
- ❖ Each location step consists of
  - An axis: one of `self`, `attribute`, `parent`, `child`, `ancestor`, `ancestor-or-self`, `descendent`, `descendent-or-self`, `following`, `following-sibling`, `preceding`, `preceding-sibling`, and `namespace`
  - A node test: either a name test (e.g., `book`, `section`, `*`) or a type test (e.g., `text()`, `node()`, `comment()`), separated from the axis by `::`
  - Zero of more predicates (or conditions) enclosed in square brackets



Example of verbose syntax

Verbose (axis, node test, predicate):

```
/child::bibliography
  /child::book[attribute::ISBN='ISBN-10']
  /descendent-or-self::node()
  /child::title
```

Abbreviated:

```
/bibliography/book[@ISBN='ISBN-10']//title
```

- `child` is the default axis
- `//` stands for `/descendent-or-self::node()/`