Prof. Dr.-Ing. Stefan Deßloch
AG Heterogene Informationssysteme
Geb. 36, Raum 329
Tel. 0631/205 3275
dessloch@informatik.uni-kl.de

Technische Universität Kaiserslautern

Chapter 13 - XML

Middleware for Heterogenous and Distributed Information Systems - WS05/06

XML Origin and Usages

- Defined by the WWW Consortium (W3C)
- Originally intended as a document markup language, not a database language
  - Documents have tags giving extra information about sections of the document
  - For example:
    - <title> XML </title>
    - <slide> XML Origin and Usages </slide>
  - Meta-language: used to define arbitrary XML languages/vocabularies (e.g. XHTML)
- Derived from SGML (Standard Generalized Markup Language)
  - standard for document description
    - enables document interchange in publishing, office, engineering, ...
  - main idea: separate form from structure
- XML is simpler to use than SGML
  - roughly 20% complexity achieves 80% functionality

XML Origin and Usages (cont.)

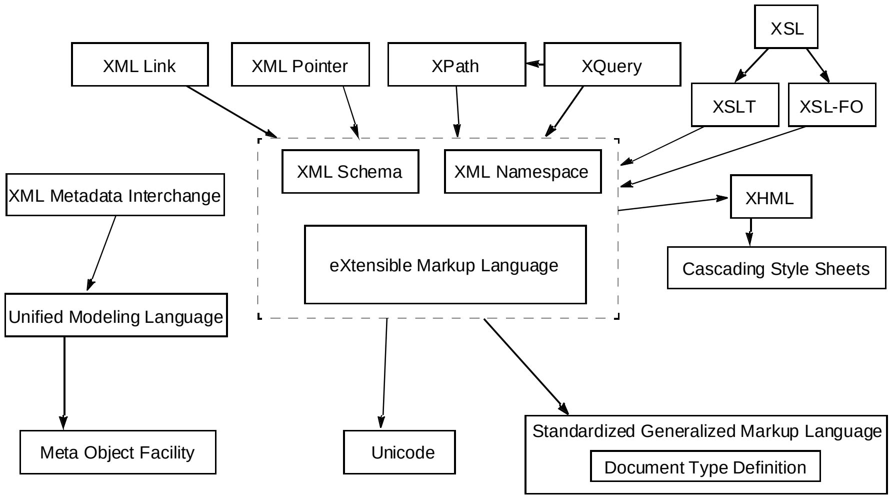
- XML documents are to some extent self-documenting
  - Tags can be used as metadata
  - Example

```
<bank>
    <account>
        <account-number> A-101     </account-number>
        <branch-name>     Downtown </branch-name>
        <balance>             500        </balance>
    </account>
    <depositor>
        <account-number> A-101    </account-number>
        <customer-name> Johnson </customer-name>
    </depositor>
</bank>
```

Forces Driving XML

- Document Processing
  - Goal: use document in various, evolving systems
  - structure – content – layout
  - grammar: markup vocabulary for mixed content
- Data Bases and Data Exchange
  - Goal: data independence
  - structured, typed data – schema-driven – integrity constraints
- Semi-structured Data and Information Integration
  - Goal: integrate autonomous data sources
  - data source schema not known in detail – schemata are dynamic
  - schema might be revealed through analysis only after data processing

XML Language Specifications



XML Documents

- XML documents are text (unicode)
  - markup (always starts with '<' or '&')
    - start/end tags
    - references (e.g., &lt, &amp, ...)
    - declarations, comments, processing instructions, ...
  - data (character data)
    - characters '<' and '&' need to be indicated using references (e.g., &lt) or using the character code
    - alternative syntax: <![CDATA[(a<b)&(c<d)]]>
- XML documents are **well-formed**
  - logical structure
    - (optional) prolog (XML version, ...)
    - (optional) schema
    - root element (possibly nested)
    - comments, ...
  - correct sequence of start/end tags (nesting)
  - uniqueness of attribute names
  - ...

XML Documents: Elements

- **Element**: section of data beginning with <*tagname*> and ending with matching </*tagname*>
- Elements must be properly **nested**
  - Formally: every start tag must have a unique matching end tag, that is in the context of the same parent element.
- Mixture of text with sub-elements is legal in XML
  - Example:

```
<account>
   This account is seldom used any more.
    <account-number> A-102</account-number>
    <branch-name> Perryridge</branch-name>
    <balance>400 </balance>
</account>
```

  - Useful for document markup, but discouraged for data representation

XML Documents: Attributes

- **Attributes:** can be used to describe elements
- Attributes are specified by *name=value* pairs inside the starting tag of an element
- Example

```
<account acct-type = "checking" >
        <account-number> A-102 </account-number>
        <branch-name> Perryridge </branch-name>
        <balance> 400 </balance>
   </account>
```

- Attribute names must be unique within the element

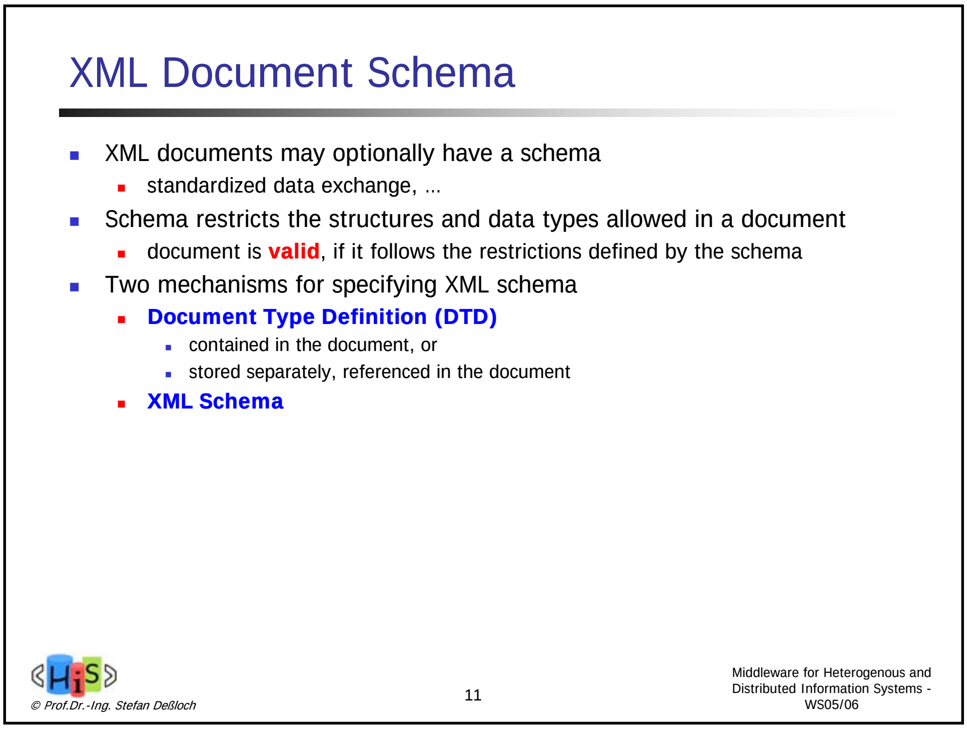
```
<account  acct-type = "checking"  monthly-fee="5">
```

XML Documents: IDs and IDREFs

- An element can have at most one attribute of type ID
- The ID attribute value of each element in an XML document must be distinct
  ➔ ID attribute (value) is an object identifier
- An attribute of type IDREF must contain the ID value of an element in the same document
- An attribute of type IDREFS contains a set of (0 or more) ID values. Each ID value must contain the ID value of an element in the same document
- IDs and IDREFs are untyped, unfortunately
  - Example below: The *owners* attribute of an account may contain a reference to another account, which is meaningless;
    owners attribute should ideally be constrained to refer to customer elements

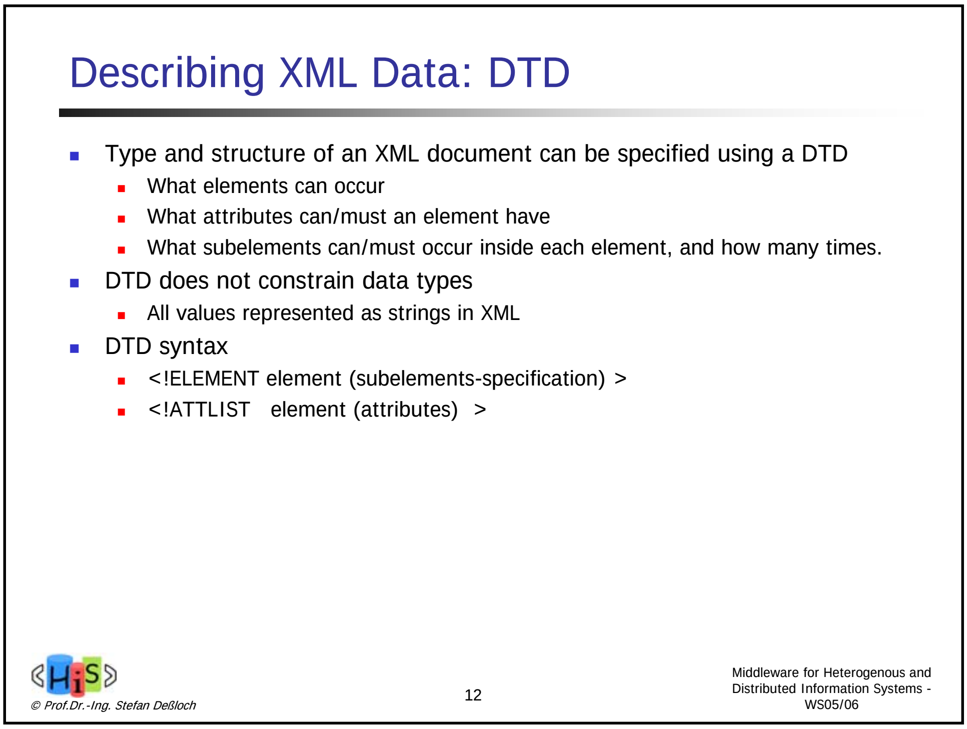
XML data with ID and IDREF attributes

```
<bank-2>
    <account account-number=“A-401” owners=“C100 C102”>
            <branch-name> Downtown </branch-name>
            <balance>500 </balance>
    </account>
            . . .
    <customer customer-id=“C100” accounts=“A-401”>
            <customer-name>Joe</customer-name>
            <customer-street>Monroe</customer-street>
            <customer-city>Madison</customer-city>
    </customer>
    <customer customer-id=“C102” accounts=“A-401 A-402”>
            <customer-name> Mary</customer-name>
            <customer-street> Erin</customer-street>
            <customer-city> Newark </customer-city>
    </customer>
</bank-2>
```



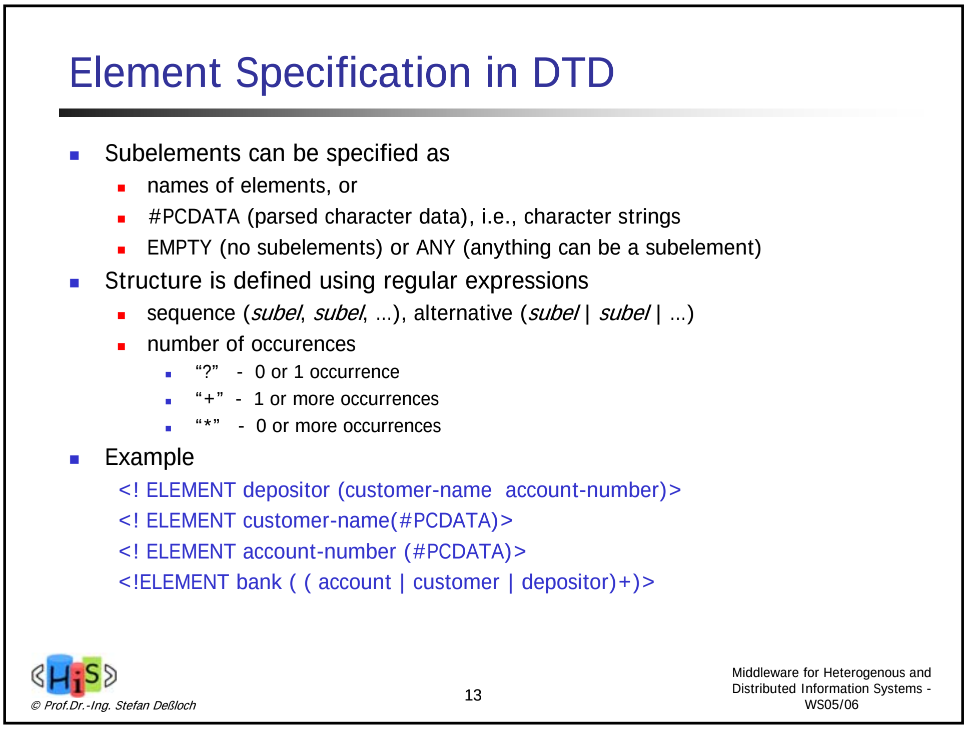
XML Document Schema

- XML documents may optionally have a schema
  - standardized data exchange, …
- Schema restricts the structures and data types allowed in a document
  - document is **valid**, if it follows the restrictions defined by the schema
- Two mechanisms for specifying XML schema
  - **Document Type Definition (DTD)**
    - contained in the document, or
    - stored separately, referenced in the document
  - **XML Schema**



Describing XML Data: DTD

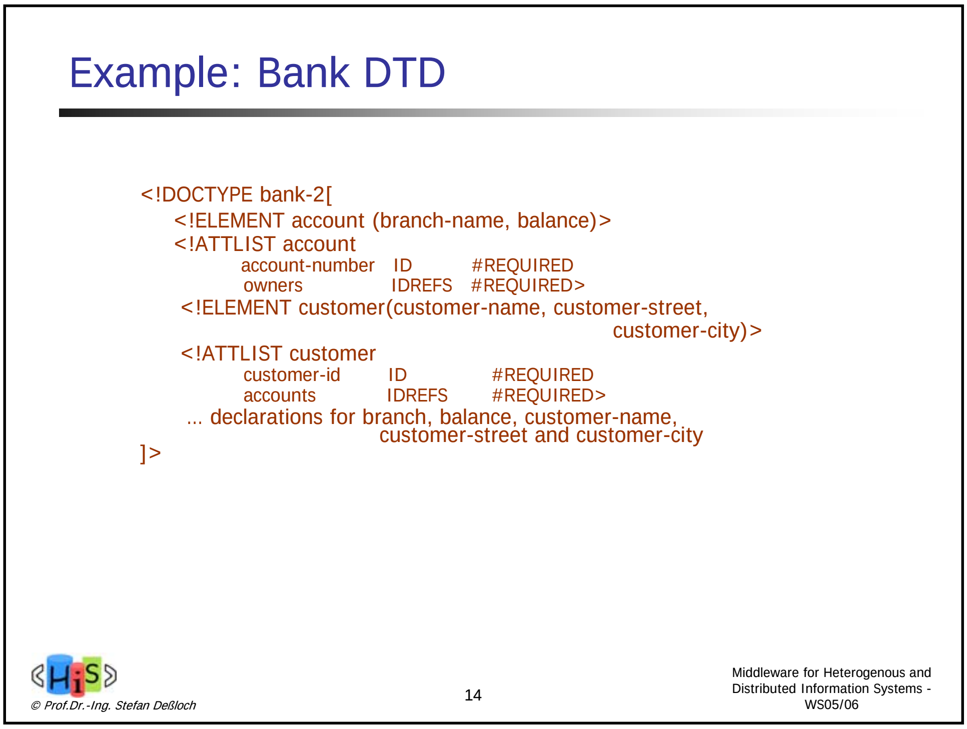
- Type and structure of an XML document can be specified using a DTD
  - What elements can occur
  - What attributes can/must an element have
  - What subelements can/must occur inside each element, and how many times.
- DTD does not constrain data types
  - All values represented as strings in XML
- DTD syntax
  - <!ELEMENT element (subelements-specification) >
  - <!ATTLIST element (attributes) >



Element Specification in DTD

- Subelements can be specified as
  - names of elements, or
  - #PCDATA (parsed character data), i.e., character strings
  - EMPTY (no subelements) or ANY (anything can be a subelement)
- Structure is defined using regular expressions
  - sequence (*subel*, *subel*, ...), alternative (*subel* | *subel* | ...)
  - number of occurences
    - "?" - 0 or 1 occurrence
    - "+" - 1 or more occurrences
    - "*" - 0 or more occurrences
- Example

```
<! ELEMENT depositor (customer-name  account-number)>
<! ELEMENT customer-name(#PCDATA)>
<! ELEMENT account-number (#PCDATA)>
<!ELEMENT bank ( ( account | customer | depositor)+)>
```



Example: Bank DTD

```
<!DOCTYPE bank-2[
    <!ELEMENT account (branch-name, balance)>
    <!ATTLIST account
            account-number   ID       #REQUIRED
            owners           IDREFS   #REQUIRED>
     <!ELEMENT customer(customer-name, customer-street,
                                                  customer-city)>
     <!ATTLIST customer
            customer-id       ID          #REQUIRED
            accounts          IDREFS      #REQUIRED>
      … declarations for branch, balance, customer-name,
                            customer-street and customer-city
]>
```

Describing XML Data: XML Schema

- XML Schema is closer to the general understanding of a (database) schema
- XML Schema supports
  - Typing of values
    - E.g. integer, string, etc
  - Constraints on min/max values
  - Typed references
  - User defined types
  - Specified in XML syntax (unlike DTDs)
  - Integrated with namespaces
  - Many more features
    - List types, uniqueness and foreign key constraints, inheritance ..
- BUT: significantly more complicated than DTDs

XML Schema Structures

- **Datatypes (Part 2)**
  Describes Types of scalar (leaf) values
- **Structures (Part 1)**
  Describes types of complex values (attributes, elements)
  - Regular tree grammars
    repetition, optionality, choice recursion
- **Integrity constraints**
  Functional (keys) & inclusion dependencies (foreign keys)
- **Subtyping (similar to OO models)**
  Describes inheritance relationships between types
- **Supports schema reuse**

XML Schema Structures (cont.)

- Elements : tag name & simple or complex type

```
<xs:element name="sponsor" type="xsd:string"/>
<xs:element name="action" type="Action"/>
```

- Attributes : tag name & simple type

```
<xs:attribute name="date" type="xsd:date"/>
```

- Complex types

```
<xs:complexType name="Action">
        <xs:sequence>
                <xs:elemref name ="action-date"/>
                <xs:elemref name ="action-desc"/>
        </xs:sequence>
</xs:complexType>
```

XML Schema Structures (cont.)

- Sequence

```
<xs:sequence>
     <xs:element name="congress" type=xsd:string"/>
     <xs:element name="session" type=xsd:string"/>
</xs:sequence>
```

- Choice

```
<xs:choice>
     <xs:element name="author" type="PersonName"/>
     <xs:element name="editor" type="PersonName"/>
</xs:choice>
```

- Repetition

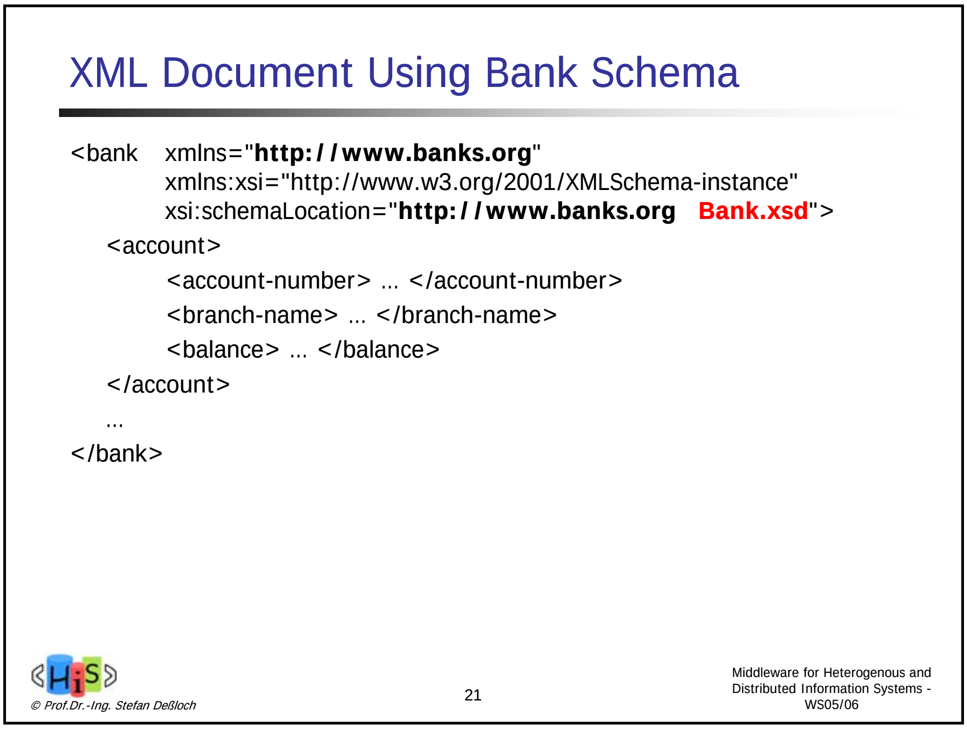
```
<xs:sequence minOccurs="1" maxOccurs="unbounded">
          <xs element name ="section" type="Section"/>
</xs:sequence>
```

Namespaces

- A single XML document may contain elements and attributes defined for and used by multiple software modules
  - Motivated by modularization considerations, for example
- Name collisions have to be avoided
- Example:
  - A **Book** XSD contains a Title element for the title of a book
  - A **Person** XSD contains a Title element for an honorary title of a person
  - A **BookOrder** XSD reference both XSDs
- Namespaces specifies how to construct universally unique names

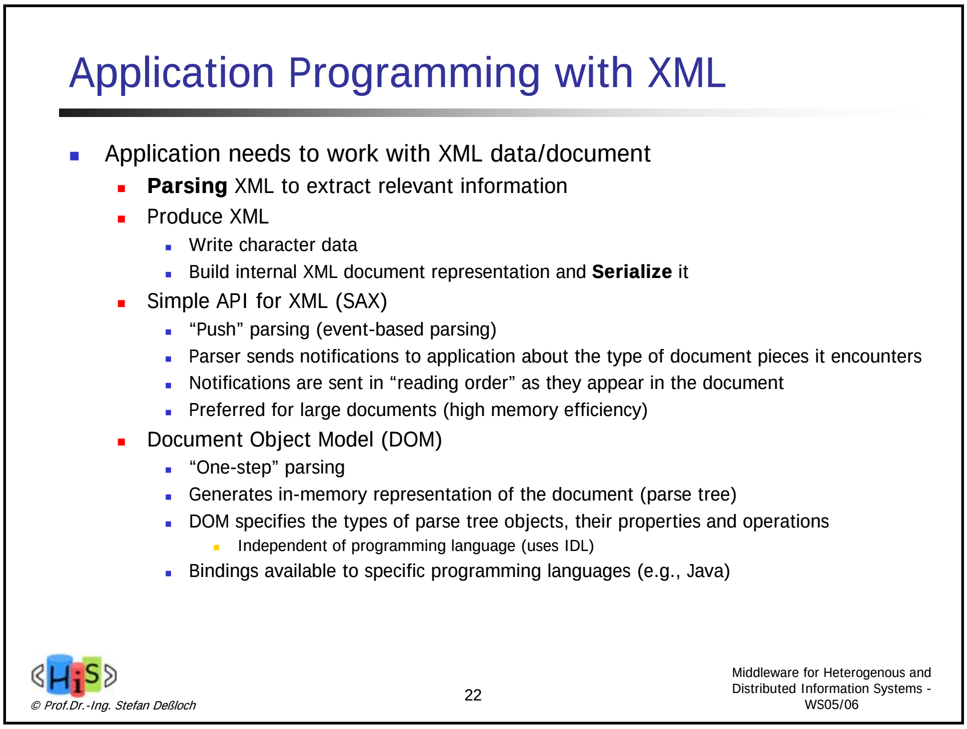
XML Schema Version of Bank DTD

```
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            targetNamespace="http://www.banks.org"
            xmlns ="http://www.banks.org" >
<xsd:element name=“bank” type=“BankType”/>
<xsd:element name=“account”>
    <xsd:complexType>
        <xsd:sequence>
            <xsd:element name=“account-number” type=“xsd:string”/>
            <xsd:element name=“branch-name”     type=“xsd:string”/>
            <xsd:element name=“balance”          type=“xsd:decimal”/>
        </xsd:sequence>
    </xsd:complexType>
</xsd:element>              ….. definitions of customer and depositor ….
<xsd:complexType name=“BankType”>
    <xsd:choice minOccurs="1" maxOccurs="unbounded">
          <xsd:element ref=“account”/>
          <xsd:element ref=“customer”/>
          <xsd:element ref=“depositor”/>
    </xsd:choice>
</xsd:complexType>
</xsd:schema>
```



XML Document Using Bank Schema

```
<bank   xmlns="http://www.banks.org"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:schemaLocation="http://www.banks.org   Bank.xsd">
    <account>
          <account-number> … </account-number>
          <branch-name> … </branch-name>
          <balance> … </balance>
    </account>
    …
</bank>
```



Application Programming with XML

- Application needs to work with XML data/document
  - **Parsing** XML to extract relevant information
  - Produce XML
    - Write character data
    - Build internal XML document representation and **Serialize** it
  - Simple API for XML (SAX)
    - “Push” parsing (event-based parsing)
    - Parser sends notifications to application about the type of document pieces it encounters
    - Notifications are sent in “reading order” as they appear in the document
    - Preferred for large documents (high memory efficiency)
  - Document Object Model (DOM)
    - “One-step” parsing
    - Generates in-memory representation of the document (parse tree)
    - DOM specifies the types of parse tree objects, their properties and operations
      - Independent of programming language (uses IDL)
    - Bindings available to specific programming languages (e.g., Java)

Processing XML Data

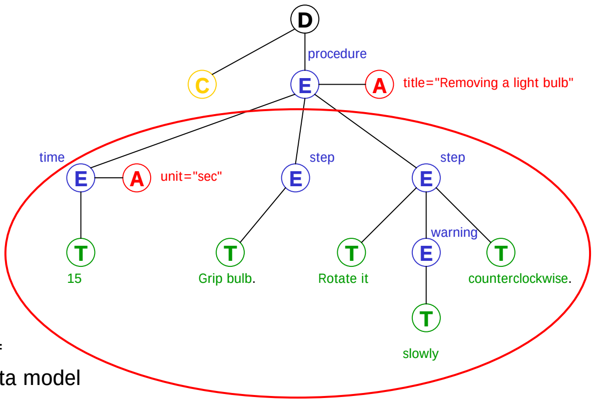
- Querying XML data
- Translation of information from one XML schema to another
- Standard XML querying/translation languages
  - **XPath**
    - Simple language consisting of path expressions
  - **XSLT**
    - Simple language designed for translation from XML to XML and XML to HTML
  - **XQuery**
    - An XML query language with a rich set of features
    - XQuery builds on experience with existing query languages: **XPath**, **Quilt**, XQL, XML-QL, Lorel, YATL, **SQL**, **OQL**, ...

XML Data Model

- There is no uniform XML data model
  - different approaches with different goals
    - XML Information Set, DOM Structure Model, XPath 1.0 data model, XQuery data model
- Common denominator: an XML document is modeled as a **tree**, with nodes of different **node types**
  - Document, Element, Attribute, Text, Namespace, Comment, Processing Instruction
- XQuery data model builds on a tree-based model, but extends it to support
  - **sequences** of items
    - nodes of different types (see above) as well as atomic values
    - can contain heterogeneous values, are ordered, can be empty
  - typed values and type annotations
    - result of schema validation
    - type may be unknown
- Closure property
  - XQuery expressions operate on/produce instances of the XQuery Data Model

Example

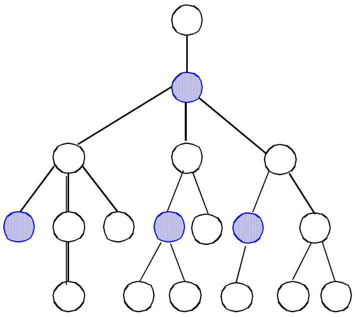
```
<?xml version = "1.0"?>
<!-- Requires one trained person -->
<procedure title = "Removing a light bulb">
  <time unit = "sec">15</time>
  <step>Grip bulb.</step>
  <step>
     Rotate it
     <warning>slowly</warning>
     counterclockwise.
  </step>
</procedure>
```



possible
instance of
XQuery data model

Processing XML Data: XPath

- XPath is used to address (select) parts of documents using path expressions
- XPath data model refers to a document as a tree of nodes
- An Xpath expression maps a node (the context node) into a set of nodes
- A path expression consists of one or more steps separated by "/"
- Result of path expression: set of values that along with their containing elements/attributes match the specified path
  - E.g.: /bank-2/customer/customer-name evaluated on the bank-2 data returns
    - <customer-name> Joe </ customer-name>
    - < customer- name> Mary </ customer-name>
  - E.g.:/bank-2/customer/cust-name/text( ) returns the same names, but without the enclosing tags



XPath (cont.)

- The initial "/" denotes root of the document (above the top-level tag)
- In general, a step has three parts:
  - The ***axis*** (direction of movement: child, descendant, parent, ancestor, following, preceding, attribute, … - 13 axes in all -)
  - A ***node test*** (type and/or name of qualifying nodes)
  - Some ***predicates*** (refine the set of qualifying nodes)
- Path expressions are evaluated left to right
  - Each step operates on the set of instances produced by the previous step
- Selection predicates may follow any step in a path, in [ ]
  - E.g. /bank-2/account[balance > 400]
    - returns account elements with a balance value greater than 400
    - /bank-2/account[balance] returns account elements containing a balance subelement
- Attributes are accessed using "@"
  - E.g. /bank-2/account[balance > 400]/@account-number
    - returns the account numbers of those accounts with balance > 400
  - IDREF attributes are not dereferenced automatically (more on this later)

XPath (cont.)

- The following examples use XPath abbreviated notation:
  - Find the first item of every list that is under the context node
    .//list/item[1]
  - Find the "lang" attribute of the parent of the context node
    ../@lang
  - Find the last paragraph-child of the context node
    para[last()]
  - Find all warning elements that are inside instruction elements
    //instruction//warning
  - Find all elements that have an ID attribute
    //*[@ID]
  - Find names of customers who have an order with today's date
    //customer [order/date = today ( )] / name

- **XPath expressions use a notation similar to paths in a file system:**

/	means "child" or "root"
//	means "descendant"
.	means "self"
..	means "parent"
*	means "any"
@	means "attribute"

XPath (cont.): Summary

- Strengths:
  - Compact and powerful syntax for navigating a tree, but not as powerfull as a regular-expression language
  - Recognized and accepted in XML community
  - Used in XML-related applications such as XPointer
- Limitations:
  - Operates on one document (no joins)
  - No grouping or aggregation
  - No facility for generating new output structures

Transforming XML Data: XSLT

- A **stylesheet** stores formatting options for a document, usually separately from document
  - E.g. HTML style sheet may specify font colors and sizes for headings, etc.
- The **XML Stylesheet Language (XSL)** was originally designed for generating HTML from XML
- XSLT is a general-purpose transformation language
  - Can translate XML to XML, and XML to HTML
- XSLT transformations are expressed using rules called **templates**
  - Templates combine selection using XPath with construction of results

Understanding A Template

- Most templates have the following form:

```
<xsl:template match="emphasis">
  <i><xsl:apply-templates/></i>
</xsl:template>
```

- The whole <xsl:template> element is a **template**
- The **match pattern** determines where this template applies
  - Xpath pattern
- **Literal result element(s)** come from non-XSL namespace(s)
- XSLT elements come from the XSL namespace

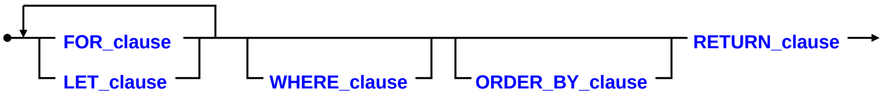
XQuery

- XQuery is a general purpose query language for XML data
- Currently being standardized by the World Wide Web Consortium (W3C)
- XQuery is derived from
  - the **Quilt** ("Quilt" refers both to the origin of the language and to its use in "knitting " together heterogeneous data sources) query language, which itself borrows from
  - **XPath**: a concise language for navigating in trees
  - **XML-QL**: a powerful language for generating new structures
  - **SQL**: a database language based on a series of keyword-clauses: SELECT - FROM – WHERE
  - **OQL**: a functional language in which many kinds of expressions can be nested with full generality

XQuery – Main Constituents

- Path expressions
  - Inherited from XPath 1.0
  - An XPath expression maps a node (the context node) into a set of nodes
- Element constructors
  - To construct an element with a known name and content, use XML-like syntax:
    ```
    <book isbn = "12345">
       <title>Huckleberry Finn</title>
    </book>
    ```
  - If the content of an element or attribute must be computed, use a nested expression enclosed in { }
    ```
    <book isbn = "{$x}">
       {$b/title }
    </book>
    ```
- FLWOR - Expressions

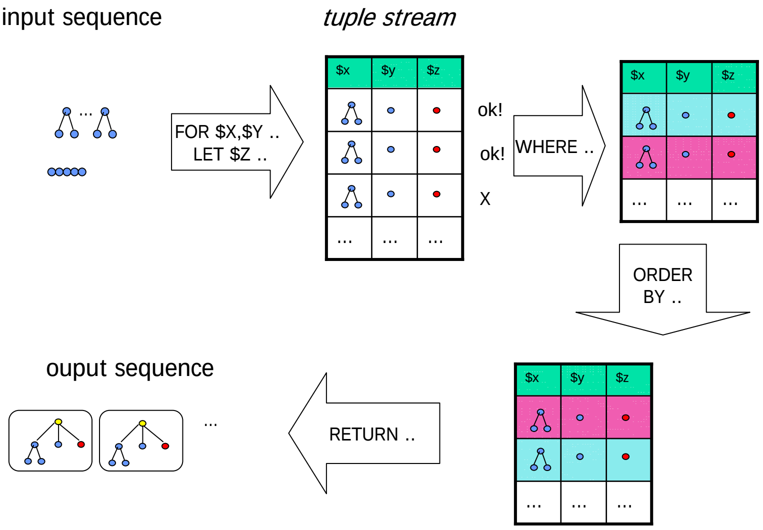
XQuery: The General Syntax Expression FLWOR



- FOR clause, LET clause generate list of tuples of bound variables (order preserving) by
  - iterating over a set of nodes (possibly specified by an XPath expression), or
  - binding a variable to the result of an expression
- WHERE clause applies a predicate to filter the tuples produced by FOR/LET
- ORDER BY clause imposes order on the surviving tuples
- RETURN clause is executed for each surviving tuple, generates ordered list of outputs
- Associations to SQL query expressions

  for ⇔ SQL from
  where ⇔ SQL where
  order by ⇔ SQL order by
  return ⇔ SQL select
  let allows temporary variables, and has no equivalent in SQL

Evaluating FLWOR Expressions



input sequence

tuple stream

FOR $X,$Y ..
LET $Z ..

$x	$y	$z
…	…	…

ok!
ok!
X

WHERE ..

ORDER BY ..

ouput sequence

RETURN ..

FLWOR - Examples

- Simple FLWR expression in XQuery
  - Find all accounts with balance > 400, with each result enclosed in an <account-number> .. </account-number> tag

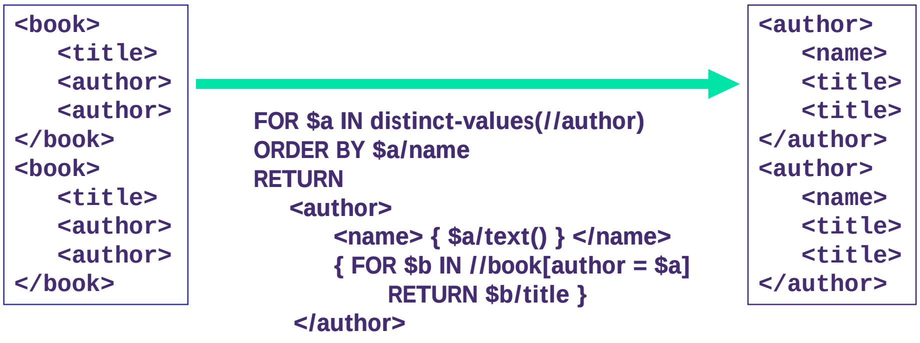
```
for     $x in /bank-2/account
let     $acctno := $x/@account-number
where $x/balance > 400
return <account-number> {$acctno} </account-number>
```

- Let and Where clause not really needed in this query, and selection can be done in XPath.
  - Query can be written as:

```
for        $x in /bank-2/account[balance>400]
return <account-number> {$x/@account-number}
                                       </account-number>
```

Nesting of Expressions

- Here: nesting inside the return clause
  - Example: inversion of a hierarchy



```
<book>
   <title>
   <author>
   <author>
</book>
<book>
   <title>
   <author>
   <author>
</book>
```

```
FOR $a IN distinct-values(//author)
ORDER BY $a/name
RETURN
   <author>
      <name> { $a/text() } </name>
      { FOR $b IN //book[author = $a]
           RETURN $b/title }
   </author>
```

```
<author>
   <name>
   <title>
   <title>
</author>
<author>
   <name>
   <title>
   <title>
</author>
```

XQuery: Joins

- Joins are specified in a manner very similar to SQL

```
for   $a  in  /bank/account,
      $c  in  /bank/customer,
      $d  in  /bank/depositor
where $a/account-number = $d/account-number
   and $c/customer-name = $d/customer-name
return <cust-acct>{ $c $a }</cust-acct>
```

- The same query can be expressed with the selections specified as XPath selections:

```
for   $a in /bank/account
      $c in /bank/customer
      $d in /bank/depositor[
                account-number =$a/account-number and
                customer-name = $c/customer-name]
return <cust-acct>{ $c $a }</cust-acct>
```

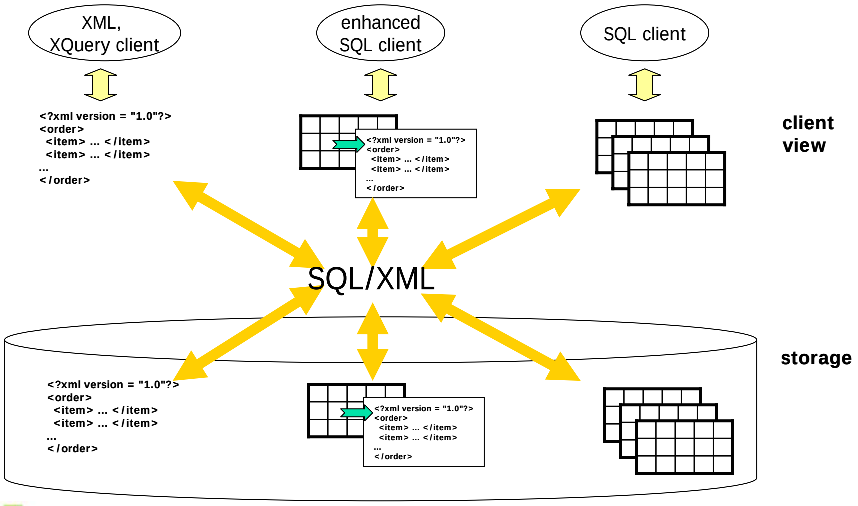
XQuery - Status

- Current status: w3c candidate recommendation
  - fairly close to becoming a w3c recommendation
- Ongoing and Future Work
  - Full-text support
  - Insert, Update, Delete
  - View definitions, DDL
  - Host language bindings, APIs
    - JSR 225: XQuery API for JavaTM (XQJ)
    - problem to overcome: traditional XML processing API is based on well-formed documents

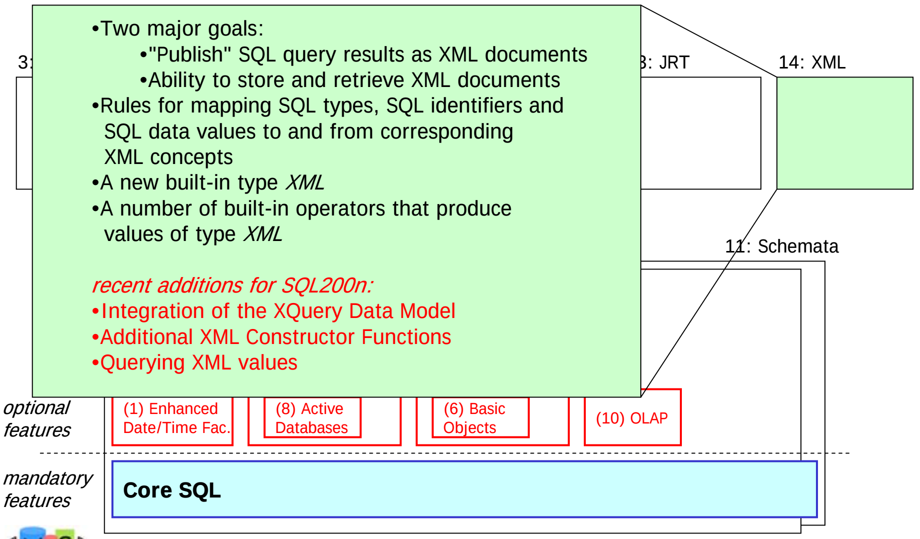
SQL and XML

- Use existing (object-)relational technology?
  - Large Objects: granularity understood by DBMS may be too coarse!
    - search/retrieval of subsets, update of documents
  - Decompose into tables: often complex, inefficient
    - mapping complexity, especially for highly "denormalized" documents
  - Useful, but not sufficient
    - should be standardized as part of SQL
    - but needs further enhancement to support "native" XML support in SQL
- Enable "hybrid" XML/relational data management
  - supports both relational and XML data
    - storage, access
    - query language
    - programming interfaces
  - ability to view/access relational as XML, and XML as relational
  - all major relational DBMS vendors are moving into this direction

SQL/XML Big Picture



SQL:2003 Parts and Packages



- Two major goals:
  - "Publish" SQL query results as XML documents
  - Ability to store and retrieve XML documents
- Rules for mapping SQL types, SQL identifiers and SQL data values to and from corresponding XML concepts
- A new built-in type *XML*
- A number of built-in operators that produce values of type *XML*

recent additions for SQL200n:

- Integration of the XQuery Data Model
- Additional XML Constructor Functions
- Querying XML values

XML Data Type

- New SQL type “XML”
  - for storing XML data "natively" in the database
  - for capturing the data type of results and input values of SQL/XML functions that work with XML data
  - can have optimized internal representation (different from character string)
- "Shape" of an XML value
  - not just a well-formed XML document
  - but also the content of an XML element
    - element, sequence of elements, text, mixed content, ...
  - based on Infoset model in SQL:2003, full support of XQuery data model in SQL:200n

XML Publishing Functions - Example

```
SELECT   XMLELEMENT ( NAME "Department",
                      XMLATTRIBUTES ( e.dept AS "name" ),
                      XMLAGG (XMLELEMENT (NAME "emp", e.lname))
                    ) AS "dept_list",
         COUNT(*) AS "dept_count"
FROM     employees e
GROUP BY dept ;

==>
```

dept_list	dept_count

`<Department name="Accounting">`
`   <emp>Yates</emp>`
`   <emp>Smith</emp>`
`</Department>`
	2

`<Department name="Shipping">`
`   <emp>Oppenheimer</emp>`
`   <emp>Martin</emp>`
`</Department>`
	2

Manipulating XML Data

- Constructor functions
  - focus on publishing SQL data as XML
  - no further manipulation of XML
- More requirements
  - how do we select or extract portions of XML data (e.g., from stored XML)?
  - how can we decompose XML into relational data?
    - XMLCAST is not sufficient
  - both require a language to identify, extract and possibly combine parts of XML values

SQL/XML utilizes the XQuery standard for this!

XMLQUERY

- Evaluates an XQuery or XPath expression
  - Provided as a character string literal
- Allows for optional arguments to be passed in
  - Zero or more named arguments
  - At most one unnamed argument can be passed in as the XQuery context item
  - Arguments can be of any predefined SQL data type incl. XML
  - Non-XML arguments will be implicitly converted using XMLCAST
- Returns a sequence of XQuery nodes

XMLQUERY – Example

```
SELECT XMLQUERY('for $e in $dept[@count > 3]/emp
                  where $e/hire > 2004-12-31 return $e/name'
             PASSING BY REF deptDoc AS "dept"
             RETURNING SEQUENCE) AS "Name_elements"
FROM XMLDept
```

=>

Name_elements
<name>Miller</name>
<name>Smith</name> <name>Johnson</name>
<name>Martin</name>

XMLTABLE

- Transforming XML data into table format
- Evaluates an XQuery or XPath expression – the "**row pattern**"
  - each item of result sequence is turned into a row
  - allows for optional arguments to be passed in, just like XMLQuery
- Element/attribute values are mapped to column values using path expressions (PATH) – the "**column pattern**"
- Names and SQL data types for extracted values/columns need to be specified
- Default values for "missing" columns can be provided
- ORDINALITY column can be generated
  - contains a sequential number of the corresponding XQuery item in the XQuery sequence (result of the row pattern)

XMLTABLE - Example

```
SELECT X.*
FROM        XMLDept d,
            XMLTABLE ('$dept/emp' PASSING d.deptDoc AS "dept"
                        COLUMNS
                        "#num" FOR ORDINALITY,
                        "name"    VARCHAR(30)        PATH 'name',
                        "hire"    DATE               PATH 'hire',
                        "dept"    VARCHAR(40)        PATH '../@name'
                        ) AS "X"
```

=>

#num	name	hire	dept
1	Smith	2005-01-01	Accounting
2	Yates	2002-02-01	Accounting
3	Martin	2000-05-01	Shipping

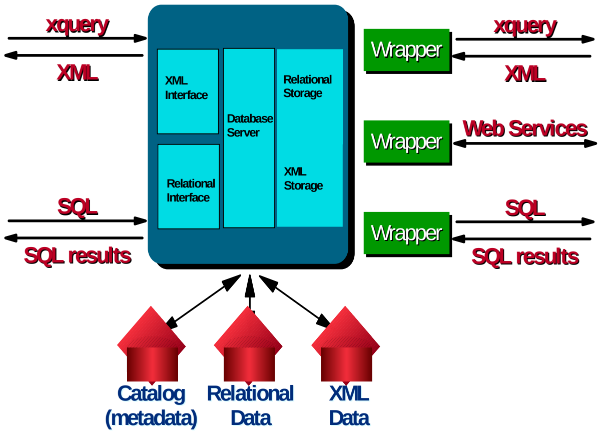
XML Advantages for Integration

- Integrates data and meta-data (tags)
  - Self-describing
- XMLSchema, Namespaces
  - Defining valid document structure
  - Integrating heterogenous terminology and structures
- XML can be validated against schema (xsd, dtd) outside the application
- Many technologies exist for processing, transforming, querying XML documents
  - DOM, SAX, XSLT, XPath, XQuery
- XML processing can help handle schema heterogenity, schema evolution
  - Focus on known element tags, attributes, namespaces ...
  - Powerful filter and transformation capabilities
- XML is independent of platforms, middleware, databases, applications ...

XML and Data Management

- Increasing importance of XML in combination with data management
  - flexible exchange of relational data using XML
  - managing XML data and documents
  - trend towards "hybrid" approaches for relational DBMS
- SQL/XML standard attempts to support the following
  - "Publish" SQL query results as XML documents
  - Ability to store and retrieve (parts of) XML documents with SQL databases
  - Rules and functionality for mapping SQL constructs to and from corresponding XML concepts
- Relies partly on XQuery standard
  - XML data model
  - queries over XML data
- Broad support by major SQL DBMS vendors
- Additional standards to further extend and complete the "big picture"!
  - XQJ: XML queries in Java
  - Grid Data Access Services (GGF): web/grid services to access DBs using SQL, XQuery

XML Support for DBMS: Direction


xquery
XML
XML Interface
Relational Interface
Database Server
Relational Storage
XML Storage
SQL
SQL results
Wrapper
xquery
XML
Wrapper
Web Services
Wrapper
SQL
SQL results
Catalog (metadata)
Relational Data
XML Data