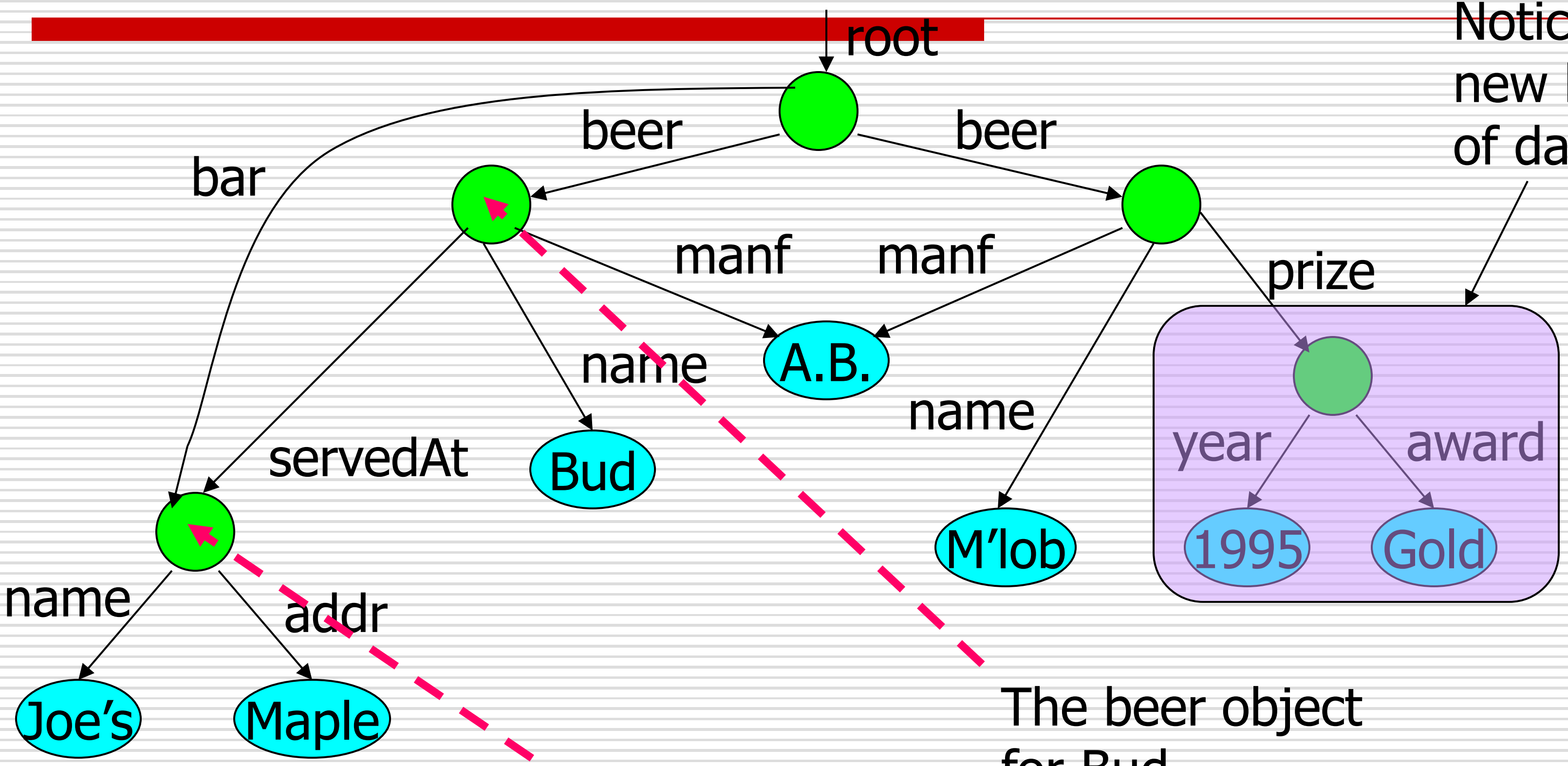
Chapter 11
The semi-structured data model

Structured data
XML (http://www.w3.org/XML/)
Document Type Definitions
XML Schema

Graphs of Semistructured Data

- Nodes = objects.
- Labels on arcs (like attribute names).
- Atomic values at leaf nodes (nodes with no arcs out).
- Flexibility: no restriction on:
  - Labels out of a node.
  - Number of successors with a given label.

Example: Data Graph



Notice a new kind of data.

The beer object for Bud

The bar object for Joe's Bar

XML

- XML = *Extensible Markup Language*.
- HTML uses tags for formatting (e.g., "italic"), XML uses tags for semantics (e.g., "this is an address").
- Key idea: create tag sets for a domain, and translate all data into properly tagged XML documents.

XML: Motivation

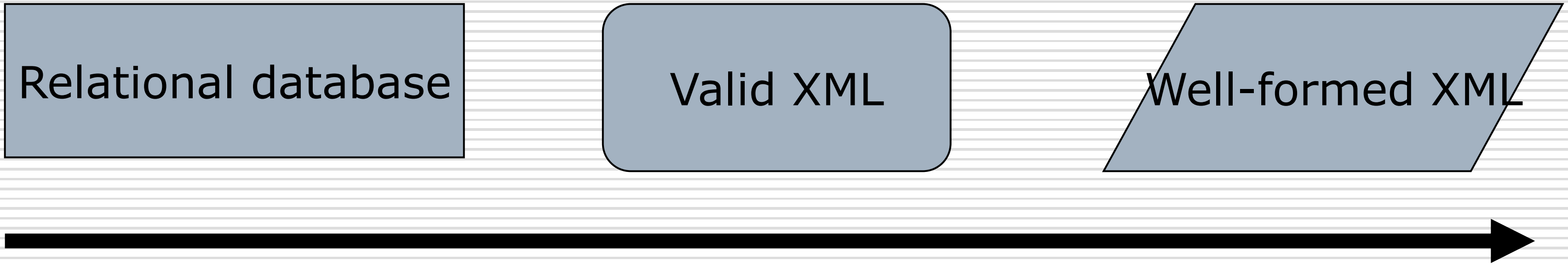
- Data interchange is critical in today’s networked world
  - Examples:
    - Banking: funds transfer
    - Order processing (especially inter-company orders)
    - Scientific data
  - Paper flow of information between organizations is being replaced by electronic flow of information
- Each application area has its own set of standards for representing information.
- XML has become the basis for all new generation data interchange formats.

Comparison with Relational Data

	Relational	XML
Structure	Table	Tree, graph Non rigid format
Schema	fixed	Flexible Tags self describing Allows nested structures
Queries	Simple, high level language	complex
Ordering	none	implied

Well-Formed and Valid XML

- *Well-Formed XML* allows you to invent your own tags.
- *Valid XML* conforms to a certain **DTD**, or **XML schema** .

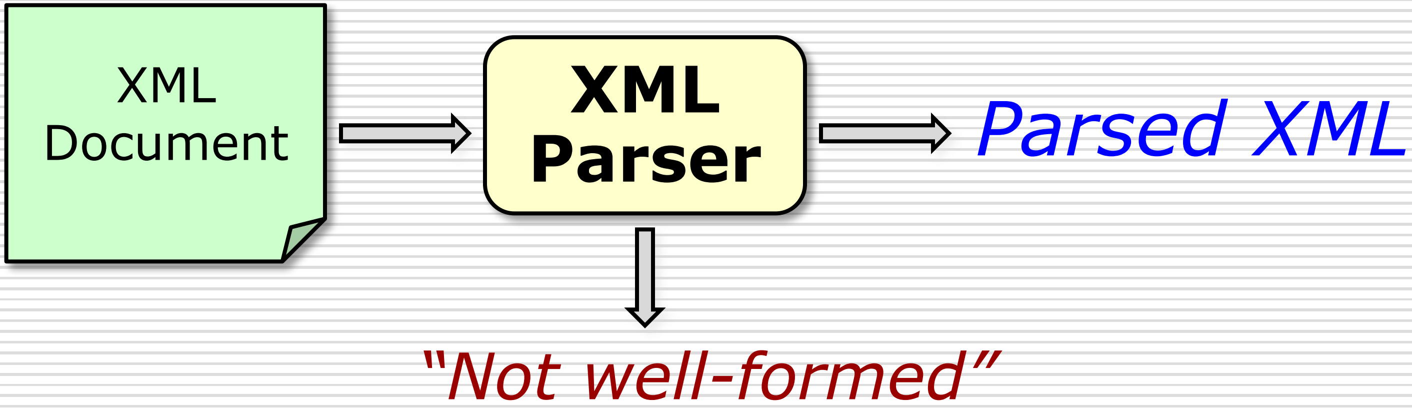


from strict Structure to loose Structure

Well-Formed XML

keep basic structural requirements

- Single root element
- Matched tags, proper nesting
- Unique attributes within elements



Well-Formed XML (cont.)

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

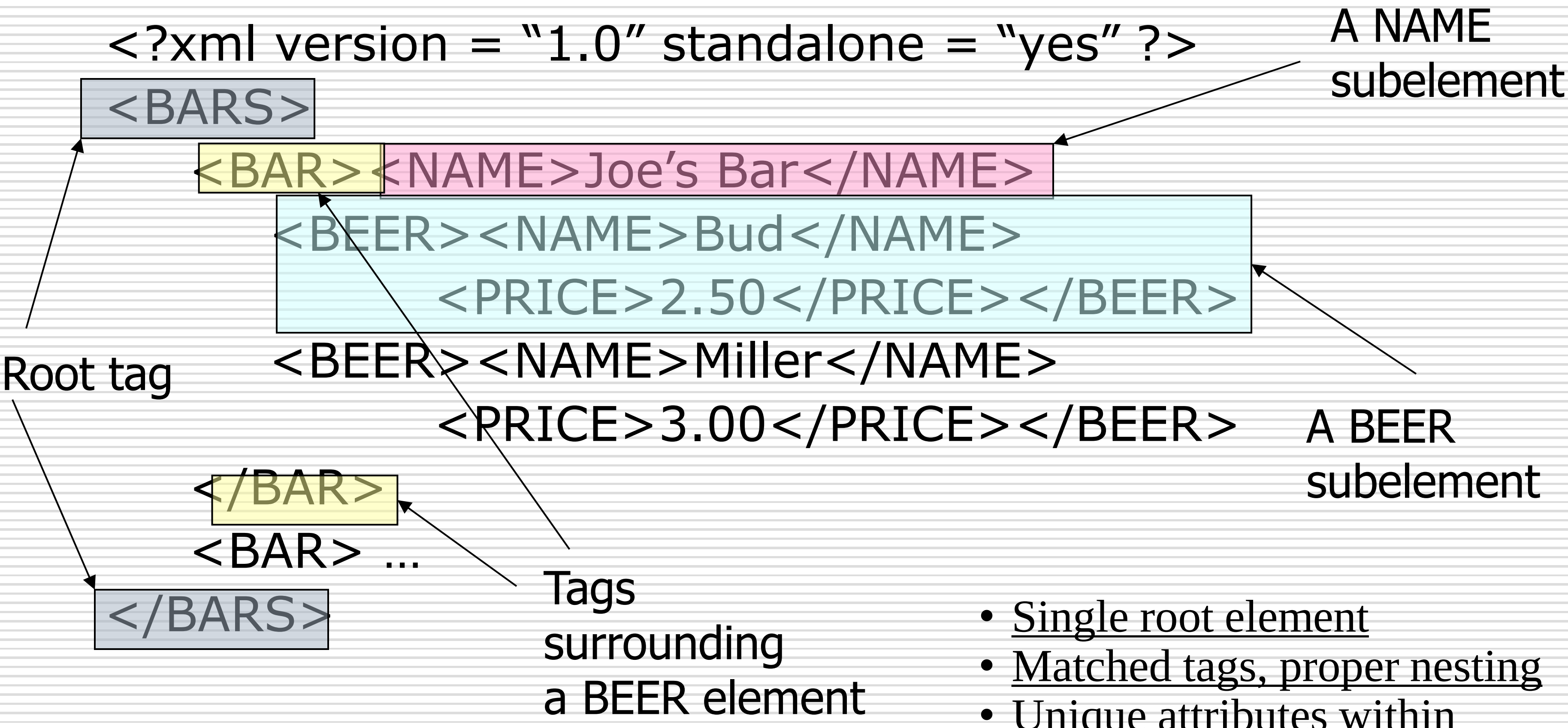
```
<?xml version = ”1.0” standalone
   = ”yes” ?>
```

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

Well-Formed XML (cont.)

- Tags are normally matched pairs, as <FOO> … </FOO>.
- Unmatched tags also allowed, as <FOO/>
- Tags may be nested arbitrarily.
- XML tags are case-sensitive.

Example: Well-Formed XML



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

A NAME subelement

A BEER subelement

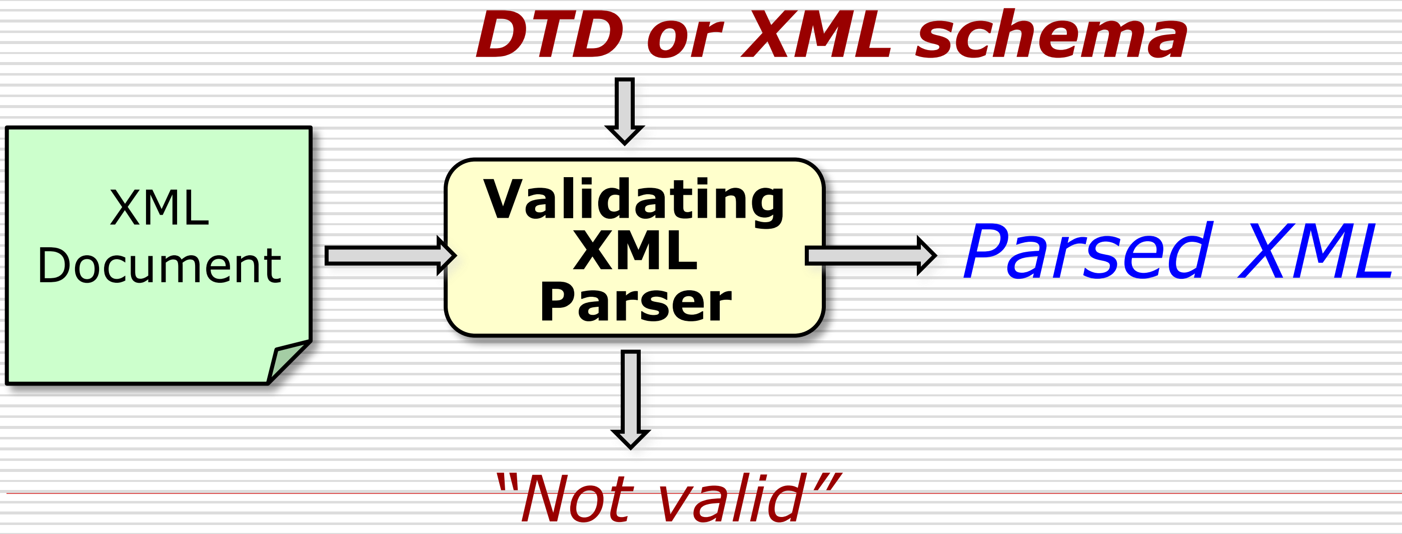
Root tag

Tags surrounding a BEER element

- Single root element
- Matched tags, proper nesting
- Unique attributes within elements

Valid XML

- Each XML needs a standard to define what are valid elements, using
  - XML type specification languages to specify the syntax
    - DTD (Document Type Descriptors)
    - XML Schema
  - Plus textual descriptions of the semantics



DTD or XML schema

XML Document

Validating XML Parser

Parsed XML

"Not valid"

DTD Structure

```
<!DOCTYPE <root tag> [
   <!ELEMENT <name>(<components>)>
   . . . more elements . . .
]>
```

Example: DTD

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

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

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

NAME and PRICE are text.

A BEER has a NAME and a PRICE.

Element Descriptions

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

Example: Element Description

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

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

Use of DTD’s

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

Example: (a)

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

The DTD

The document

Example: (b)

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

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

Get the DTD from the file bar.dtd

Attributes

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

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

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

The declaration of the form:

<!ATTLIST element-name, **attribute-name**, type>

Attribute Declaration

<!ATTLIST element-name, **attribute-name**, type>

- Name
- Type of attribute
  - CDATA
  - ID (identifier) or IDREF (ID reference) or IDREFS (multiple IDREFs)
- Whether
  - mandatory (#REQUIRED)
  - has a default value (value),
  - or neither (#IMPLIED)

Example: Attributes

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

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

Character string type; no tags

Attribute is optional
opposite: #REQUIRED

Example: Attributes (Cont.)

Example

```
<!ELEMENT BAR (NAME BEER*)>
<!ATTLIST BAR
    TYPE (sushi | sports | other)
>
```

- Bar objects can have a type, and the value of that type is limited to the three strings shown.

Example: Attribute Use

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

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

ID’s and IDREF’s

- Attributes can be pointers (*IDREF*) from one object to another (*ID*).
- Allows the structure of an XML document to be a general graph, rather than just a tree.

Example: ID's and IDREF's

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

The DTD

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

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

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

No matched closing tag, No subelements, Nor have text as a value

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

Example: A Document

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

No matched closing tag, No subelements, Nor have text as a value

Example DTD for bookstore data

```
<!ELEMENT Bookstore (Book*, Author*)>

<!ELEMENT Book (Title, Remark?)>

<!ATTLIST Book ISBN ID #REQUIRED Price CDATA #REQUIRED
    Edition CDATA #IMPLIED Authors IDREFS #REQUIRED>

<!ELEMENT Title (#PCDATA)>

<!ELEMENT Remark (#PCDATA | BookRef)*>

 <!ELEMENT BookRef EMPTY>

<!ATTLIST BookRef book IDREF #REQUIRED>

<!ELEMENT Author (First_Name, Last_Name)>

<!ATTLIST Author Ident ID #REQUIRED>

<!ELEMENT First_Name (#PCDATA)>

<!ELEMENT Last_Name (#PCDATA)>
```

EMPTY (no subelements) or ANY (anything can be a subelement)

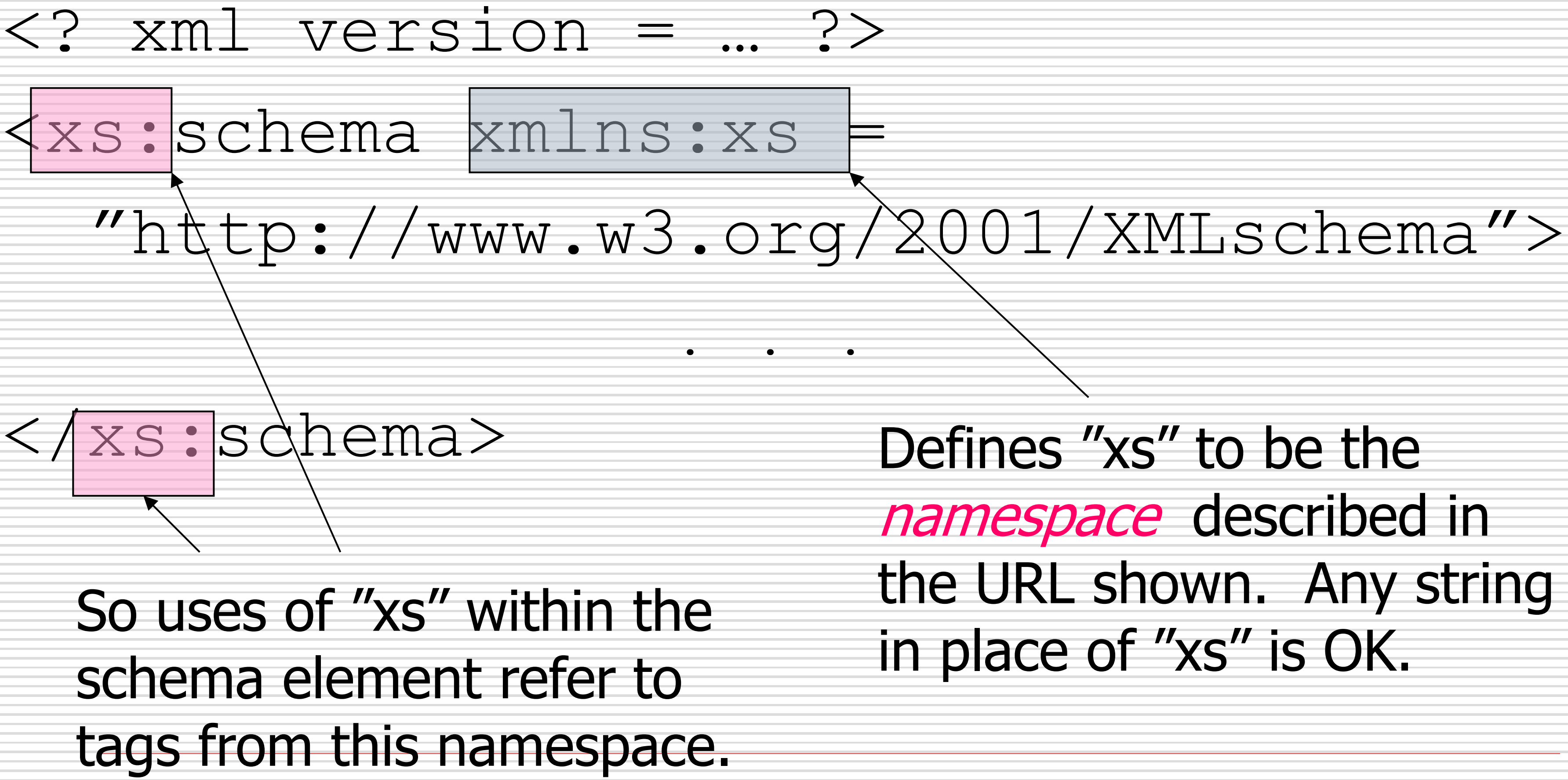
Limitations of DTDs

- No typing of text elements and attributes
  - All values are strings, no integers, reals, etc.
- Difficult to specify unordered sets of subelements
  - Order is usually irrelevant in databases (unlike in the document-layout environment from which XML evolved)
- IDs and IDREFs are untyped

XML Schema

- A more powerful way to describe the structure of XML documents.
- XML-Schema declarations are themselves XML documents.
  - They describe "elements" and the things doing the describing are also "elements."

Structure of an XML-Schema Document



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

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

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

The xs:element Element

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

Example: xs:element

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

- □ Describes elements such as

  <NAME>Joe’s Bar</NAME>

XML Schema: Simple Types

- Elements that do not contain other elements or attributes are of type simpleType.

- Attributes must be defined last:

Complex Types

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

Example: a Type for Beers

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

Exactly one occurrence

Like ? in a DTD

Construct a complex type

- In place of xs:sequence, use:
- xs:all: each of the elements between the opening tag and its matched closing tag must occur, in any order, exactly once each.
- xs:choice: one of the elements found between the opening tag and closing tag.

An Element of Type beerType

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

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

```
<xs:element name
= ”BEER”
type = ”beerType” />
```

xs:attribute

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

Example: xs:attribute

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

An Element of This New Type beerType

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

We still don’t know the element name.

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

Restricted Simple Types

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

Restrictions

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

Example: license Attribute for BAR

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

Example: Prices in Range [1,5)

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

Keys in XML Schema

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

Example: Key

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

And @ indicates an attribute rather than a tag.

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

Foreign Keys

- An xs:keyref subelement within an xs:element says that within this element, certain values (defined by selector and field(s), as for keys) must appear as values of a certain key.
- An element has a field or fields that serve as a reference to the key for some other element.

Example: Foreign Key

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

Example: Foreign Key in XML Schema

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

Foreign-key name

Key name

XML document (with a XML schema)

```
<?xml version=“1.0”?>
< XXX
xmlns=“http://www.w3school.com.cn”
xmlns:xsi=
“http://www.s3.org/2001/xml Schema-instance”
xsi:schemalocation=“http://www.w3school.com.cn XXX.xsd”>
<>….</>
</XXX>
```

```xml
<?xml version="1.0" encoding="ISO-8859-1"?>

   <shiporder orderid="889923"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:noNamespaceSchemaLocation="shiporder.xsd">

    <orderperson>John Smith</orderperson>
    <shipto>
     <name>Ola Nordmann</name>
     <address>Langgt 23</address>
     <city>4000 Stavanger</city>
     <country>Norway</country>
    </shipto>
    <item>
     <title>Empire Burlesque</title>
     <note>Special Edition</note>
     <quantity>1</quantity>
     <price>10.90</price>
    </item>
    <item>
     <title>Hide your heart</title>
     <quantity>1</quantity>
     <price>9.90</price>
    </item>
   </shiporder>
```

Tells the XML parser that this document should be validated against a schema

Specifies where the schema resides

XML doc.

The xml schema (example)

```
<?xml version="1.0" encoding="ISO-8859-1" ?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
<xs:element name="shiporder">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="orderperson" type="xs:string"/>

      <xs:element name="shipto">
        <xs:complexType>
          <xs:sequence>
            <xs:element name="name" type="xs:string"/>
            <xs:element name="address" type="xs:string"/>
            <xs:element name="city" type="xs:string"/>
            <xs:element name="country" type="xs:string"/>
          </xs:sequence>
        </xs:complexType>
      </xs:element>
```

The xml schema (example)

```
<xs:element name="item" maxOccurs="unbounded">
    <xs:complexType>
     <xs:sequence>
      <xs:element name="title" type="xs:string"/>
      <xs:element name="note" type="xs:string" minOccurs="0"/>
      <xs:element name="quantity" type="xs:positiveInteger"/>
      <xs:element name="price" type="xs:decimal"/>
     </xs:sequence>
    </xs:complexType>
   </xs:element>
  </xs:sequence>
  <xs:attribute name="orderid" type="xs:string" use="required"/>
 </xs:complexType>
</xs:element>

</xs:schema>
```

XML Schema (Summary)

- XML Schema is a more sophisticated schema language which addresses the drawbacks of DTDs. Supports
  - Typing of values
    - E.g. integer, string, etc
    - Also, constraints on min/max values
  - User-defined, comlex types
  - Many more features, including
    - uniqueness and foreign key constraints, inheritance
- XML Schema is itself specified in XML syntax, unlike DTDs
  - More-standard representation, but verbose
- XML Scheme is integrated with namespaces
- BUT: XML Schema is significantly more complicated than DTDs.

Summarization

- XML and its application
  - XML Elements and attributes
- DTD
  - Identifiers and references in DTD’s
- XML schema
  - Simple types, complex types in XML schema, key and foreign key declaration.

Classroom Exercises:

1)what are the minimum and maximum possible number of Mayor elements?
2)what are the minimum and maximum possible number of Library elements?

```
<!DOCTYPE CityInfo [
   <!ELEMENT CityInfo (Government, Neighborhood+)>
   <!ATTLIST CityInfo Name CDATA #REQUIRED>
   <!ELEMENT Government (Mayor, Assistant)>
   <!ELEMENT Mayor (#PCDATA)>
   <!ELEMENT Assistant (#PCDATA)>
   <!ELEMENT Neighborhood (Library | Bookshop)?>
   <!ATTLIST Neighborhood Name CDATA #REQUIRED>
   <!ELEMENT Library (#PCDATA)>
   <!ELEMENT Bookshop (#PCDATA)>
]>
```

Classroom Exercises

1) what are the minimum and maximum possible number of Name elements?
2) what are the minimum and maximum possible number of Snack elements?

```
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
 <xs:element name="PassengerInfo">
   <xs:complexType>
     <xs:sequence>
       <xs:element name="Name" type="xs:string" maxOccurs="2"
      />
       <xs:element name="Seat" type="xs:string"/>
       <xs:choice>
         <xs:element name="Meal" type="xs:string"/>
         <xs:element name="Snack" type="xs:string" maxOccurs="2
      "/>
       </xs:choice>
     </xs:sequence>
   </xs:complexType>
 </xs:element>
</xs:schema>
```

XML → SQL

```
Create table students
(Sid char(8) primary key,
Name varchar(30),
Dept char(4)
Hobbies XMLTYPE)    --- table created
Insert into students values (‘10403050’,’LI Hong’,’CS’,
’<Hobbies><English level>6</English level><piano>8</piano><basketball>well</basketball></Hobbies>’);
```

XML → SQL (cont.)

Select * from “students”;

SID	name	dept	Hobbies
10403050	LI Hong	CS	<hobbies><English level>6</English level><piano>8</piano><basketball>well</basketball></hobbies>

Select XMLELEMENT(“students”, XMLFOREST(name as “StudentName, dept as “Department”)) from “students” ;

XMLELEMENT(“students”, XMLFOREST(name as “StudentName, dept as “Department”
<students><StudentName>LI Hong</StudentName><Department>cs</Department></students>