XML

Semistructured Data

Extensible Markup Language

Document Type Definitions

XPATH

XQUERY

Framework

1. *Information Integration* : Making databases from various places work as one.
2. *Semistructured Data* : A new data model designed to cope with problems of information integration.
3. *XML* : A standard language for describing semistructured data schemas and representing data.

The Information-Integration Problem

- Related data exists in many places and could, in principle, work together.
- But different databases differ in:
  1. Model (relational, object-oriented?).
  2. Schema (normalized/unnormalized?).
  3. Terminology: are consultants employees? Retirees? Subcontractors?
  4. Conventions (meters versus feet?).

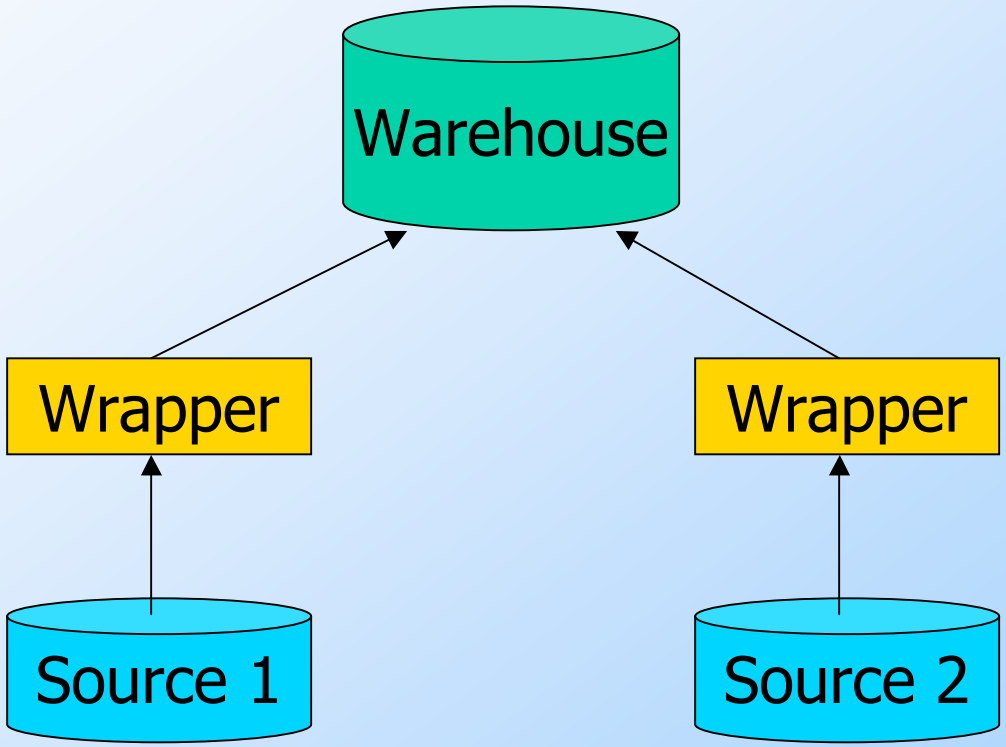
Example

- Every bar has a database.
  - One may use a relational DBMS; another keeps the menu in an MS-Word document.
  - One stores the phones of distributors, another does not.
  - One distinguishes ales from other beers, another doesn't.
  - One counts beer inventory by bottles, another by cases.

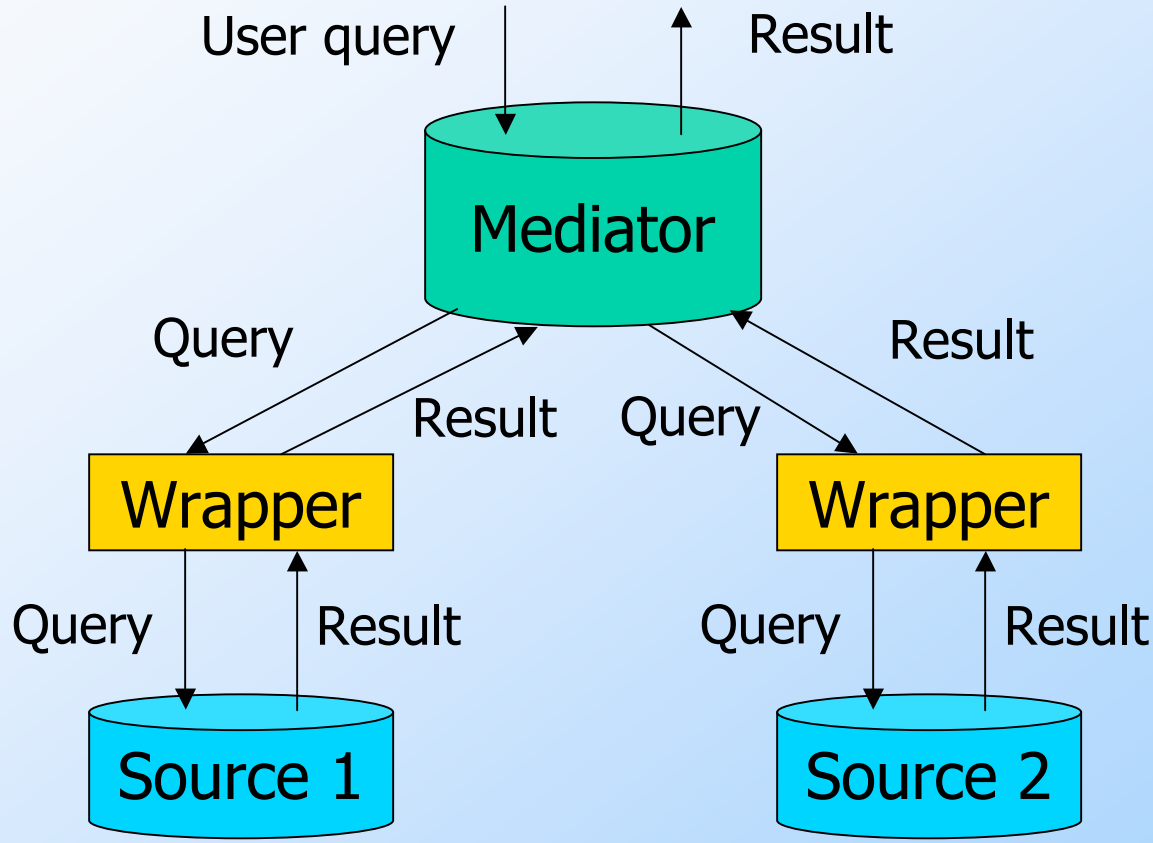
Two Approaches to Integration

1. *Warehousing* : Make copies of the data sources at a central site and transform it to a common schema.
   - Reconstruct data daily/weekly, but do not try to keep it more up-to-date than that.
2. *Mediation* : Create a view of all sources, as if they were integrated.
   - Answer a view query by translating it to terminology of the sources and querying them.

Warehouse Diagram



A Mediator


User query
Result
Mediator
Query
Result
Result
Query
Wrapper
Wrapper
Query
Result
Query
Result
Source 1
Source 2

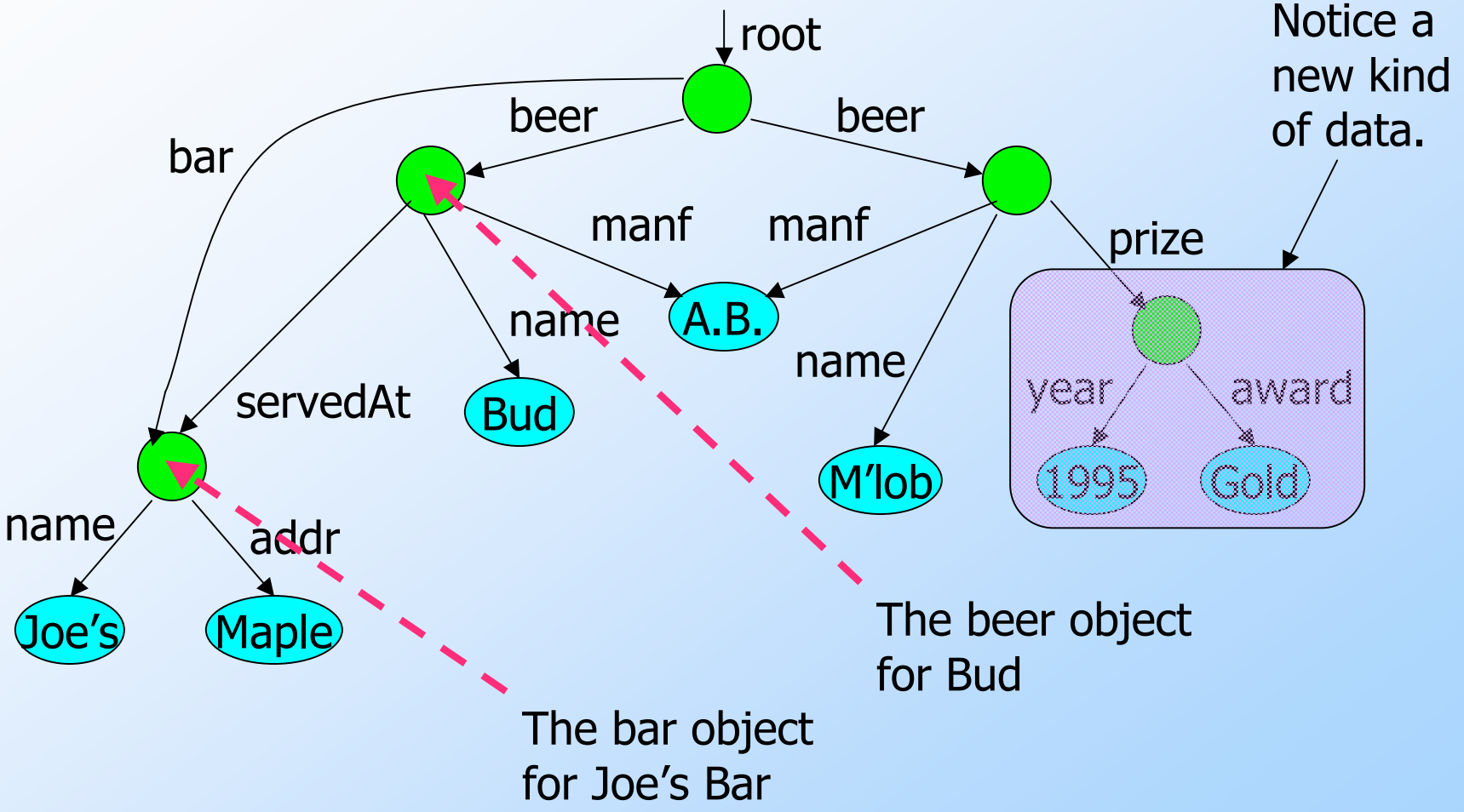
Semistructured Data

- Purpose: represent data from independent sources more flexibly than either relational or object-oriented models.
- Think of objects, but with the type of each object its own business, not that of its "class."
- Labels to indicate meaning of substructures.

Graphs of Semistructured Data

- Nodes = objects.
- Labels on arcs (attributes, relationships).
- 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



XML

- XML = Extensible Markup Language.
- While 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 (e.g., genomics), and translate all data into properly tagged XML documents.

Well-Formed and Valid XML

- *Well-Formed XML* allows you to invent your own tags.
  - Similar to labels in semistructured data.
- *Valid XML* involves a DTD (Document Type Definition), which limits the labels and gives a grammar for their use.

Well-Formed XML

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

```
<? XML VERSION = “1.0”
  STANDALONE = “yes” ?>
```

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

Tags

- Tags, as in HTML, are normally matched pairs, as <FOO> ... </FOO> .
- Tags may be nested arbitrarily.

Example: Well-Formed XML

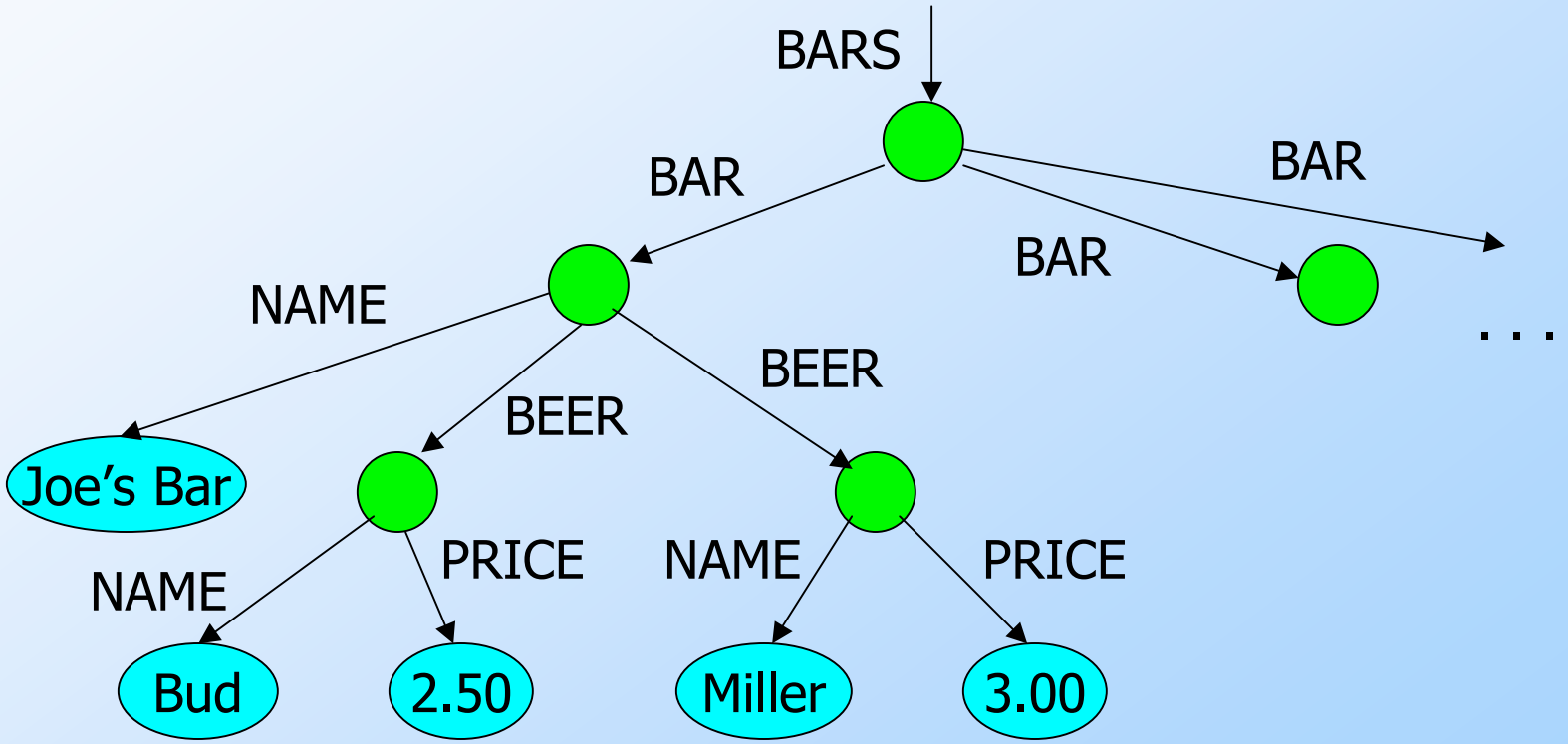
```
<?XML VERSION = "1.0" STANDALONE = "yes" ?>
<BARS>
   <BAR><NAME>Joe's Bar</NAME>
        <BEER><NAME>Bud</NAME>
              <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME>
              <PRICE>3.00</PRICE></BEER>
   </BAR>
   <BAR> …
</BARS>
```

XML and Semistructured Data

- Well-Formed XML with nested tags is exactly the same idea as trees of semistructured data.
- We shall see that XML also enables nontree structures, as does the semistructured data model.

Example

- The <BARS> XML document is:



Document Type Definitions

- Essentially a context-free grammar for describing XML tags and their nesting.
- Each domain of interest (e.g., electronic components, bars-beers-drinkers) creates one DTD that describes all the documents this group will share.

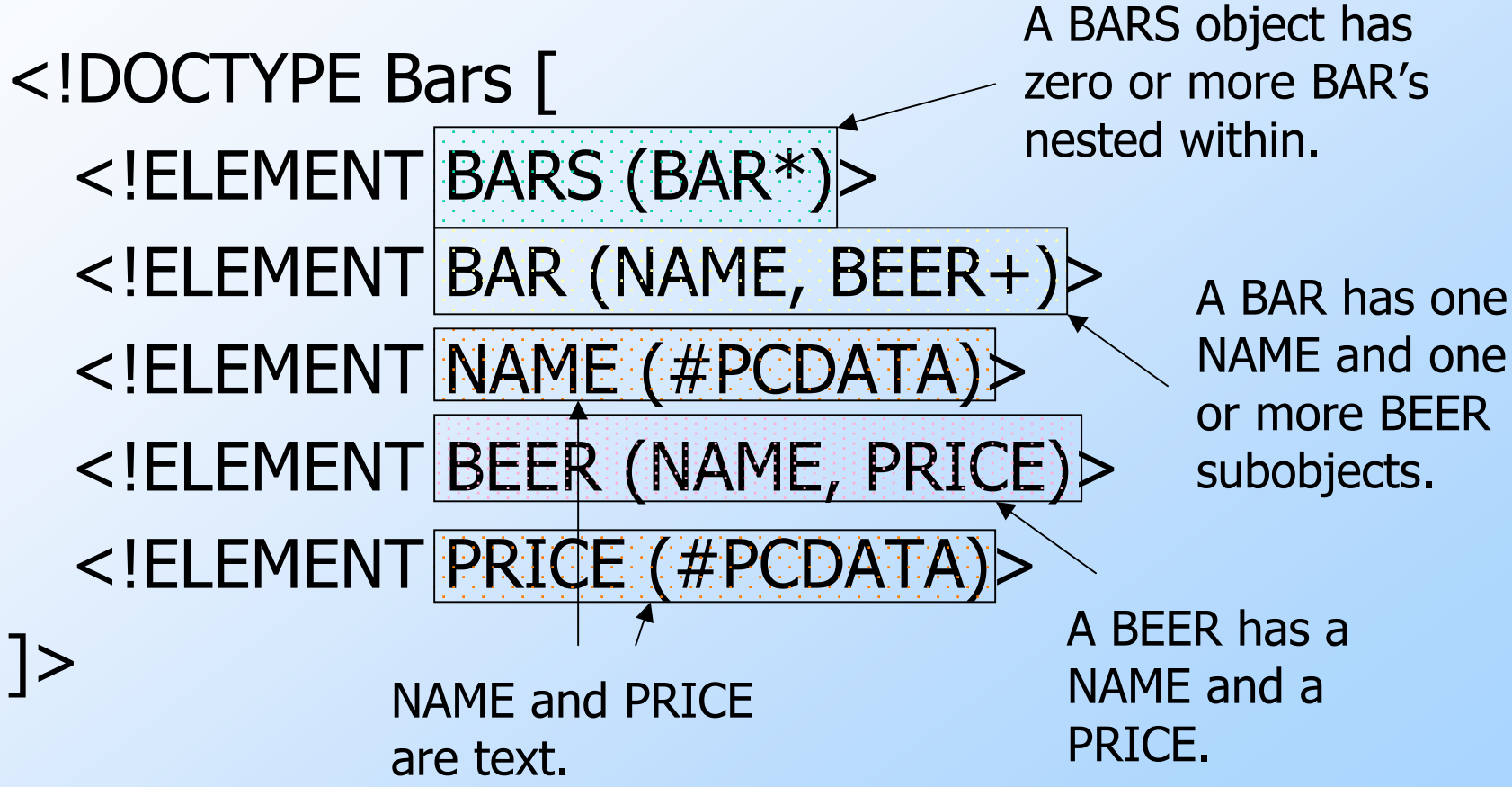
DTD Structure

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

DTD Elements

- The description of an element consists of its name (tag), and a parenthesized description of any nested tags.
  - Includes order of subtags and their multiplicity.
- **Leaves** (text elements) have #PCDATA in place of nested tags.

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.
A BEER has a NAME and a PRICE.
NAME and PRICE are text.

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)>
]>
```

The DTD

The document

```
<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>
```

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*, like <A HREF = "..."> in HTML.
- In a DTD,

`<!ATTLIST` <element name>... `>`

gives a list of attributes and their datatypes for this element.

Example: Attributes

- Bars can have an attribute `kind`, which is either sushi, sports, or "other."

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

Example: Attribute Use

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

```
<BAR kind = "sushi">
  <NAME>Akasaka</NAME>
  <BEER><NAME>Sapporo</NAME>
        <PRICE>5.00</PRICE></BEER>
  ...
</BAR>
```

ID's and IDREF's

- These are pointers from one object to another, in analogy to HTML's NAME = "foo" and HREF = "#foo".
- Allows the structure of an XML document to be a **general graph**, rather than just a tree.

Creating ID's

- Give an element, say *E,* an attribute, say *A,* of type ID.
- When using tag <*E* > in an XML document, give its attribute *A* a unique value.
- Example:

```
<E   A = "xyz">
```

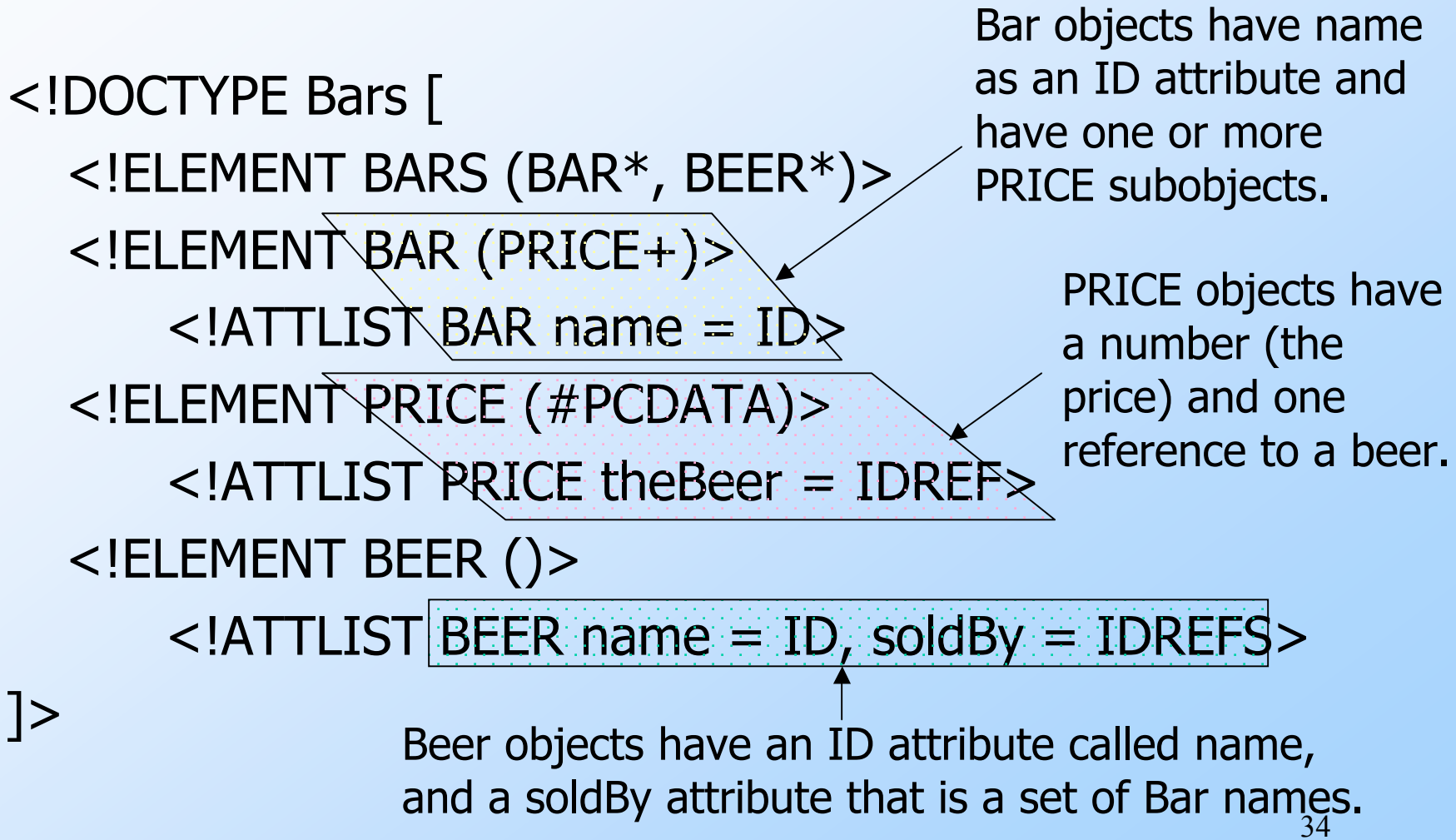
Creating IDREF's

- To allow objects of type *F* to refer to another object with an ID attribute, give *F* an attribute of type IDREF.
- Or, let the attribute have type IDREFS, so the *F*–object can refer to any number of other objects.

Example: ID's and IDREF's

- Let's redesign our BARS DTD to include both BAR and BEER subelements.
- Both bars and beers will have ID attributes called `name`.
- Bars have PRICE subobjects, 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


<!DOCTYPE Bars [
<!ELEMENT BARS (BAR*, BEER*)>
<!ELEMENT BAR (PRICE+)>
<!ATTLIST BAR name = ID>
<!ELEMENT PRICE (#PCDATA)>
<!ATTLIST PRICE theBeer = IDREF>
<!ELEMENT BEER ()>
<!ATTLIST BEER name = ID, soldBy = IDREFS>
]>
Bar objects have name as an ID attribute and have one or more PRICE subobjects.
PRICE objects have a number (the price) and one reference to a beer.
Beer objects have an ID attribute called name, and a soldBy attribute that is a set of Bar names.

Example Document

```
<BARS>
   <BAR name = "JoesBar">
        <PRICE theBeer = "Bud">2.50</PRICE>
        <PRICE theBeer = "Miller">3.00</PRICE>
   </BAR>
   …
   <BEER name = "Bud",
              soldBy = "JoesBar, SuesBar,…">
   </BEER>
   …
</BARS>
```

XPATH and XQUERY

- XPATH is a language for describing paths in XML documents.
  - Really think of the semistructured data graph and *its* paths.
- XQUERY is a full query language for XML documents with power similar to OQL.

Example DTD

```
<!DOCTYPE Bars [
    <!ELEMENT BARS (BAR*, BEER*)>
    <!ELEMENT BAR (PRICE+)>
        <!ATTLIST BAR name = ID>
    <!ELEMENT PRICE (#PCDATA)>
        <!ATTLIST PRICE theBeer = IDREF>
    <!ELEMENT BEER ()>
        <!ATTLIST BEER name = ID, soldBy = IDREFS>
]>
```

Example Document

```
<BARS>
   <BAR name = "JoesBar">
        <PRICE theBeer = "Bud">2.50</PRICE>
        <PRICE theBeer = "Miller">3.00</PRICE>
   </BAR> …
   <BEER name = "Bud", soldBy = "JoesBar,
        SuesBar,…">
   </BEER> …
</BARS>
```

Path Descriptors

- Simple path descriptors are sequences of tags separated by slashes (/).
- If the descriptor begins with /, then the path starts at the root and has those tags, in order.
- If the descriptor begins with //, then the path can start anywhere.

Example: /BARS/BAR/PRICE

```
<BARS>
   <BAR name = "JoesBar">
      <PRICE theBeer = "Bud">2.50</PRICE>
      <PRICE theBeer = "Miller">3.00</PRICE>
   </BAR> …
   <BEER name = "Bud", soldBy = "JoesBar,
        SuesBar,…">
   </BEER> …
</BARS>
```

/BARS/BAR/PRICE describes the set with these two PRICE objects as well as the PRICE objects for any other bars.

Example: //PRICE

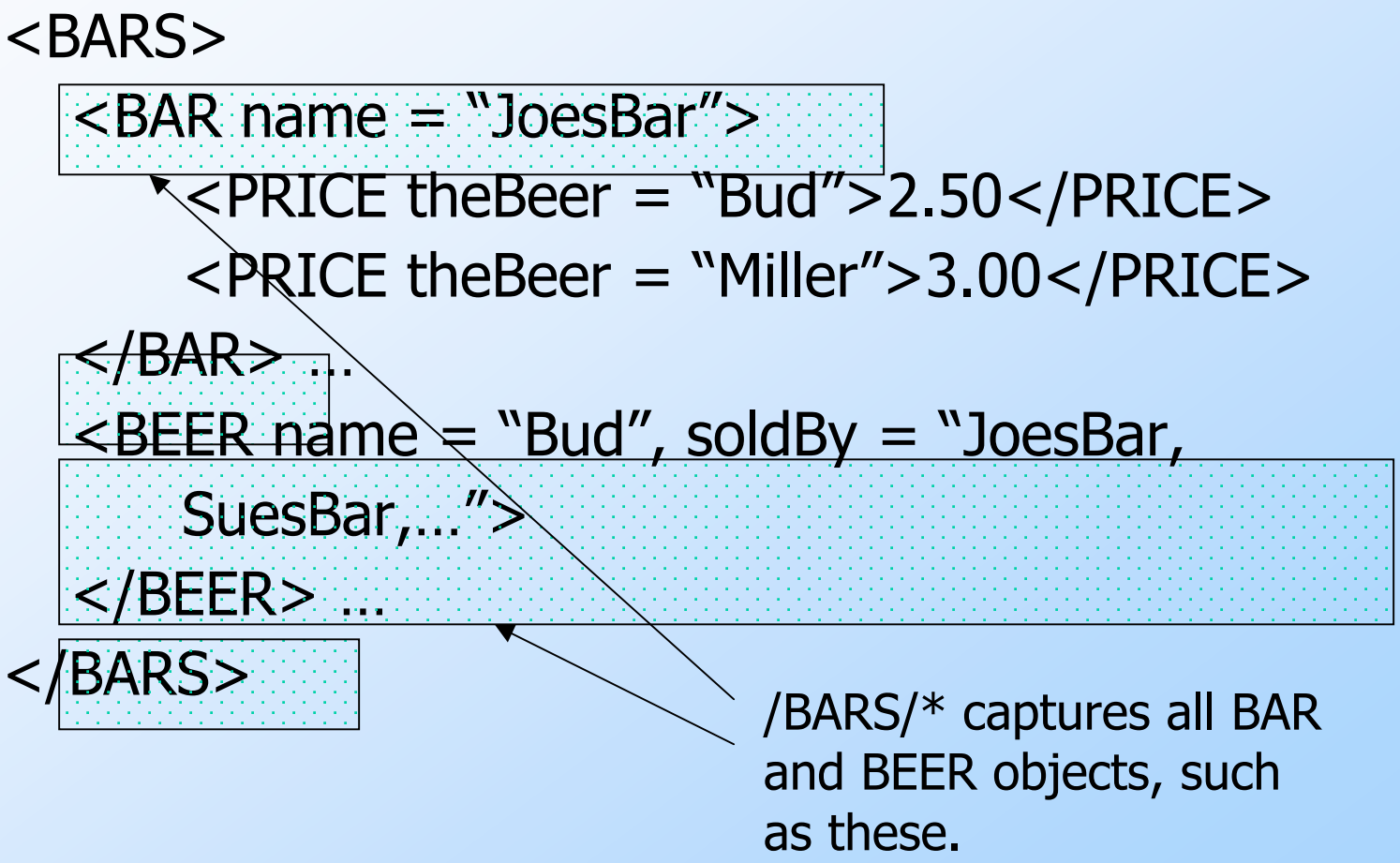
```
<BARS>
   <BAR name = "JoesBar">
      <PRICE theBeer = "Bud">2.50</PRICE>
      <PRICE theBeer = "Miller">3.00</PRICE>
   </BAR> …
   <BEER name = "Bud", soldBy = "JoesBar,
        SuesBar,…">
   </BEER> …
</BARS>
```

//PRICE describes the same PRICE objects, but only because the DTD forces every PRICE to appear within a BARS and a BAR.

Wild-Card *

- A star (*) in place of a tag represents any one tag.
- Example: /*/*/PRICE represents all price objects at the third level of nesting.

Example: /BARS/*



Attributes

- In XPATH, we refer to attributes by **prepending @ to their name**.
- Attributes of a tag may appear in paths as if they were nested within that tag.

Example: /BARS/*/@name

```
<BARS>
   <BAR name = "JoesBar">
        <PRICE theBeer = "Bud">2.50</PRICE>
        <PRICE theBeer = "Miller">3.00</PRICE>
   </BAR> …
   <BEER name = "Bud", soldBy = "JoesBar,
        SuesBar,…">
   </BEER> …
</BARS>
```

/BARS/*/@name selects all name attributes of immediate subobjects of the BARS object.

Selection Conditions

- A condition inside [...] may follow a tag.
- If so, then only paths that have that tag and also satisfy the condition are included in the result of a path expression.

Example: Selection Condition

- /BARS/BAR/PRICE[PRICE < 2.75]

```
<BARS>
   <BAR name = "JoesBar">
        <PRICE theBeer = "Bud">2.50</PRICE>
        <PRICE theBeer = "Miller">3.00</PRICE>
   </BAR> …
```

The condition that the PRICE be < $2.75 makes this price but not the Miller price satisfy the path descriptor.

Example: Attribute in Selection

- /BARS/BAR/PRICE[@theBeer = “Miller”]

```
<BARS>
   <BAR name = “JoesBar”>
        <PRICE theBeer = “Bud”>2.50</PRICE>
        <PRICE theBeer = “Miller”>3.00</PRICE>
   </BAR> …
```

Now, this PRICE object is selected, along with any other prices for Miller.

Axes

- In general, path expressions allow us to start at the root and execute a sequence of steps to find a set of nodes at each step.
- At each step, we may follow any one of several *axes*.
- The default axis is **child**:: --- go to any child of the current set of nodes.

Example: Axes

- /BARS/BEER is really shorthand for /BARS/child::BEER .
- @ is really shorthand for the attribute:: axis.
  - Thus, /BARS/BEER[@name = "Bud"] is shorthand for

    /BARS/BEER[attribute::name = "Bud"]

More Axes

- Some other useful axes are:
  1. parent:: = parent(s) of the current node(s).
  2. descendant-or-self:: = the current node(s) and all descendants.
     - Note: // is really a shorthand for this axis.
  3. ancestor::, ancestor-or-self, etc.

XQUERY

- XQUERY allows us to query XML documents, using path expressions from XPATH to describe important sets.
- Corresponding to SQL's select-from-where is the XQUERY *FLWR expression*, standing for "for-let-where-return."

FLWR Expressions

1. One or more FOR and/or LET clauses.
2. Then an optional WHERE clause.
3. A RETURN clause.

FOR Clauses

FOR <variable> IN <path expression>,...

- Variables begin with $.
- A FOR variable takes on each object in the set denoted by the path expression, in turn.
- Whatever follows this FOR is executed once for each value of the variable.

Example: FOR

FOR $beer IN /BARS/BEER/@name

RETURN

<BEERNAME>$beer</BEERNAME>

- $beer ranges over the name attributes of all beers in our example document.
- Result is a list of tagged names, like <BEERNAME>Bud</BEERNAME> <BEERNAME>Miller</BEERNAME>…

LET Clauses

LET <variable> := <path expression>,...

- Value of the variable becomes the ***set*** of objects defined by the path expression.
- Note LET does not cause iteration; FOR does.

Example: LET

```
LET $beers := /BARS/BEER/@name
RETURN
   <BEERNAMES>$beers</BEERNAMES>
```

- Returns one object with all the names of the beers, like:

```
<BEERNAMES>Bud, Miller,…</BEERNAMES>
```

Following IDREF's

- XQUERY (but not XPATH) allows us to use paths that follow attributes that are IDREF's.
- If *x* denotes a set of IDREF's, then *x* =>*y* denotes all the objects with tag *y* whose ID's are one of these IDREF's.

Example

- Find all the beer objects where the beer is sold by Joe's Bar for less than 3.00.
- Strategy:
  1. $beer will for-loop over all beer objects.
  2. For each $beer, let $joe be either the Joe's-Bar object, if Joe sells the beer, or the empty set of bar objects.
  3. Test whether $joe sells the beer for < 3.00.

Example: The Query

Attribute soldBy is of type IDREFS. Follow each ref to a BAR and check if its name is Joe's Bar.

```
FOR $beer IN /BARS/BEER
LET $joe := $beer/@soldBy=>BAR[@name="JoesBar"]
LET $joePrice := $joe/PRICE[@theBeer=$beer/@name]
WHERE $joePrice < 3.00
RETURN <CHEAPBEER>$beer</CHEAPBEER>
```

Only pass the values of $beer, $joe, $joePrice to the RETURN clause if the string inside the PRICE object $joePrice is < 3.00

Find that PRICE subobject of the Joe's Bar object that represents whatever beer is currently $beer.