XML Technologies and Applications

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IV. XML Parsing APIs

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Outline

- Introduction
- XML Basics
- XML Structural Constraint Specification
  - Document Type Definitions (DTDs)
  - XML Schema
- XML/Database Mappings
- XML Parsing APIs
  - Simple API for XML (SAX)
  - Document Object Model (DOM)
- XML Querying and Transformation
  - XPath
  - XQuery
  - XSLT
- XML Applications

Parsers

What is a parser?

- **A program that analyses the grammatical structure of an input, with respect to a given formal grammar**

- The parser determines how a sentence can be constructed from the grammar of the language by describing the atomic elements of the input and the relationship among them

XML-Parsing Standards

We will consider two parsing methods that implement W3C standards for accessing XML

- **SAX (Simple API for XML)**
  - event-driven parsing
  - “serial access” protocol
  - Read only API
- **DOM (Document Object Model)**
  - convert XML into a tree of objects
  - “random access” protocol
  - Can update XML document (insert/delete nodes)

SAX Parser

- SAX = Simple API for XML
- XML is read sequentially
- When a *parsing event* happens, the parser invokes the corresponding method of the corresponding handler
- The handlers are programmer's implementation of standard Java API (i.e., interfaces and classes)
- Similar to an I/O-Stream, goes in one direction

Sample Data

Orders Data in XML:

several orders, each with several items

each item has a part number and a quantity

```
<orders>
<order>
 <onum>1020</onum>
 <takenBy>1000</takenBy>
 <customer>1111</customer>
 <recDate>10-DEC 94</recDate>
 <items>
   <item>
     <pnum>10506</pnum>
     <quantity>1</quantity>
   </item>
   <item>
     <pnum>10507</pnum>
     <quantity>1</quantity>
   </item>
   <item>
     <pnum>10508</pnum>
     <quantity>2</quantity>
   </item>
   <item>
     <pnum>10509</pnum>
     <quantity>3</quantity>
   </item>
  </items>
</order>
...
</orders>
```

Sample Data

Orders Data in XML:
several orders, each with several items
each item has a part number and a quantity

Parsing Event

startDocument

```
<orders>
 <order>
  <onum>1020</onum>
  <takenBy>1000</takenBy>
  <customer>1111</customer>
  <recDate>10-DEC 94</recDate>
  <items>
    <item>
      <pnum>10506</pnum>
      <quantity>1</quantity>
    </item>
    <item>
      <pnum>10507</pnum>
      <quantity>1</quantity>
    </item>
    <item>
      <pnum>10508</pnum>
      <quantity>2</quantity>
    </item>
    <item>
      <pnum>10509</pnum>
      <quantity>3</quantity>
    </item>
  </items>
</order>
...
</orders>
```

endDocument

Sample Data

Orders Data in XML:
several orders, each with several items
each item has a part number and a quantity

```
<orders>
<order>
 <onum>1020</onum>
 <takenBy>1000</takenBy>
 <customer>1111</customer>
 <recDate>10-DEC-94</recDate>
 <items>
   <item>
     <pnum>10506</pnum>
     <quantity>1</quantity>
   </item>
   <item>
     <pnum>10507</pnum>
     <quantity>1</quantity>
   </item>
   <item>
     <pnum>10508</pnum>
     <quantity>2</quantity>
   </item>
   <item>
     <pnum>10509</pnum>
     <quantity>3</quantity>
   </item>
 </items>
</order>
...
</orders>
```

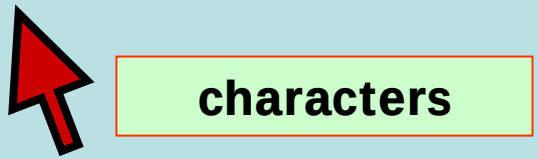
startElement

endElement

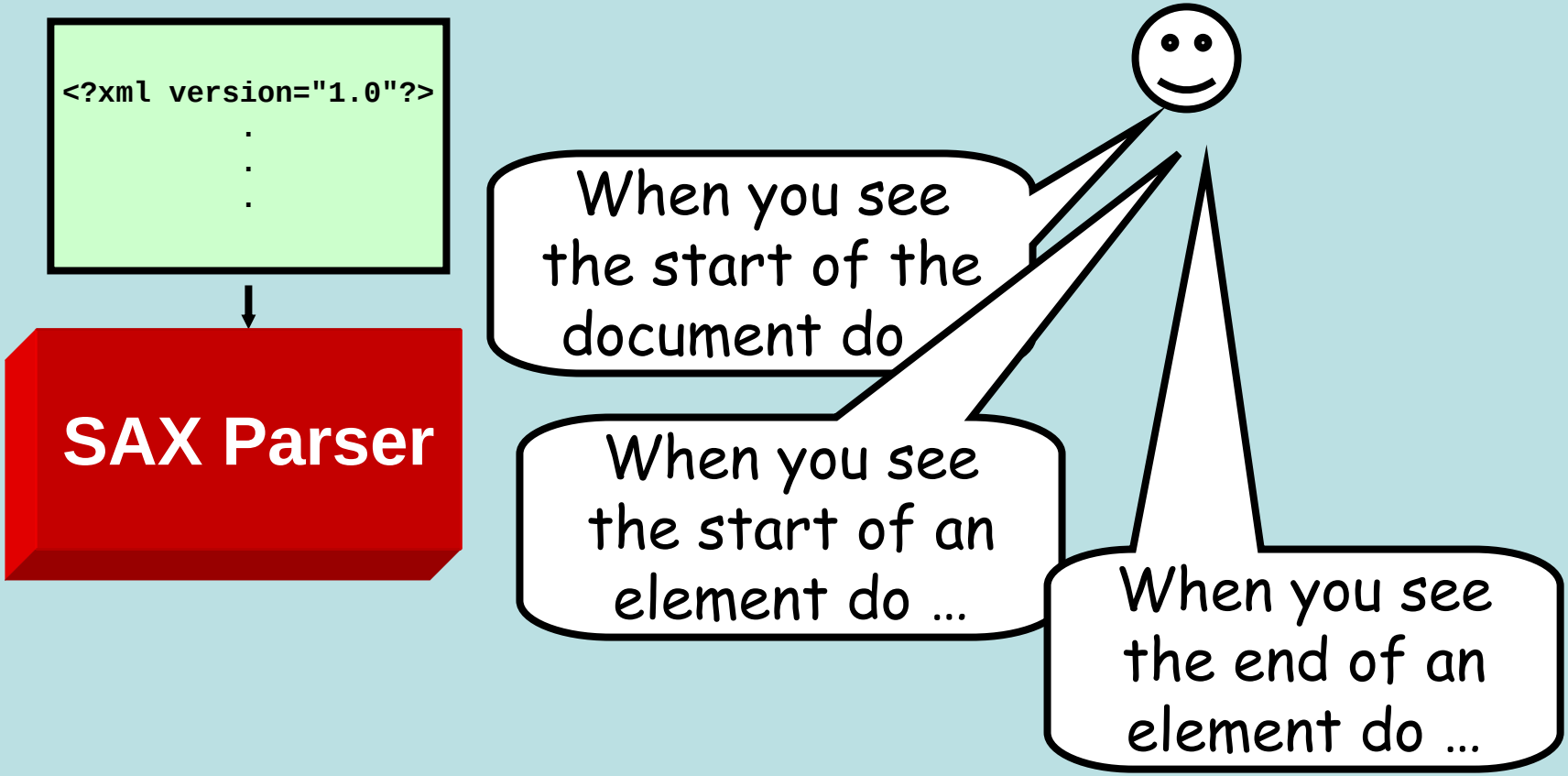
Sample Data

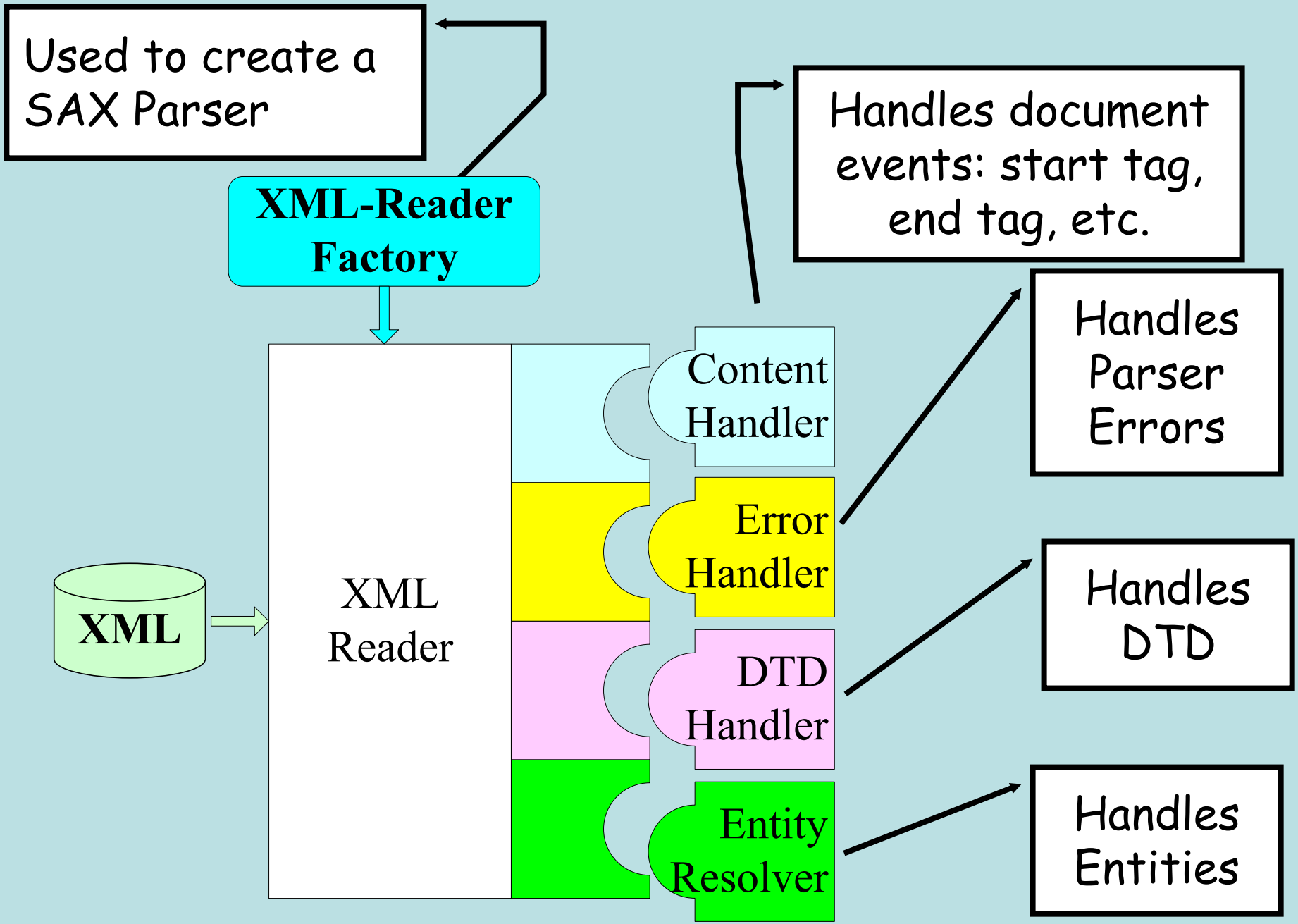
Orders Data in XML:
several orders, each with several items
each item has a part number and a quantity

```
<orders>
<order>
 <onum>1020</onum>
 <takenBy>1000</takenBy>
 <customer>1111</customer>
 <recDate>10-DEC-94</recDate>
 <items>
   <item>
     <pnum>10506</pnum>
     <quantity>1</quantity>
   </item>
   <item>
     <pnum>10507</pnum>
     <quantity>1</quantity>
   </item>
   <item>
     <pnum>10508</pnum>
     <quantity>2</quantity>
   </item>
   <item>
     <pnum>10509</pnum>
     <quantity>3</quantity>
   </item>
  </items>
</order>
...
</orders>
```



SAX Parsers


<?xml version="1.0"?>
.
.
.
SAX Parser
When you see the start of the document do
When you see the start of an element do …
When you see the end of an element do …


Used to create a SAX Parser
XML-Reader Factory
Handles document events: start tag, end tag, etc.
Handles Parser Errors
Handles DTD
Handles Entities
XML
XML Reader
Content Handler
Error Handler
DTD Handler
Entity Resolver

SAX API

Two important classes in the SAX API: `SAXParser` and `HandlerBase`.

A new `SAXParser` object is created by:

```
public SAXParser()
```

Register a SAX handler with the parser object to receive notifications of various parser events by:

```
public void setDocumentHandler(DocumentHandler h)
```

A similar method is available to register an error handler:

```
public void setErrorHandler(ErrorHandler h)
```

SAX API - Continued

- The `HandlerBase` class is a default base class for all handlers.
- It implements the default behavior for the various handlers.
- Application writers extend this class by rewriting the following event handler methods:

```
public void startDocument() throws SAXException
public void endDocument() throws SAXException
public void startElement() throws SAXException
public void endElement() throws SAXException
public void characters() throws SAXException
public void warning() throws SAXException
public void error() throws SAXException
```

Creating a SAX Parser

```
import org.xml.sax.*;
import oracle.xml.parser.v2.SAXParser;
public class SampleApp extends HandlerBase {
  // Global variables declared here
  static public void main(String [] args){
    Parser parser = new SAXParser();
    SampleApp app = new SampleApp();
    parser.setDocumentHandler(app);
    parser.setErrorHandler(app);
    try {
      parser.parse(createURL(args[0]).toString());
    } catch (SAXParseException e) {
        System.out.println(e.getMessage());
      }
  }
}
```

SAX API – Sample Application

Write a SAX Parser that reads the `orders.xml` file and extracts the various data items and creates SQL insert statements to insert the data into a relational database table.

```
//Global Variables
Vector itemNum = new Vector();
int numberOfRows, numberOfItems;
String elementEncountered, orderNumber, takenBy,
       customer, receivedDate, partNumber, quantity;
//elementEncountered holds most recent element name

public void startDocument() throws SAXException {
  //Print SQL comment, initialize variable
  System.out.println("--Start of SQL insert Statements");
  itemNum.setSize(1);
  numberOfRows = 0;
}//end startDocument
```

SAX API – Sample Application continued

```
public void startElement(String name,
                         AttributeList atts) throws SAXException {
  elementEncountered = name;
  if (name.equalsIgnoreCase("items")) {
    numberOfItems = 0;
  }//end if statement
}//end startElement

public void characters(char[] cbuf, int start, int len) {
  if (elementEncountered.equals("orderNumber")
    orderNumber = new String(cbuf,start,len);
  else if(elementEncountered.equals("takenBy")) {
    takenBy = new String(cbuf,start,len);
  ...
}//end characters
```

SAX API – Sample Application continued

```
public void endElement(String name) throws SAXException{
  if (name.equalsIgnoreCase("item")) {
    numberOfItems++;
    if (numberOfItems == 1) { // first item; create orders row
      System.out.println(
        "insert into orders values('"+
           orderNumber +"','"+ customer +"','"+
           takenBy +"','"+ receivedDate +"','null');");
      }
      System.out.println("insert into odetails values('"+
          orderNumber +"','"+ partNumber +"','"+
          quantity +"');");
  }//end if statement
  if (name.equalsIgnoreCase("items")) {
    System.out.println("--------");
  }
}//end endElement
```

SAX API – Sample Application continued

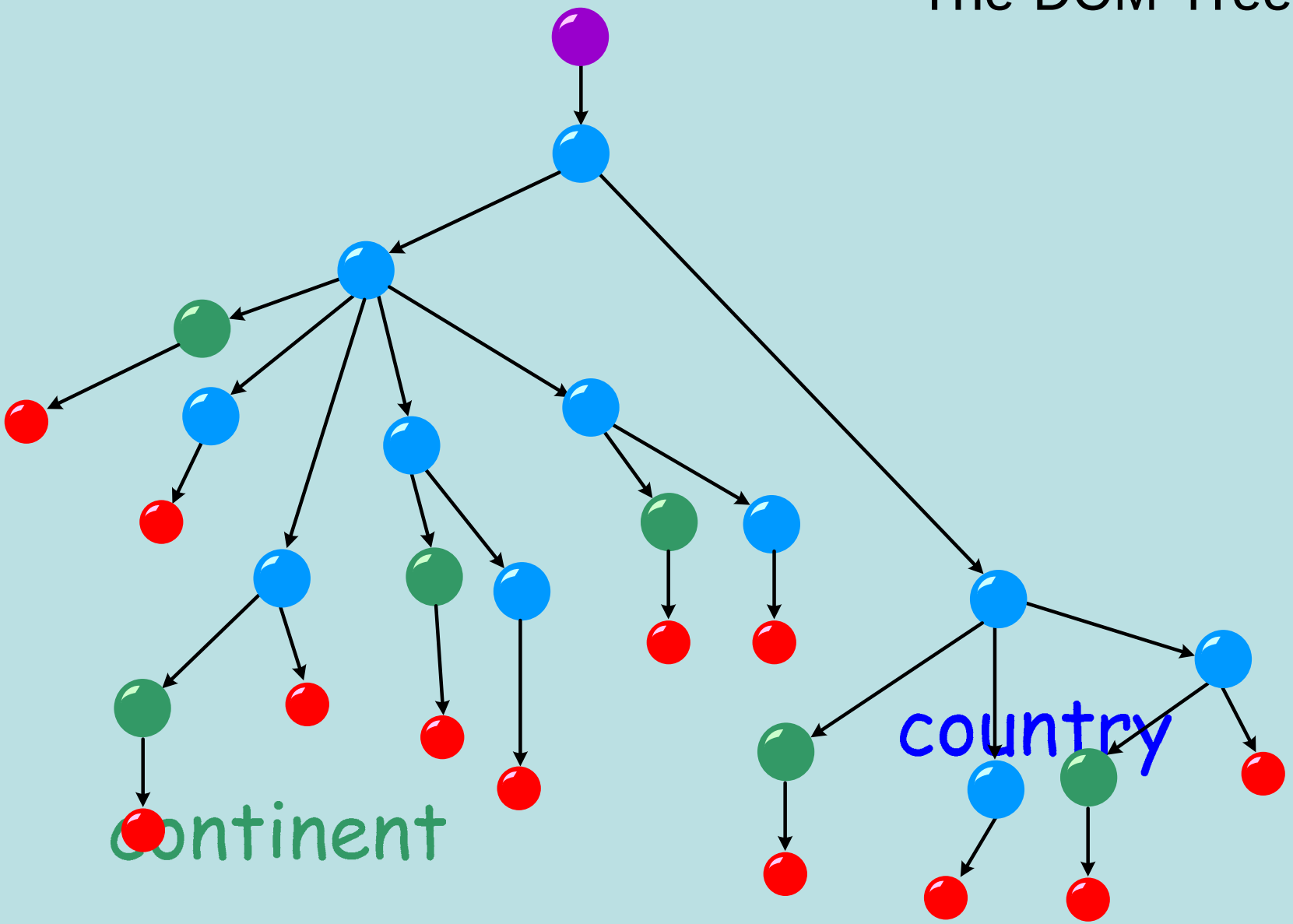
```
public void endDocument(){
  System.out.println("End of SQL insert statements.");
}//end endDocument

public void warning(SAXParseException e)
               throws SAXException {
  System.out.println("Warning:"+ e.getMessage());
}

public void error(SAXParseException e)
               throws SAXException{
  throw new SAXException(e.getMessage());
}
```

DOM Parser

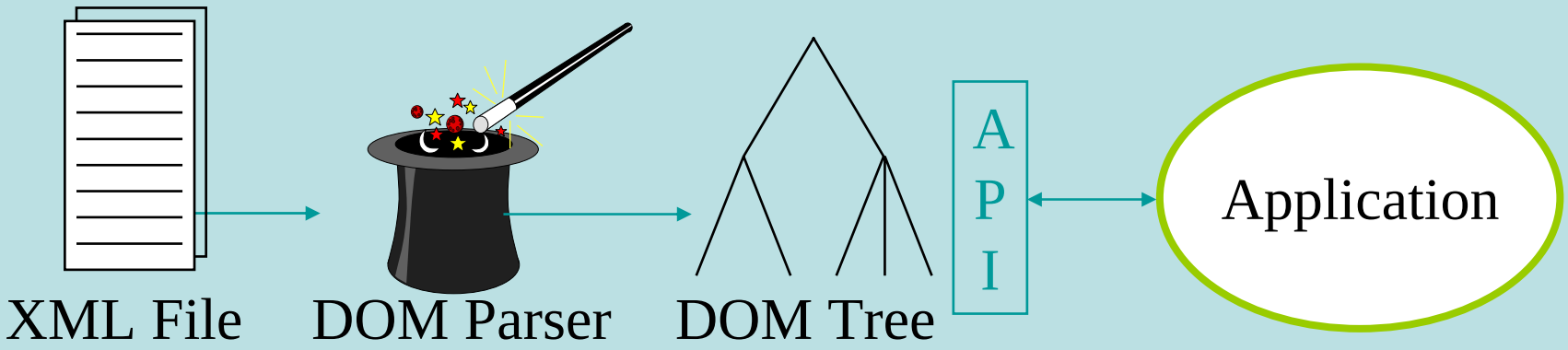
- DOM = Document Object Model
- Parser creates a tree object out of the document
- User accesses data by traversing the tree
  - The tree and its traversal conform to a W3C standard
- The API allows for constructing, accessing and manipulating the structure and content of XML documents

```
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6,199,008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60,424,213</population>
  </country>
</countries>
```

The DOM Tree



Using a DOM Tree



The Node Interface

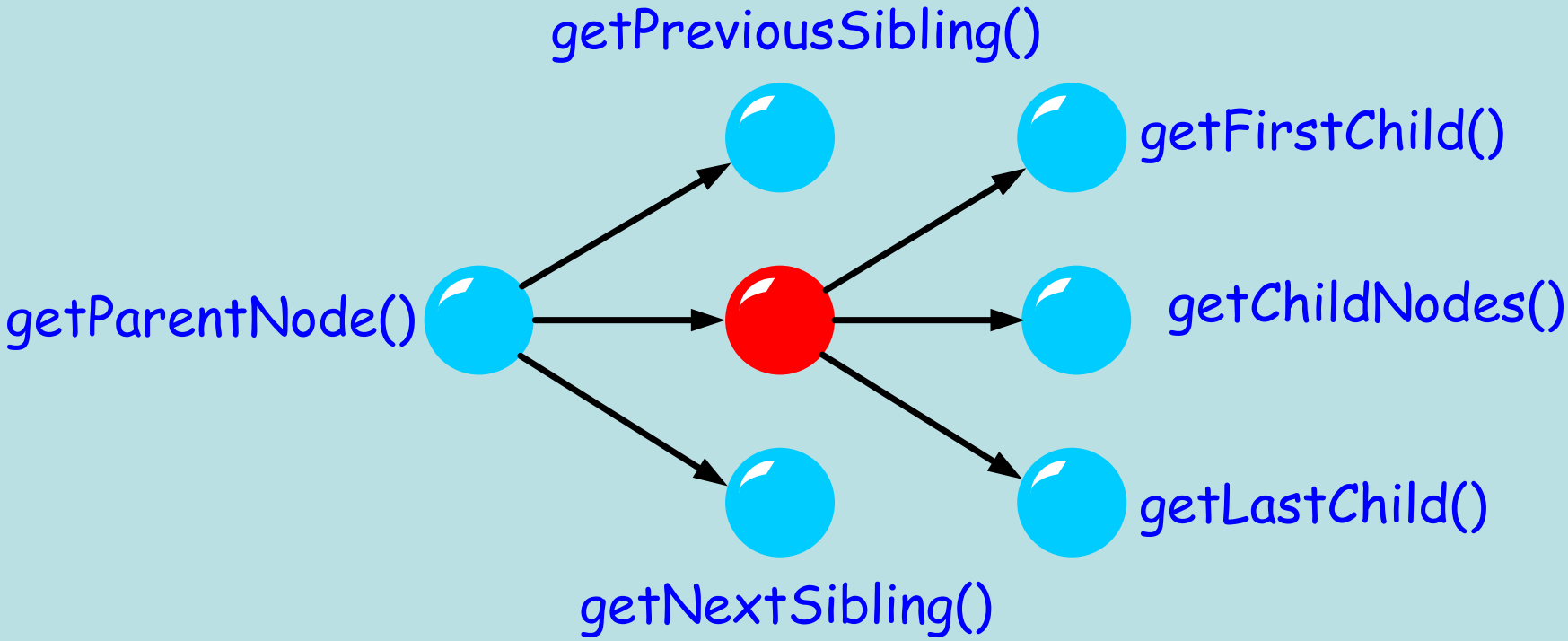
- The nodes of the DOM tree include
  - a special root (denoted *document*)
  - element nodes
  - text nodes and CDATA sections
  - attributes
  - comments
  - and more ...

- Every node in the DOM tree implements the **Node** interface

Node Navigation

- Every node has a specific location in tree
- **Node** interface specifies methods for tree navigation
  - `Node getFirstChild();`
  - `Node getLastChild();`
  - `Node getNextSibling();`
  - `Node getPreviousSibling();`
  - `Node getParentNode();`
  - `NodeList getChildNodes();`
  - `NamedNodeMap getAttributes()`

Node Navigation (cont)



DOM Parsing Example

Consider the following XML data file describing geographical information about states in U.S.

```
<?xml version="1.0" standalone="no"?>
<!DOCTYPE geography SYSTEM "geo.dtd">
<geography>
  <state id="georgia">
    <scode>GA</scode>
    <sname>Georgia</sname>
    <capital idref="atlanta"/>
    <citiesin idref="atlanta"/>
    <citiesin idref="columbus"/>
    <citiesin idref="savannah"/>
    <citiesin idref="macon"/>
    <nickname>Peach State</nickname>
    <population>6478216</population>
  </state>
  ...
  <city id="atlanta">
    <ccode>ATL</ccode>
    <cname>Atlanta</cname>
    <stateof idref="georgia"/>
  </city>
  ...
</geography>
```

Geography XML Data DTD

```
<!ELEMENT geography (state|city)*>
<!ELEMENT state (scode, sname, capital,
                 citiesin*, nickname, population)>
   <!ATTLIST state id ID #REQUIRED>
<!ELEMENT scode (#PCDATA)>
<!ELEMENT sname (#PCDATA)>
<!ELEMENT capital EMPTY>
   <!ATTLIST capital idref IDREF #REQUIRED>
<!ELEMENT citiesin EMPTY>
   <!ATTLIST citiesin idref IDREF #REQUIRED>
<!ELEMENT nickname (#PCDATA)>
<!ELEMENT population (#PCDATA)>
<!ELEMENT city (ccode, cname, stateof)>
   <!ATTLIST city id ID #IMPLIED>
<!ELEMENT ccode (#PCDATA)>
<!ELEMENT cname (#PCDATA)>
<!ELEMENT stateof EMPTY>
   <!ATTLIST stateof idref IDREF #REQUIRED>
```

Geography Data: SQL Schema (Oracle Objects)

```
create type city_type as object (
  ccode      varchar2(15),
  cname      varchar2(50)
);

create type cities_in_table as table of city_type;

create table state (
  scode      varchar2(15),
  sname      varchar2(50),
  nickname   varchar2(100),
  population number(30),
  capital    city_type,
  cities_in  cities_in_table,
  primary key (scode))
nested table cities_in store as cities_tab;
```

Create DOM Parser Object

```
import org.w3c.dom.*;
import org.w3c.dom.Node;
import oracle.xml.parser.v2.*;

public class CreateGeoData {
  static public void main(String[] argv)
      throws SQLException {
  // Get an instance of the parser
  DOMParser parser = new DOMParser();

  // Set various parser options: validation on,
  // warnings shown, error stream set to stderr.
  parser.setErrorStream(System.err);
  parser.setValidationMode(true);
  parser.showWarnings(true);

  // Parse the document.
  parser.parse(url);

  // Obtain the document.
  XMLDocument doc = parser.getDocument();
```

Traverse DOM Tree

```
NodeList sl = doc.getElementsByTagName("state");
NodeList cl = doc.getElementsByTagName("city");


XMLNode e = (XMLNode) sl.item(j);
scode = e.valueOf("scode");
sname = e.valueOf("sname");
nickname = e.valueOf("nickname");
population = Long.parseLong(e.valueOf("population"));

XMLNode child = (XMLNode) e.getFirstChild();
while (child != null) {
  if (child.getNodeName().equals("capital"))
     break;
  child = (XMLNode) child.getNextSibling();
}

NamedNodeMap nnm = child.getAttributes();
XMLNode n = (XMLNode) nnm.item(0);
```

Node Manipulation

- Children of a node in a DOM tree can be manipulated - added, edited, deleted, moved, copied, etc.

- To constructs new nodes, use the methods of Document
  - createElement, createAttribute, createTextNode, createCDATASection etc.

- To manipulate a node, use the methods of Node
  - appendChild, insertBefore, removeChild, replaceChild, setNodeValue, cloneNode(boolean deep) etc.

SAX vs DOM Parsing: Efficiency

- The DOM object built by DOM parsers is usually complicated and requires more memory storage than the XML file itself
  - A lot of time is spent on construction before use
  - For some very large documents, this may be impractical
- SAX parsers store only local information that is encountered during the serial traversal
- Hence, programming with SAX parsers is, in general, more efficient

Programming using SAX is Difficult

- In some cases, programming with SAX is difficult:
  - How can we find, using a SAX parser, elements *e1* with ancestor *e2*?
  - How can we find, using a SAX parser, elements *e1* that have a descendant element *e2*?
  - How can we find the element *e1* referenced by the IDREF attribute of *e2*?

Node Navigation

- SAX parsers do not provide access to elements other than the one currently visited in the serial (DFS) traversal of the document
- In particular,
  - They do not read backwards
  - They do not enable access to elements by ID or name
- DOM parsers enable any traversal method
- Hence, using DOM parsers is usually more comfortable

More DOM Advantages

- DOM object ⇔ compiled XML
- You can save time and effort if you send and receive DOM objects instead of XML files
  - But, DOM object are generally larger than the source
- DOM parsers provide a natural integration of XML reading and manipulating
  - e.g., “cut and paste” of XML fragments

Which should we use? DOM vs. SAX

- If your document is very large and you only need to extract only a few elements – use SAX
- If you need to manipulate (i.e., change) the XML – use DOM
- If you need to access the XML many times – use DOM (assuming the file is not too large)