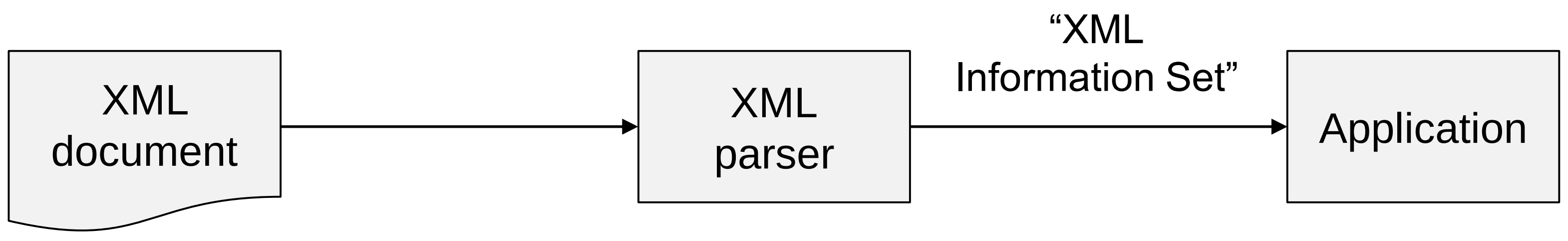
Up to Now

- **Week 1:** Semi-structured Data
- **Week 2:** XML Fundamentals & Namespaces
- **Week 3:** Document Type Definitions (DTDs)
- **Week 4:** XML Schema Definition (XSD)

How XML Works

- Strict rules regarding the syntax of XML documents - allows for the development of XML parsers that can read documents

- Applications that need to understand an XML document will use a parser

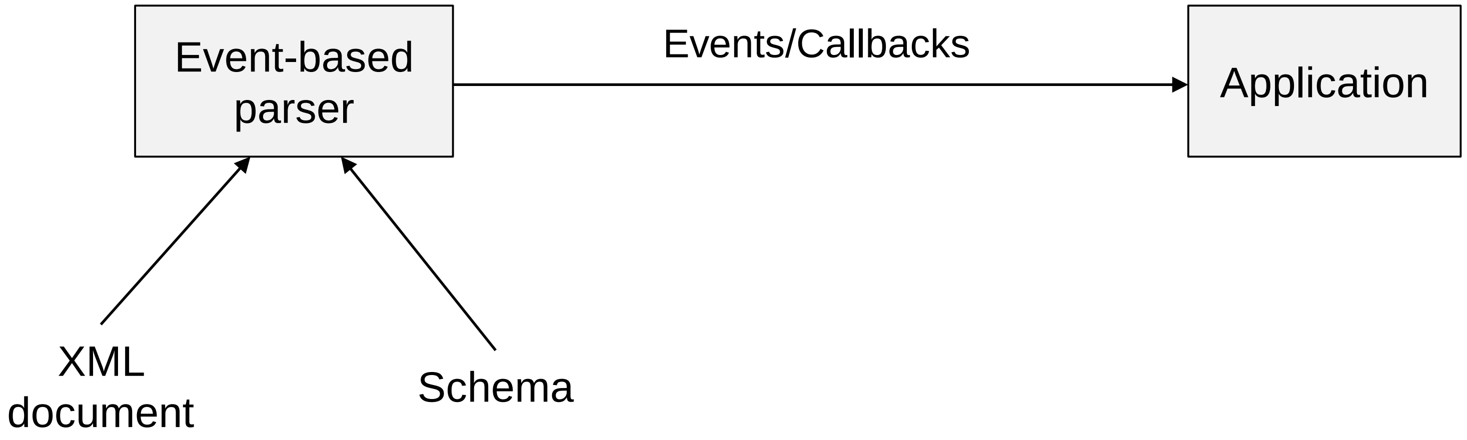


Splits the document into individual pieces

Event-Based Parsers

- Report parsing events, such as the start and end of elements, directly to the application

- The application implements handlers to deal with the different events



Event-Based Parsers

parse

```
<element attr=“attr-value”>
      …text-1…
      <subelement>…text-2…</subelement>
</element>
```

Events/Callbacks

start document

start element: “element”

attribute name=“attr” value=“attr-value”

characters: “…text-1…”

start element: “subelement”

characters: “…text-2…”

end element: “subelement”

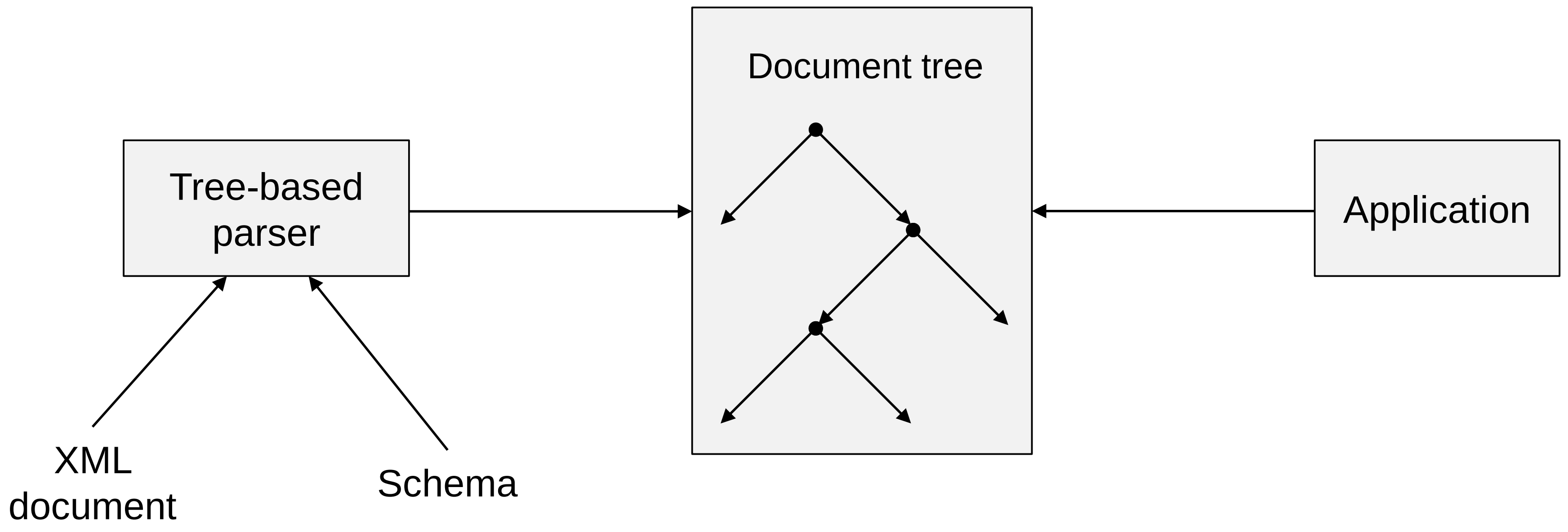
end element: “element”

end document

Tree-Based Parsers

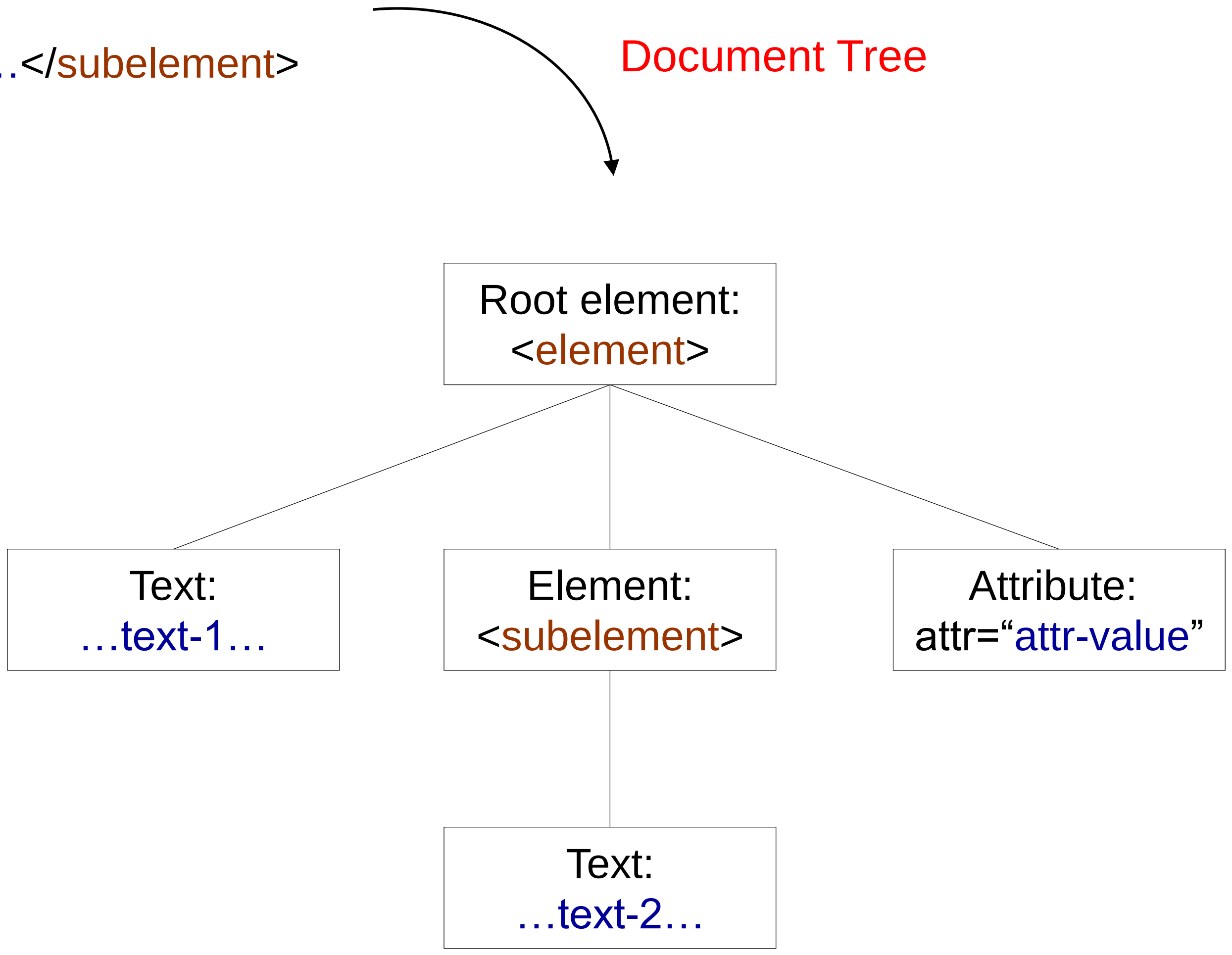
- Map an XML document into an internal tree structure stored in main memory

- The application navigates that tree



Tree-Based Parsers

```
<element attr="attr-value">
    …text-1…
    <subelement>…text-2…</subelement>
</element>
```



Event-Based vs. Tree-Based Parsers

Event-based	Tree-based
• Sequential access	• Random access
• Fast	• Slow
• Constant memory	• Proportional to the document size

+

• Large documents	• Small documents
• Lack of data structure	• Ready-made data structure

Standards for XML Parsers

- SAX - Simple API for XML (event-based)
    - “De facto” standard

- DOM - Document Object Model (tree-based)
    - W3C standard

… APIs to read and interpret XML documents

… we first focus on SAX

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Semi-structured Data

6 - Simple API for XML (SAX)

Andreas Pieris and Wolfgang Fischl, Summer Term 2016

Outline

- Callbacks
- A Simple SAX Program
- Content Handling
- Error Handling
- Features

SAX - Simple API for XML

- An event-based API for reading XML documents

- No W3C standard, but a “de facto” standard - very popular

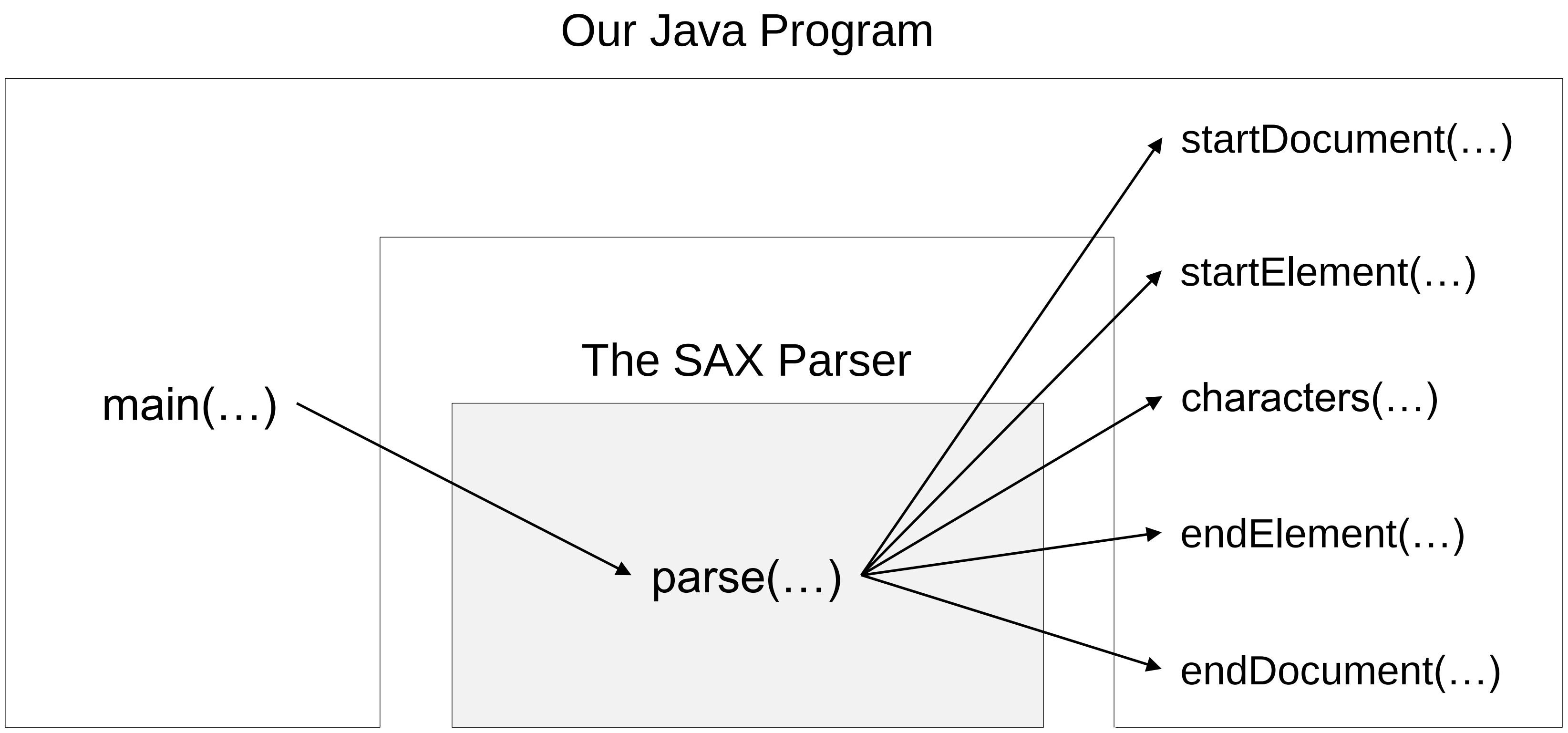
- Free and open source - http://www.saxproject.org

- Originally a Java-only API, but there are versions for several other programming languages (C++, Python, Perl, etc.)

ATTENTION: We focus on the Java version of the API

Callbacks

- SAX works through callbacks - we call the parser, it calls methods that we supply



Callbacks

- SAX works through callbacks - we call the parser, it calls methods that we supply

- Callback functions are divided into four event handlers:
    - ContentHandler - it handles basic parsing callbacks (e.g., element starts)
    - ErrorHandler - it handles parsing errors
    - DTDHandler - it handles notation and unparsed entity declarations
    - EntityResolution - customized handling for external entities

the crucial event handlers

A Simple SAX Program

course.xml

```
<?xml version="1.0"?>
<course>Semi-structured Data</course>
```

Expected Result

```
startElement: course
characters: Semi-structured Data
endElement: course
```

A Simple SAX Program

- The program consists of two classes:
    - Course - it contains the main method
        - Creates an XMLReader - the actual parser that reads the XML document and calls the callbacks

```
XMLReader parser = XMLReaderFactory.createXMLReader();
```

        - Installs the content handler

```
Handler handler = new Handler();
parser.setContentHandler(handler);
```

        - Starts the parsing

```
parser.parse(“course.xml”);
```

A Simple SAX Program

- The program consists of two classes:
    - Handler - contains handlers for three kinds of callbacks
        - startElement callbacks, generated when a start tag is seen
        - endElement callbacks, generated when an end tag is seen
        - characters callbacks, generated for the content of an element

A Simple SAX Program: Class Course

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;

public class Course {
	public static void main(String[] args) throws Exception {
		//create XMLReader
		XMLReader parser = XMLReaderFactory.createXMLReader();

		//install the content handler
		Handler handler = new Handler();
		parser.setContentHandler(handler);

		//start parsing
		for (int i =0; i < args.length; i++) {
			parser.parse(args[i]);
		}
	}
}
```

A Simple SAX Program: Class Handler

```
import org.xml.sax.*;

public class Handler implements ContentHandler {
        //SAX calls this method when it encounters a start tag
        public void startElement(String namespaceURI,
                                         String localName,
                                         String qualifiedName,
                                         Attributes atts) throws SAXException {
                System.out.println(“startElement: ” + qualifiedName);
        }
```

A Simple SAX Program: Class Handler

```
import org.xml.sax.*;

public class Handler implements ContentHandler {
    //SAX calls this method when it encounters a start tag
    ...

    //SAX calls this method to pass in character data
    public void characters(char[] text, int start, int length)
                throws SAXException {
        System.out.println(“characters: ” + new String(text, start, length));
    }
```

A Simple SAX Program: Class Handler

```
import org.xml.sax.*;

public class Handler implements ContentHandler {
    //SAX calls this method when it encounters a start tag
    ...

    //SAX calls this method to pass in character data
    ...

    //SAX calls this method when it encounters an end tag
    public void endElement(String namespaceURI,
                           String localName,
                           String qualifiedName) throws SAXException {
        System.out.println(“endElement: ” + qualifiedName);
    }
} // end of Handler class
```

A Simple SAX Program: Class Handler

```
import org.xml.sax.*;

public class Handler implements ContentHandler {
    //SAX calls this method when it encounters a start tag
    ...

    //SAX calls this method to pass in character data
    ...

    //SAX calls this method when it encounters an end tag
    ...

    //we have to implement do-nothing methods to fulfil the interface requirements
    //for example
    public void processingInstruction(String target, String data) { }
    //and several other methods
} // end of Handler class
```

A Simple SAX Program

course.xml

```
<?xml version="1.0"?>
<course>Semi-structured Data</course>
```

Result

```
startElement: course
characters: Semi-structured Data
endElement: course
```

A Simple SAX Program

course.xml

```
<?xml version="1.0"?>
<course>
        <acronym>SSD</acronym>
        Semi-structured Data
</course>
```

Result

```
startElement: course
characters: \n
characters:
startElement: acronym
characters: SSD
endElement: acronym
characters:       Semi-structured Data
characters: \n
endElement: course
```

A Simple SAX Program: Class Handler

```
import org.xml.sax.*;

public class Handler implements ContentHandler {
	//SAX calls this method when it encounters a start tag
	...

	//SAX calls this method to pass in character data
	...

	//SAX calls this method when it encounters an end tag
	...

	//we have to implement do-nothing methods to fulfil the interface requirements
	//for example
	public void processingInstruction(String target, String data) { }
	//and several other methods
} // end of Handler class
```

…is it possible to avoid this?

Class DefaultHandler

- In package org.xml.sax.helpers
- Implements all the handlers mentioned before (ContentHandler, ErrorHandler, DTDHandler, EntityResolver)
- An adapter class - it provides empty methods for every method declared in each of the four interfaces
- Extend it and override the methods that are important for the current application

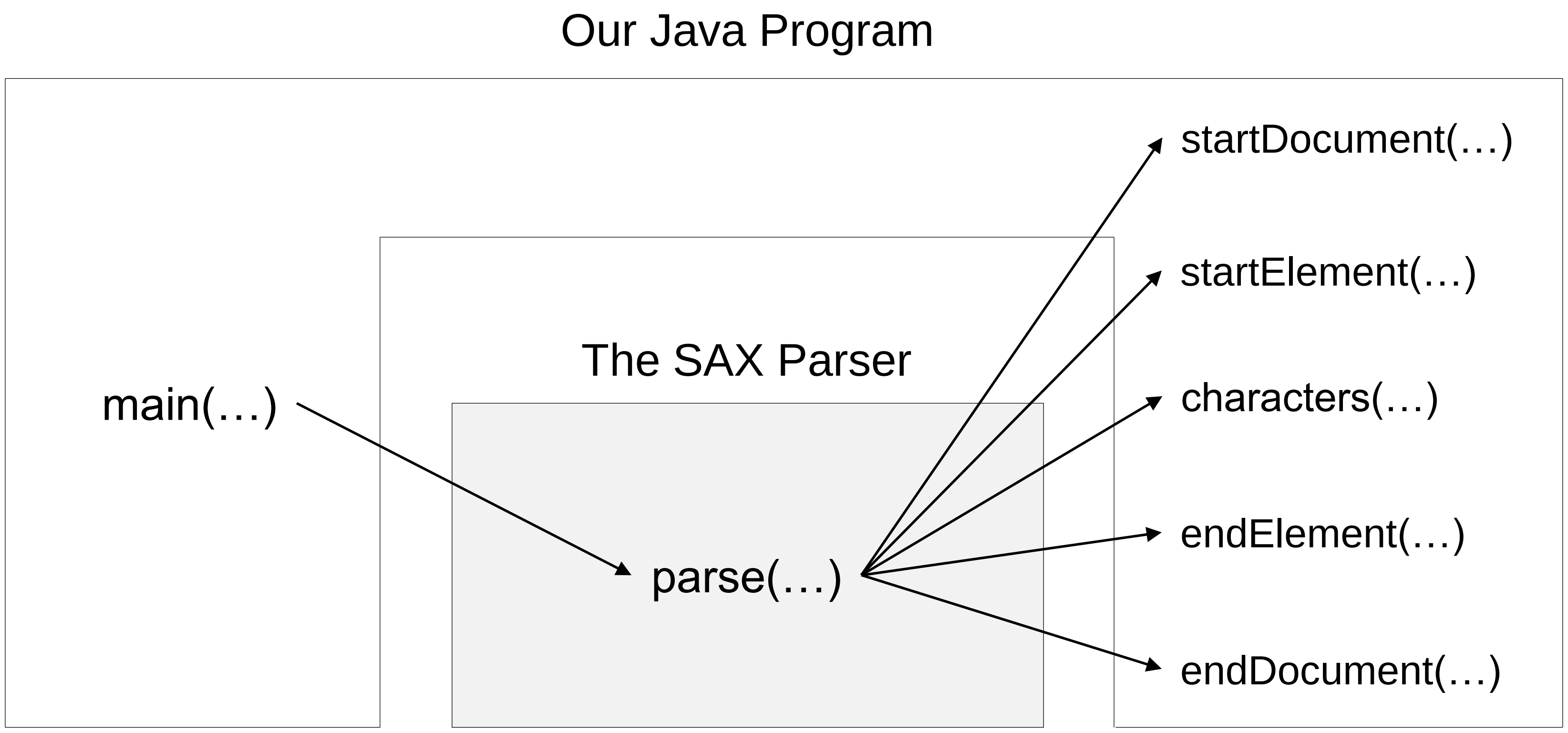
http://docs.oracle.com/javase/7/docs/api/org/xml/sax/helpers/DefaultHandler.html

A Simple SAX Program: Class Handler Revisited

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;

public class Handler extends DefaultHandler {
        //SAX calls this method when it encounters a start tag
        ...

        //SAX calls this method to pass in character data
        ...

        //SAX calls this method when it encounters an end tag
        ...

        //the do-nothing methods are not needed anymore
} // end of Handler class
```

Callbacks

- SAX works through callbacks - we call the parser, it calls methods that we supply



Callbacks

- SAX works through callbacks - we call the parser, it calls methods that we supply

- Callback functions are divided into four event handlers:
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    - DTDHandler - it handles notation and unparsed entity declarations
    - EntityResolution - customized handling for external entities

… more details for the methods of ContentHandler
can be found in the SAX-methods slides

https://docs.oracle.com/javase/7/docs/api/org/xml/sax/ContentHandler.html

Up to Now

- **Callbacks**
- **A Simple SAX Program**
- **Content Handling**
- Error Handling
- Features

Error Handling

- We need to install an error handler
- … otherwise, most parsing errors will be ignored
- ErrorHandler - it handles parsing errors

Error Handling: Example

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;

public class Course {
        public static void main(String[] args) throws Exception {
                //create XMLReader
                XMLReader parser = XMLReaderFactory.createXMLReader();

                //install the content and error handler
                Handler handler = new Handler();
                parser.setContentHandler(handler);
                parser.setErrorHandler(handler);

                //start parsing
                for (int i =0; i < args.length; i++) {
                        parser.parse(args[i]);
                }
        }
}
```

ErrorHandler Methods

```
public void fatalError(SAXParseException ex) throws SAXException
```

well-formedness error

```
public void error(SAXParseException ex) throws SAXException
```

validation error

```
public void warning(SAXParseException ex) throws SAXException
```

minor error

https://docs.oracle.com/javase/7/docs/api/org/xml/sax/ErrorHandler.html

Error Handling: Example

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;
public class Handler extends DefaultHandler {
        //Content handling
        //Error handling
        public void fatalError(SAXParseException ex) throws SAXException {
                printError(“FATAL ERROR”, ex)
        }
        public void error(SAXParseException ex) throws SAXException {
                printError(“ERROR”, ex)
        }
        public void warning(SAXParseException ex) throws SAXException {
                printError(“WARNING”, ex)
        }

        private void printError(String err, SAXParseException ex) {
                System.out.printf(“%s at %3d, %3d: %s \n”, err, ex.getLineNumber(), ex.getColumnNumber(),
                                                                        ex.getMessage());
        }
} // end of Handler class
```

Up to Now

- **Callbacks**
- **A Simple SAX Program**
- **Content Handling**
- **Error Handling**
- Features

Features

- SAX uses features to control parser’s behavior
- Each feature has an absolute URI as a name
- Features are either true or false

Some Features

- http://xml.org/sax/features/validation
    - Validate the document and report validity errors
    - Default value is false

- http://xml.org/sax/features/namespaces
    - The parser is namespace-aware
    - Default value is true

see https://xerces.apache.org/xerces2-j/features.html

Example startElement Method

```
public void startElement(String namespaceURI,
                         String localName,
                         String qualifiedName,
                         Attributes atts) throws SAXException
```

is called once at the beginning of every element

- If the parser is namespace-aware
  - namespaceURI holds the prefix (prefix:localname)
  - localName holds the element name (without a prefix)
  - qualifiedName is empty
- If the parser is not namespace-aware
  - namespaceURI, localName are empty
  - qualifiedName holds the element name (possibly with a prefix)

Set Feature

```
public void setFeature(java.lang.String name, boolean value)
          throws SAXNotRecognizedException
          throws SAXNotSupportedException
```

- name - the name of the feature (an absolute URI)
- value - value of the feature (true or false)
- SAXNotRecognizedException - if the feature cannot be assigned
  - Turn on validation in a non-validating parser
- SAXNotSupportedException - if the feature cannot be activated
  - Turn on validation (in a validating parser) when part of the document has been already parsed

Set Feature: Example

```
import org.xml.sax.*;
import org.xml.sax.helpers.*;
public class Course {
        public static void main(String[] args) throws Exception {
                //create XMLReader
                XMLReader parser = XMLReaderFactory.createXMLReader();

                //install the content and error handler
                Handler handler = new Handler();
                parser.setContentHandler(handler);
                parser.setErrorHandler(handler);

                //turn on validation
                parser.setFeature("http://xml.org/sax/features/validation", true);

                //start parsing
                for (int i =0; i < args.length; i++) {
                        parser.parse(args[i]);
                }
        }
}
```

Sum Up

- Callbacks
- A Simple SAX Program
- Content Handling
- Error Handling
- Features

Standards for XML Parsers

- SAX - Simple API for XML (event-based)
  - “De facto” standard ✓

- DOM - Document Object Model (tree-based)
  - W3C standard

… APIs to read and interpret XML documents

… next we will focus on DOM