24

XML and LINQ to XML

I played with an idea, and grew willful; tossed it into the air; transformed it; let it escape and recaptured it; made it iridescent with fancy, and winged it with paradox.
—Oscar Wilde

Objectives

In this chapter you'll:

- Mark up data using XML.
- Specify and validate an XML document's structure.
- Create and use simple XSL style sheets to render XML document data.
- Use the Document Object Model (DOM) to manipulate XML in C# programs.
- Use LINQ to XML to extract and manipulate data from XML documents.
- Create new XML documents using the classes provided by the .NET Framework.
- Work with XML namespaces in your C# code.
- Transform XML documents into XHTML using class `XslCompiledTransform`.

Outline

24.1 Introduction

In this chapter, we begin our introduction to XML. The .NET Framework uses XML extensively. Many of the configuration files that Visual Studio creates—such as those that represent project settings—use XML format. XML is also used heavily in serialization, as you'll see in Chapter 30, Web Services. In Chapters 25–27 and Chapters 32–33, you'll also use XAML—an XML *vocabulary* used for creating user interfaces. XAML is also used with Microsoft Silverlight to develop rich Internet applications

In this chapter, you'll learn XML's syntax and how to use XML namespaces. You'll also learn how to create DTDs and schemas to validate your XML documents. Sections 24.7–24.11 demonstrate techniques for working with XML documents in C# applications. Visual C# provides language features and .NET Framework classes for working with XML. **LINQ to XML** provides a convenient way to manipulate data in XML documents using the same LINQ syntax you used on arrays and collections in Chapter 9. LINQ to XML also provides a set of classes for easily navigating and creating XML documents in your code.

24.2 XML Basics

The Extensible Markup Language was developed in 1996 by the **World Wide Web Consortium's** (**W3C's**) XML Working Group. XML is a widely supported standard for describing data that is commonly used to exchange that data between applications over the Internet. It permits document authors to create markup for virtually any type of information. This enables them to create entirely new markup languages for describing any type of data, such as mathematical formulas, software-configuration instructions, chemical molecular structures, music, news, recipes and financial reports. XML describes data in a way that both human beings and computers can understand.

Figure 24.1 is a simple XML document that describes information for a baseball player. We focus on lines 5–11 to introduce basic XML syntax. You'll learn about the other elements of this document in Section 24.3.

XML documents contain text that represents content (that is, data), such as `John` (line 6), and **elements** that specify the document's structure, such as `firstName` (line 6). XML documents delimit elements with **start tags** and **end tags**. A start tag consists of the element name in **angle brackets** (for example, `<player>` and `<firstName>` in lines 5 and 6,

```
1  <?xml version = "1.0"?>
2  <!-- Fig. 24.1: player.xml -->
3  <!-- Baseball player structured with XML -->
4
5  <player>
6     <firstName>John</firstName>
7
8     <lastName>Doe</lastName>
9
10    <battingAverage>0.375</battingAverage>
11 </player>
```

Fig. 24.1 | XML that describes a baseball player's information.

respectively). An end tag consists of the element name preceded by a **forward slash** (`/`) in angle brackets (for example, `</firstName>` and `</player>` in lines 6 and 11, respectively). An element's start and end tags enclose text that represents a piece of data (for example, the `firstName` of the `player`—`John`—in line 6, which is enclosed by the `<firstName>` start tag and and `</firstName>` end tag) or other elements (for example, the `firstName`, `lastName`, and `battingAverage` elements in the `player` element). Every XML document must have exactly one **root element** that contains all the other elements. In Fig. 24.1, `player` (lines 5–11) is the root element.

Some XML-based markup languages include MathML (for mathematics), VoiceXML™ (for speech), CML (Chemical Markup Language—for chemistry) and XBRL (Extensible Business Reporting Language—for financial data exchange). ODF (Open Document Format—developed by Sun Microsystems) and OOXML (Office Open XML—developed by Microsoft as a replacement for the old proprietary Microsoft Office formats) are two competing standards for electronic office documents such as spreadsheets, presentations, and word processing documents. These markup languages are called XML **vocabularies** and provide a means for describing particular types of data in standardized, structured ways.

Massive amounts of data are currently stored on the Internet in a variety of formats (for example, databases, web pages, text files). Based on current trends, it's likely that much of this data, especially that which is passed between systems, will soon take the form of XML. Organizations see XML as the future of data encoding. Information-technology groups are planning ways to integrate XML into their systems. Industry groups are developing custom XML vocabularies for most major industries that will allow computer-based business applications to communicate in common languages. For example, web services, which we discuss in Chapter 30, allow web-based applications to exchange data seamlessly through standard protocols based on XML. Also, web services are described by an XML vocabulary called WSDL (Web Services Description Language).

The next generation of the Internet and World Wide Web is being built on a foundation of XML, which enables the development of more sophisticated web-based applications. XML allows you to assign meaning to what would otherwise be random pieces of data. As a result, programs can "understand" the data they manipulate. For example, a web browser might view a street address listed on a simple web page as a string of characters without any real meaning. In an XML document, however, this data can be clearly identified (that is, marked up) as an address. A program that uses the document can recognize this data as an address and provide links to a map of that location, driving directions from that location or other location-specific information. Likewise, an application can recognize names of people, dates, ISBN numbers and any other type of XML-encoded data. Based on this data, the application can present users with other related information, providing a richer, more meaningful user experience.

Viewing and Modifying XML Documents

XML documents are portable. Viewing or modifying an XML document—a text file, usually with the `.xml` file-name extension—does not require special software, although many software tools exist, and new ones are frequently released that make it more convenient to develop XML-based applications. Most text editors can open XML documents for viewing and editing. Visual C# Express includes an XML editor that provides *IntelliSense*. The editor also checks that the document is well formed and is valid if a schema (discussed shortly) is present. Also, most web browsers can display an XML document in a formatted manner that shows its structure. We demonstrate this using Internet Explorer in Section 24.3. One important characteristic of XML is that it's both human readable and machine readable.

Processing XML Documents

Processing an XML document requires software called an **XML parser** (or **XML processor**). A parser makes the document's data available to applications. While reading the contents of an XML document, a parser checks that the document follows the syntax rules specified by the W3C's XML Recommendation (`www.w3.org/XML`). XML syntax requires a single root element, a start tag and end tag for each element and properly nested tags (that is, the end tag for a nested element must appear before the end tag of the enclosing element). Furthermore, XML is case sensitive, so the proper capitalization must be used in elements. A document that conforms to this syntax is a **well-formed XML document**, and is syntactically correct. We present fundamental XML syntax in Section 24.3. If an XML parser can process an XML document successfully, that XML document is well formed. Parsers can provide access to XML-encoded data in well-formed documents only—if a document is not well-formed, the parser will report an error to the user or calling application.

Often, XML parsers are built into software such as Visual Studio or available for download over the Internet. You can find a list of many popular XML parsers at

```
http://en.wikipedia.org/wiki/Category:XML_parsers
```

Validating XML Documents

An XML document can optionally reference a **Document Type Definition** (**DTD**) or a **W3C XML Schema** (referred to simply as a "schema" for the rest of this book) that defines the XML document's proper structure. When an XML document references a DTD or a schema, some parsers (called **validating parsers**) can use the DTD/schema to check that it has the appropriate structure. If the XML document conforms to the DTD/schema (that is, the document has the appropriate structure), the XML document is **valid**. For example, if in Fig. 24.1 we were referencing a DTD that specifies that a `player` element must have `firstName`, `lastName` and `battingAverage` elements, then omitting the `lastName` element (line 8) would cause the XML document `player.xml` to be invalid. The

XML document would still be well formed, however, because it follows proper XML syntax (that is, it has one root element, and each element has a start and an end tag). By definition, a valid XML document is well formed. Parsers that cannot check for document conformity against DTDs/schemas are **nonvalidating parsers**—they determine only whether an XML document is well formed.

You'll learn more about validation, DTDs and schemas, as well as the key differences between these two types of structural specifications, later in this chapter. For now, schemas are XML documents themselves, whereas DTDs are not. As you'll learn, this difference presents several advantages in using schemas over DTDs.

Software Engineering Observation 24.1

DTDs and schemas are essential for business-to-business (B2B) transactions and mission-critical systems. Validating XML documents ensures that disparate systems can manipulate data structured in standardized ways and prevents errors caused by missing or malformed data.

Formatting and Manipulating XML Documents

XML documents contain only data, not formatting instructions, so applications that process XML documents must decide how to manipulate or display each document's data. For example, a PDA (personal digital assistant) may render an XML document differently than a wireless phone or a desktop computer. You can use **Extensible Stylesheet Language** (**XSL**) to specify rendering instructions for different platforms. We discuss XSL in Section 24.7.

XML-processing programs can also search, sort and manipulate XML data using technologies such as XSL. Some other XML-related technologies are XPath (XML Path Language—a language for accessing parts of an XML document), XSL-FO (XSL Formatting Objects—an XML vocabulary used to describe document formatting) and XSLT (XSL Transformations—a language for transforming XML documents into other documents). We present XSLT and XPath in Section 24.7. We'll also present new C# features that greatly simplify working with XML in your code. With these features, XSLT and similar technologies are not needed while coding in C#, but they remain relevant on platforms where C# and .NET are not available.

24.3 Structuring Data

In Fig. 24.2, we present an XML document that marks up a simple article using XML. The line numbers shown are for reference only and are not part of the XML document.

```
<?xml version = "1.0"?>
<!-- Fig. 24.2: article.xml -->
<!-- Article structured with XML -->

<article>
   <title>Simple XML</title>

```

Fig. 24.2 | XML used to mark up an article. (Part 1 of 2.)

```
 8     <date>July 24, 2013</date>
 9
10     <author>
11        <firstName>John</firstName>
12        <lastName>Doe</lastName>
13     </author>
14
15     <summary>XML is pretty easy.</summary>
16
17     <content>
18        In this chapter, we present a wide variety of examples that use XML.
19     </content>
20  </article>
```

Fig. 24.2 | XML used to mark up an article. (Part 2 of 2.)

This document begins with an **XML declaration** (line 1), which identifies the document as an XML document. The **version attribute** specifies the XML version to which the document conforms.

Some XML documents also specify an **encoding attribute** in the XML declaration. An encoding specifies how characters are stored in memory and on disk—historically, the way an uppercase "A" was stored on one computer architecture was different than the way it was stored on a different computer architecture. Appendix F discusses Unicode, which specifies encodings that can describe characters in any written language. An introduction to different encodings in XML can be found at the website bit.ly/EncodeXMLData.

Portability Tip 24.1

Documents should include the XML declaration to identify the version of XML used. A document that lacks an XML declaration might be assumed erroneously to conform to the latest version of XML—in which case, errors could result.

Common Programming Error 24.1

Placing whitespace characters before the XML declaration is an error.

XML comments (lines 2–3), which begin with <!-- and end with -->, can be placed almost anywhere in an XML document. XML comments can span to multiple lines—an end marker on each line is not needed; the end marker can appear on a subsequent line, as long as there is exactly one end marker (-->) for each begin marker (<!--). Comments are used in XML for documentation purposes. Line 4 is a blank line. As in a C# program, blank lines, whitespaces and indentation are used in XML to improve readability. Later you'll see that the blank lines are normally ignored by XML parsers.

Common Programming Error 24.2

In an XML document, each start tag must have a matching end tag; omitting either tag is an error. Soon, you'll learn how such errors are detected.

> **Common Programming Error 24.3**
> *XML is case sensitive. Using different cases for the start-tag and end-tag names for the same element is a syntax error.*

In Fig. 24.2, `article` (lines 5–20) is the root element. The lines that precede the root element (lines 1–4) are the XML **prolog**. In an XML prolog, the XML declaration must appear before the comments and any other markup.

The elements we used in the example do not come from any specific markup language. Instead, we chose the element names and markup structure that best describe our particular data. You can invent whatever elements make sense for the particular data you're dealing with. For example, element `title` (line 6) contains text that describes the article's title (for example, `Simple XML`). Similarly, `date` (line 8), `author` (lines 10–13), `firstName` (line 11), `lastName` (line 12), `summary` (line 15) and `content` (lines 17–19) contain text that describes the date, author, the author's first name, the author's last name, a summary and the content of the document, respectively. XML element and attribute names can be of any length and may contain letters, digits, underscores, hyphens and periods. However, they must begin with either a letter or an underscore, and they should not begin with "`xml`" in any combination of uppercase and lowercase letters (for example, `XML`, `Xml`, `xMl`), as this is reserved for use in the XML standards.

> **Common Programming Error 24.4**
> *Using a whitespace character in an XML element name is an error.*

> **Good Programming Practice 24.1**
> *XML element names should be meaningful to humans and should not use abbreviations.*

XML elements are **nested** to form hierarchies—with the root element at the top of the hierarchy. This allows document authors to create parent/child relationships between data. For example, elements `title`, `date`, `author`, `summary` and `content` are nested within `article`. Elements `firstName` and `lastName` are nested within `author`.

> **Common Programming Error 24.5**
> *Nesting XML tags improperly is a syntax error—it causes an XML document to not be well-formed. For example, `<x><y>hello</x></y>` is an error, because the `</y>` tag must precede the `</x>` tag.*

Any element that contains other elements (for example, `article` or `author`) is a **container element**. Container elements also are called **parent elements**. Elements nested inside a container element are **child elements** (or children) of that container element.

Viewing an XML Document in Internet Explorer

The XML document in Fig. 24.2 is simply a text file named `article.xml`. This document does not contain formatting information for the article. The reason is that XML is a technology for describing the structure of data. Formatting and displaying data from an XML document are application-specific issues. For example, when the user loads `article.xml` in Internet Explorer (IE), the browser parses and displays the document's data. Internet

Explorer uses a built-in **style sheet** to format the data. The resulting format (Fig. 24.3) is similar to the code listing in Fig. 24.2. In Section 24.7, we show how to create style sheets to transform your XML data into various formats suitable for display.

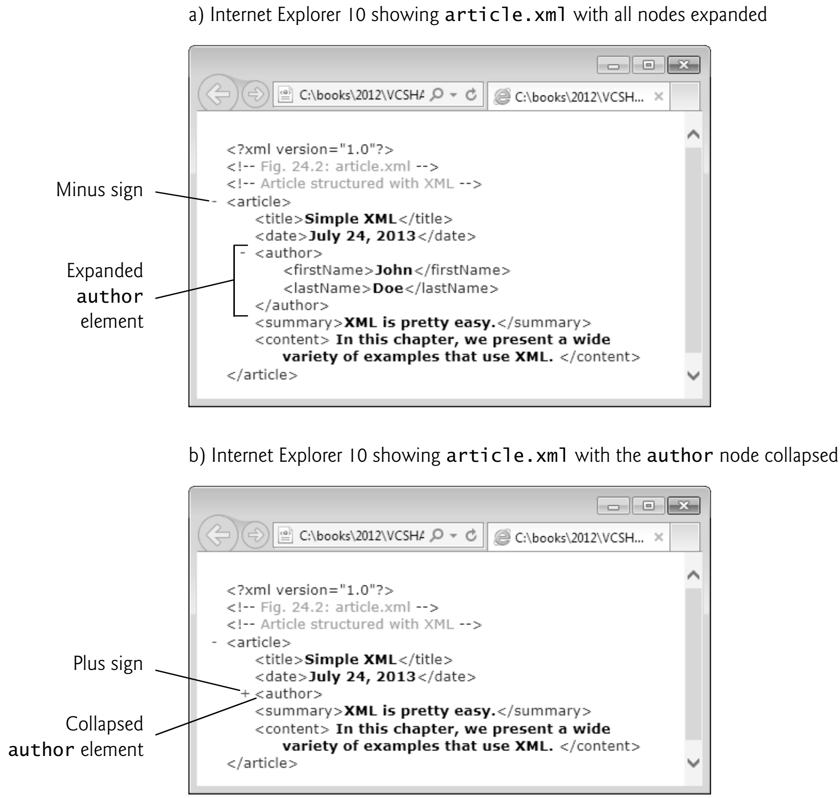


Fig. 24.3 | `article.xml` displayed by Internet Explorer 10 on Windows 7.

Note the minus sign (–) and plus sign (+) in the screenshots of Fig. 24.3. Although these symbols are not part of the XML document, Internet Explorer places them next to every container element. A minus sign indicates that Internet Explorer is displaying the container element's child elements. Clicking the minus sign next to an element collapses that element (that is, causes Internet Explorer to hide the container element's children and replace the minus sign with a plus sign). Conversely, clicking the plus sign next to an element expands that element (that is, causes Internet Explorer to display the container element's children and replace the plus sign with a minus sign). This behavior is similar to viewing the directory structure using Windows Explorer. In fact, a directory structure often is modeled as a series of tree structures, in which the **root** of a tree represents a drive letter (for example, `C:`), and **nodes** in the tree represent directories. Parsers often store XML data as tree structures to facilitate efficient manipulation.

XML Markup for a Business Letter

Now that we have seen a simple XML document, let's examine a more complex one that marks up a business letter (Fig. 24.4). Again, we begin the document with the XML declaration (line 1) that states the XML version to which the document conforms.

```
1  <?xml version = "1.0"?>
2  <!-- Fig. 24.4: letter.xml -->
3  <!-- Business letter marked up as XML -->
4
5  <!DOCTYPE letter SYSTEM "letter.dtd">
6
7  <letter>
8     <contact type = "sender">
9        <name>Jane Doe</name>
10       <address1>Box 12345</address1>
11       <address2>15 Any Ave.</address2>
12       <city>Othertown</city>
13       <state>Otherstate</state>
14       <zip>67890</zip>
15       <phone>555-4321</phone>
16       <flag gender = "F" />
17    </contact>
18
19    <contact type = "receiver">
20       <name>John Doe</name>
21       <address1>123 Main St.</address1>
22       <address2></address2>
23       <city>Anytown</city>
24       <state>Anystate</state>
25       <zip>12345</zip>
26       <phone>555-1234</phone>
27       <flag gender = "M" />
28    </contact>
29
30    <salutation>Dear Sir:</salutation>
31
32    <paragraph>It is our privilege to inform you about our new database
33       managed with XML. This new system allows you to reduce the
34       load on your inventory list server by having the client machine
35       perform the work of sorting and filtering the data.
36    </paragraph>
37
38    <paragraph>Please visit our website for availability
39       and pricing.
40    </paragraph>
41
42    <closing>Sincerely,</closing>
43    <signature>Ms. Jane Doe</signature>
44 </letter>
```

Fig. 24.4 | Business letter marked up as XML.

Line 5 specifies that this XML document references a DTD. Recall from Section 24.2 that DTDs define the structure of the data for an XML document. For example, a DTD specifies the elements and parent/child relationships between elements permitted in an XML document.

Error-Prevention Tip 24.1

An XML document is not required to reference a DTD, but validating XML parsers can use a DTD to ensure that the document has the proper structure.

Portability Tip 24.2

Validating an XML document helps guarantee that independent developers will exchange data in a standardized form that conforms to the DTD.

The DTD reference (line 5) contains three items: the name of the root element that the DTD specifies (`letter`); the keyword **`SYSTEM`** (which denotes an **external DTD**—a DTD declared in a separate file, as opposed to a DTD declared locally in the same file); and the DTD's name and location (that is, `letter.dtd` in the same directory as the XML document). DTD document file names typically end with the **`.dtd`** extension. We discuss DTDs and `letter.dtd` in detail in Section 24.5.

Root element `letter` (lines 7–44 of Fig. 24.4) contains the child elements `contact`, `contact`, `salutation`, `paragraph`, `paragraph`, `closing` and `signature`. Besides being placed between tags, data also can be placed in **attributes**—name/value pairs that appear within the angle brackets of start tags. Elements can have any number of attributes (separated by spaces) in their start tags, provided all the attribute names are unique. The first `contact` element (lines 8–17) has an attribute named `type` with **attribute value** `"sender"`, which indicates that this `contact` element identifies the letter's sender. The second `contact` element (lines 19–28) has attribute `type` with value `"receiver"`, which indicates that this `contact` element identifies the letter's recipient. Like element names, attribute names are case sensitive, can be of any length, may contain letters, digits, underscores, hyphens and periods, and must begin with either a letter or an underscore character. A `contact` element stores various items of information about a contact, such as the contact's name (represented by element `name`), address (represented by elements `address1`, `address2`, `city`, `state` and `zip`), phone number (represented by element `phone`) and gender (represented by attribute `gender` of element `flag`). Element `salutation` (line 30) marks up the letter's salutation. Lines 32–40 mark up the letter's body using two `paragraph` elements. Elements `closing` (line 42) and `signature` (line 43) mark up the closing sentence and the author's "signature," respectively.

Common Programming Error 24.6

Failure to enclose attribute values in double (`""`) or single (`''`) quotes is a syntax error.

Line 16 introduces the **empty element** `flag`. An empty element contains no content. However, it may sometimes contain data in the form of attributes. Empty element `flag` contains an attribute that indicates the gender of the contact (represented by the parent `contact` element). Document authors can close an empty element either by placing a slash immediately preceding the rightmost angle bracket, as shown in line 16, or by explicitly writing an end tag, as in line 22:

```
<address2></address2>
```

Line 22 can also be written as:

```
<address2/>
```

The `address2` element in line 22 is empty, because there is no second part to this contact's address. However, we must include this element to conform to the structural rules specified in the XML document's DTD—`letter.dtd` (which we present in Section 24.5). This DTD specifies that each `contact` element must have an `address2` child element (even if it's empty). In Section 24.5, you'll learn how DTDs indicate that certain elements are required while others are optional.

24.4 XML Namespaces

XML allows you to create custom elements. This extensibility can result in **naming collisions**—elements with identical names that represent different things—when combining content from multiple sources. For example, we may use the element `book` to mark up data about a Deitel publication. A stamp collector may use the element `book` to mark up data about a book of stamps. Using both of these elements in the same document could create a naming collision, making it difficult to determine which kind of data each element contains.

An XML **namespace** is a collection of element and attribute names. Like C# namespaces, XML namespaces provide a means for document authors to unambiguously refer to elements that have the same name (that is, prevent collisions). For example,

```
<subject>Math</subject>
```

and

```
<subject>Cardiology</subject>
```

use element `subject` to mark up data. In the first case, the subject is something one studies in school, whereas in the second case, the subject is a field of medicine. Namespaces can differentiate these two `subject` elements. For example,

```
<school:subject>Math</school:subject>
```

and

```
<medical:subject>Cardiology</medical:subject>
```

Both `school` and `medical` are **namespace prefixes**. A document author places a namespace prefix and colon (`:`) before an element name to specify the namespace to which that element belongs. Document authors can create their own namespace prefixes using virtually any name except the reserved namespace prefixes `xml` and `xmlns`. In the subsections that follow, we demonstrate how document authors ensure that namespaces are unique.

Common Programming Error 24.7

Attempting to create a namespace prefix named `xml` in any mixture of uppercase and lowercase letters is a syntax error—the `xml` namespace is reserved for internal use by XML itself.

Differentiating Elements with Namespaces

Figure 24.5 uses namespaces to differentiate two distinct elements—the `file` element related to a text file and the `file` document related to an image file.

```
1  <?xml version = "1.0"?>
2  <!-- Fig. 24.5: namespace.xml -->
3  <!-- Demonstrating namespaces -->
4
5  <text:directory
6     xmlns:text = "urn:deitel:textInfo"
7     xmlns:image = "urn:deitel:imageInfo">
8
9     <text:file filename = "book.xml">
10       <text:description>A book list</text:description>
11    </text:file>
12
13    <image:file filename = "funny.jpg">
14       <image:description>A funny picture</image:description>
15       <image:size width = "200" height = "100" />
16    </image:file>
17 </text:directory>
```

Fig. 24.5 | XML namespaces demonstration.

Lines 6–7 use the XML-namespace reserved attribute `xmlns` to create two namespace prefixes—`text` and `image`. Creating a namespace prefix is similar to using a `using` statement in C#—it allows you to access XML elements from a given namespace. Each namespace prefix is bound to a series of characters called a **Uniform Resource Identifier** (**URI**) that uniquely identifies the namespace. Document authors create their own namespace prefixes and URIs. A URI is a way to identify a resource, typically on the Internet. Two popular types of URI are **Uniform Resource Name** (**URN**) and **Uniform Resource Locator** (**URL**).

To ensure that namespaces are unique, document authors must provide unique URIs. We chose `urn:deitel:textInfo` and `urn:deitel:imageInfo` as URIs. These URIs employ the URN scheme frequently used to identify namespaces. Under this naming scheme, a URI begins with `"urn:"`, followed by a unique series of additional names separated by colons. These URIs are not guaranteed to be unique—the idea is simply that creating a long URI in this way makes it unlikely that two authors will use the same namespace.

Another common practice is to use URLs, which specify the location of a file or a resource on the Internet. For example, `http://www.deitel.com` is the URL that identifies the home page of the Deitel & Associates website. Using URLs for domains that you own guarantees that the namespaces are unique, because the domain names (for example, `www.deitel.com`) are guaranteed to be unique. For example, lines 5–7 could be rewritten as

```
<text:directory
   xmlns:text = "http://www.deitel.com/xmlns-text"
   xmlns:image = "http://www.deitel.com/xmlns-image">
```

where URLs related to the Deitel & Associates, Inc. domain name serve as URIs to identify the `text` and `image` namespaces. The parser does not visit these URLs, nor do these URLs need to refer to actual web pages. Each simply represents a unique series of characters used to differentiate URI names. In fact, any string can represent a namespace. For example, our `image` namespace URI could be `hgjfkdlsa4556`, in which case our prefix assignment would be

```
xmlns:image = "hgjfkdlsa4556"
```

Lines 9–11 use the `text` namespace prefix for elements `file` and `description`. The end tags must also specify the namespace prefix `text`. Lines 13–16 apply namespace prefix `image` to the elements `file`, `description` and `size`. Attributes do not require namespace prefixes, because each attribute is already part of an element that specifies the namespace prefix. For example, attribute `filename` (line 9) is already uniquely identified by being in the context of the `filename` start tag, which is prefixed with `text`.

Specifying a Default Namespace

To eliminate the need to place namespace prefixes in each element, document authors may specify a **default namespace** for an element and its children. Figure 24.6 demonstrates using a default namespace (`urn:deitel:textInfo`) for element `directory`.

```
1  <?xml version = "1.0"?>
2  <!-- Fig. 24.6: defaultnamespace.xml -->
3  <!-- Using default namespaces -->
4
5  <directory xmlns = "urn:deitel:textInfo"
6     xmlns:image = "urn:deitel:imageInfo">
7
8     <file filename = "book.xml">
9        <description>A book list</description>
10    </file>
11
12    <image:file filename = "funny.jpg">
13       <image:description>A funny picture</image:description>
14       <image:size width = "200" height = "100" />
15    </image:file>
16 </directory>
```

Fig. 24.6 | Default namespace demonstration.

Line 5 defines a default namespace using attribute `xmlns` with a URI as its value. Once we define this default namespace, child elements which do not specify a prefix belong to the default namespace. Thus, element `file` (lines 8–10) is in the default namespace `urn:deitel:textInfo`. Compare this to lines 9–11 of Fig. 24.5, where we had to prefix the `file` and `description` element names with the namespace prefix `text`.

Common Programming Error 24.8

The default namespace can be overridden at any point in the document with another `xmlns` *attribute. All direct and indirect children of the element with the* `xmlns` *attribute use the new default namespace.*

The default namespace applies to the `directory` element and all elements that are not qualified with a namespace prefix. However, we can use a namespace prefix to specify a different namespace for particular elements. For example, the `file` element in lines 12–15 includes the `image` namespace prefix, indicating that this element is in the `urn:deitel:imageInfo` namespace, not the default namespace.

Namespaces in XML Vocabularies

XML-based languages, such as XML Schema and Extensible Stylesheet Language (XSL), often use namespaces to identify their elements. Each vocabulary defines special-purpose elements that are grouped in namespaces. These namespaces help prevent naming collisions between predefined and user-defined elements.

24.5 Document Type Definitions (DTDs)

Document Type Definitions (DTDs) are one of two technologies you can use to specify XML document structure. Section 24.6 presents W3C XML Schema documents, which provide an improved method of specifying XML document structure.

Software Engineering Observation 24.2

XML documents can have many different structures, and for this reason an application cannot be certain whether a particular document it receives is complete, ordered properly, and not missing data. DTDs and schemas (Section 24.6) solve this problem by providing an extensible way to describe XML document structure. Applications should use DTDs or schemas to confirm whether XML documents are valid.

Software Engineering Observation 24.3

Many organizations and individuals are creating DTDs and schemas for a broad range of applications. These collections—called ***repositories****—are available free for download from the web (e.g.,* `www.xml.org`*,* `www.oasis-open.org`*).*

Creating a Document Type Definition

Figure 24.4 presented a simple business letter marked up with XML. Recall that line 5 of `letter.xml` references a DTD—`letter.dtd` (Fig. 24.7). This DTD specifies the business letter's element types and attributes and their relationships to one another.

```
<!-- Fig. 24.7: letter.dtd      -->
<!-- DTD document for letter.xml -->

<!ELEMENT letter ( contact+, salutation, paragraph+,
   closing, signature )>

<!ELEMENT contact ( name, address1, address2, city, state,
   zip, phone, flag )>
<!ATTLIST contact type CDATA #IMPLIED>

<!ELEMENT name ( #PCDATA )>
<!ELEMENT address1 ( #PCDATA )>
<!ELEMENT address2 ( #PCDATA )>
<!ELEMENT city ( #PCDATA )>
<!ELEMENT state ( #PCDATA )>
<!ELEMENT zip ( #PCDATA )>
<!ELEMENT phone ( #PCDATA )>
<!ELEMENT flag EMPTY>
<!ATTLIST flag gender (M | F) "M">
```

Fig. 24.7 | Document Type Definition (DTD) for a business letter. (Part 1 of 2.)

```
20
21  <!ELEMENT salutation ( #PCDATA )>
22  <!ELEMENT closing ( #PCDATA )>
23  <!ELEMENT paragraph ( #PCDATA )>
24  <!ELEMENT signature ( #PCDATA )>
```

Fig. 24.7 | Document Type Definition (DTD) for a business letter. (Part 2 of 2.)

A DTD describes the structure of an XML document and enables an XML parser to verify whether an XML document is valid (i.e., whether its elements contain the proper attributes and appear in the proper sequence). DTDs allow users to check document structure and to exchange data in a standardized format. A DTD expresses the set of rules for document structure by specifying what attributes and other elements may appear inside a given element.

Common Programming Error 24.9

For documents validated with DTDs, any document that uses elements, attributes or relationships not explicitly defined by a DTD is an invalid document.

Defining Elements in a DTD

The **`ELEMENT` element type declaration** in Fig. 24.7, lines 4–5 defines the rules for element `letter`. In this case, `letter` contains one or more `contact` elements, one `salutation` element, one or more `paragraph` elements, one `closing` element and one `signature` element, in that sequence. The **plus sign** (+) **occurrence indicator** specifies that the DTD allows one or more occurrences of an element. Other occurrence indicators include the **asterisk** (*), which indicates an *optional* element that can occur *zero or more* times, and the **question mark** (?), which indicates an optional element that can occur at most once (i.e., zero or one occurrence). If an element does not have an occurrence indicator, the DTD allows exactly one occurrence.

The `contact` element type declaration (lines 7–8) specifies that a `contact` element contains child elements `name`, `address1`, `address2`, `city`, `state`, `zip`, `phone` and `flag`—in that order. The DTD requires exactly one occurrence of each of these elements.

Defining Attributes in a DTD

Line 9 uses the **`ATTLIST` attribute-list declaration** to define an attribute named `type` for the `contact` element. Keyword **`#IMPLIED`** specifies that the `type` attribute of the `contact` element is *optional*—a missing `type` attribute will not invalidate the document. Other keywords that can be used in place of `#IMPLIED` in an `ATTLIST` declaration include `#REQUIRED` and `#FIXED`. Keyword **`#REQUIRED`** specifies that the attribute must be present in the element, and keyword **`#FIXED`** specifies that the attribute (if present) must have the given fixed value. For example,

```
<!ATTLIST address zip CDATA #FIXED "01757">
```

indicates that attribute `zip` (if present in element `address`) must have the value `01757` for the document to be valid. If the attribute is not present, then the parser, by default, uses the fixed value that the `ATTLIST` declaration specifies. You can supply a default value instead of one of these keywords. Doing so makes the attribute optional, but the default value will be used if the attribute's value is not specified.

Character Data vs. Parsed Character Data

Keyword **`CDATA`** (line 9) specifies that attribute `type` contains **character data** (i.e., a string). A parser will pass such data to an application without modification.

> **Software Engineering Observation 24.4**
>
> *DTD syntax cannot describe an element's (or attribute's) type. For example, a DTD cannot specify that a particular element or attribute can contain only integer data.*

Keyword **`#PCDATA`** (line 11) specifies that an element (e.g., `name`) may contain **parsed character data** (i.e., data that is processed by an XML parser). Elements with parsed character data cannot contain markup characters, such as less than (<), greater than (>) or ampersand (&). The document author should replace any markup character in a `#PCDATA` element with the character's corresponding **character entity reference**. For example, the character entity reference `<` should be used in place of the less-than symbol (<), and the character entity reference `>` should be used in place of the greater-than symbol (>). A document author who wishes to use a literal ampersand should use the entity reference `&` instead—parsed character data can contain ampersands (&) only for inserting entities. The final two entities defined by XML are `'` and `"`, representing the single (`'`) and double (`"`) quote characters, respectively.

> **Common Programming Error 24.10**
>
> *Using markup characters (e.g., <, > and &) in parsed character data is an error. Use character entity references (e.g., `<`, `>` and `&` instead).*

Defining Empty Elements in a DTD

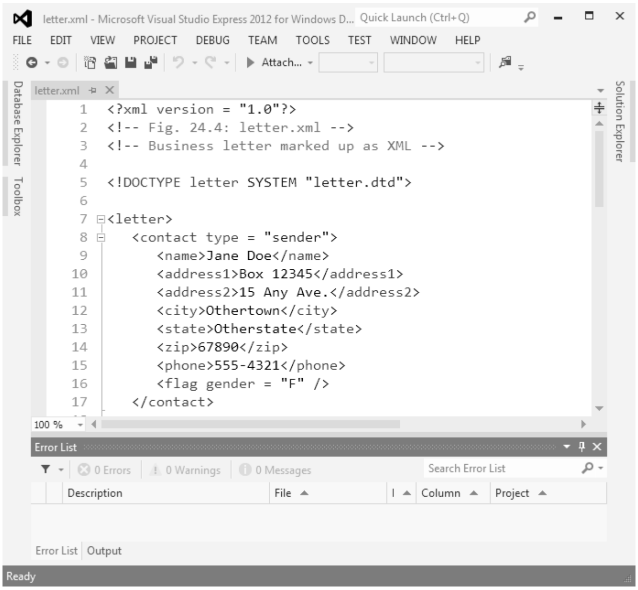
Line 18 defines an empty element named `flag`. Keyword **`EMPTY`** specifies that the element does not contain any data between its start and end tags. Empty elements commonly describe data via attributes. For example, `flag`'s data appears in its `gender` attribute (line 19). Line 19 specifies that the `gender` attribute's value must be one of the enumerated values (`M` or `F`) enclosed in parentheses and delimited by a vertical bar (`|`) meaning "or." Line 19 also indicates that `gender` has a default value of `M`.

Well-Formed Documents vs. Valid Documents

Recall that a well-formed document is *syntactically correct* (i.e., each start tag has a corresponding end tag, the document contains only one root element, and so on), and a valid document contains the proper elements with the proper attributes in the proper sequence. An XML document cannot be valid unless it's well formed.

Visual Studio can validate XML documents against both DTDs and schemas. You do not have to create a project to use this facility—simply open the XML file in Visual Studio as in Fig. 24.8. If the DTD or schema referenced in the XML document can be retrieved, Visual Studio will automatically validate the XML. If the XML file does not validate, Visual Studio will display a warning just as it does with errors in your C# code. Visit `www.w3.org/XML/Schema` for a list of additional validation tools.

a) No errors or warnings in the Error List window indicate that this XML document validated properly



b) The XML document did not validate properly because the value for the `gender` attribute (line 16) as invald

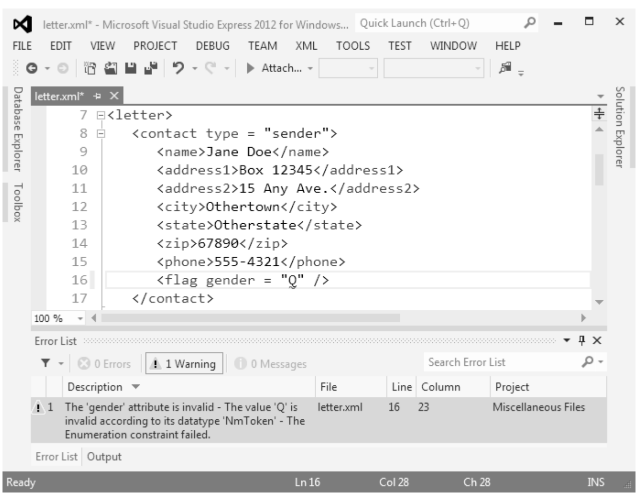


Fig. 24.8 | XML file open in Visual Studio Express 2012 for Windows Desktop.

24.6 W3C XML Schema Documents

In this section, we introduce schemas for specifying XML document structure and validating XML documents. Many developers in the XML community believe that DTDs are not flexible enough to meet today's programming needs. For example, DTDs lack a way of indicating what specific type of data (e.g., numeric, text) an element can contain, and

DTDs are not themselves XML documents, which makes it difficult to manipulate them programmatically. These and other limitations have led to the development of schemas.

Unlike DTDs, schemas use XML syntax and are actually XML documents that programs can manipulate. Like DTDs, schemas are used by validating parsers to validate documents.

In this section, we focus on the W3C's **XML Schema** vocabulary. For the latest information on XML Schema, visit `www.w3.org/XML/Schema`. For tutorials on XML Schema concepts beyond what we present here, visit `www.w3schools.com/schema/default.asp`.

A DTD describes an XML document's structure, not the content of its elements. For example,

```
<quantity>5</quantity>
```

contains character data. If the document that contains element `quantity` references a DTD, an XML parser can validate the document to confirm that this element indeed does contain `PCDATA` content. However, the parser cannot validate that the content is numeric; DTDs do not provide this capability. So, unfortunately, the parser also considers

```
<quantity>hello</quantity>
```

to be valid. An application that uses the XML document containing this markup should test that the data in element `quantity` is numeric and take appropriate action if it's not.

XML Schema enables schema authors to specify that element `quantity`'s data must be numeric or, even more specifically, an integer. A parser validating the XML document against this schema can determine that `5` conforms and `hello` does not. An XML document that conforms to a schema document is **schema valid**, and one that does not conform is **schema invalid**. Schemas are XML documents and can also be validated.

Validating Against an XML Schema Document

Figure 24.9 shows a schema-valid XML document named `book.xml`, and Fig. 24.10 shows the pertinent XML Schema document (`book.xsd`) that defines the structure for `book.xml`. By convention, schemas use the **`.xsd`** extension. Recall that Visual Studio can perform schema validation if it can locate the schema document. Visual Studio can locate a schema if it's specified in the XML document, is in the same solution or is simply open in Visual Studio at the same time as the XML document. To validate the schema document itself (i.e., `book.xsd`) and produce the output shown in Fig. 24.10, we used an online XSV (XML Schema Validator) provided by the W3C at

```
www.w3.org/2001/03/webdata/xsv
```

These tools enforce the W3C's specifications regarding XML Schemas and schema validation. Figure 24.9 contains markup describing several books. The `books` element (line 5) has the namespace prefix `deitel` (declared in line 5), indicating that the `books` element is a part of the namespace `http://www.deitel.com/booklist`.

```
1 <?xml version = "1.0"?>
2 <!-- Fig. 24.9: book.xml -->
3 <!-- Book list marked up as XML -->
```

Fig. 24.9 | Schema-valid XML document describing a list of books. (Part 1 of 2.)

```

<deitel:books xmlns:deitel = "http://www.deitel.com/booklist">
   <book>
      <title>Visual Basic 2012 How to Program</title>
   </book>

   <book>
      <title>Visual C# 2012 How to Program</title>
   </book>

   <book>
      <title>Java How to Program</title>
   </book>

   <book>
      <title>C++ How to Program</title>
   </book>

   <book>
      <title>Internet and World Wide Web How to Program</title>
   </book>
</deitel:books>
```

Fig. 24.9 | Schema-valid XML document describing a list of books. (Part 2 of 2.)

Creating an XML Schema Document

Figure 24.10 presents the XML Schema document that specifies the structure of `book.xml` (Fig. 24.9). This document defines an XML-based language (i.e., a vocabulary) for writing XML documents about collections of books. The schema defines the elements, attributes and parent-child relationships that such a document can (or must) include. The schema also specifies the type of data that these elements and attributes may contain.

```
<?xml version = "1.0"?>
<!-- Fig. 24.10: book.xsd           -->
<!-- Simple W3C XML Schema document -->

<schema xmlns = "http://www.w3.org/2001/XMLSchema"
   xmlns:deitel = "http://www.deitel.com/booklist"
   targetNamespace = "http://www.deitel.com/booklist">

   <element name = "books" type = "deitel:BooksType"/>

   <complexType name = "BooksType">
      <sequence>
         <element name = "book" type = "deitel:SingleBookType"
            minOccurs = "1" maxOccurs = "unbounded"/>
      </sequence>
   </complexType>

```

Fig. 24.10 | XML Schema document for `book.xml`. (Part 1 of 2.)

```
18    <complexType name = "SingleBookType">
19       <sequence>
20          <element name = "title" type = "string"/>
21       </sequence>
22    </complexType>
23 </schema>
```

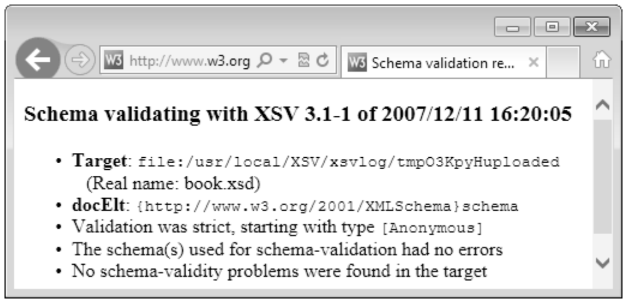


Fig. 24.10 | XML Schema document for `book.xml`. (Part 2 of 2.)

Root element **`schema`** (Fig. 24.10, lines 5–23) contains elements that define the structure of an XML document such as `book.xml`. Line 5 specifies as the default namespace the standard W3C XML Schema namespace URI—**`http://www.w3.org/2001/XMLSchema`**. This namespace contains predefined elements (e.g., root element `schema`) that comprise the XML Schema vocabulary—the language used to write an XML Schema document.

Portability Tip 24.3

W3C XML Schema authors specify URI `http://www.w3.org/2001/XMLSchema` when referring to the XML Schema namespace. This namespace contains predefined elements that comprise the XML Schema vocabulary. Specifying this URI ensures that validation tools correctly identify XML Schema elements and do not confuse them with those defined by document authors.

Line 6 binds the URI `http://www.deitel.com/booklist` to namespace prefix `deitel`. As we discuss momentarily, the schema uses this namespace to differentiate names created by us from names that are part of the XML Schema namespace. Line 7 also specifies `http://www.deitel.com/booklist` as the **`targetNamespace`** of the schema. This attribute identifies the namespace of the XML vocabulary that this schema defines. The `targetNamespace` of `book.xsd` is the same as the namespace referenced in line 5 of `book.xml` (Fig. 24.9). This is what "connects" the XML document with the schema that defines its structure. When an XML schema validator examines `book.xml` and `book.xsd`, it will recognize that `book.xml` uses elements and attributes from the `http://www.deitel.com/booklist` namespace. The validator also will recognize that this namespace is the one defined in `book.xsd` (i.e., the schema's `targetNamespace`). Thus the validator knows where to look for the structural rules for the elements and attributes used in `book.xml`.

Defining an Element in XML Schema

In XML Schema, the **`element`** tag (Fig. 24.10, line 9) defines an element to be included in an XML document that conforms to the schema. In other words, `element` specifies the actual *elements* that can be used to mark up data. Line 9 defines the `books` element, which we use as the root element in `book.xml` (Fig. 24.9). Attributes **`name`** and **`type`** specify the `element`'s name and type, respectively. An element's `type` attribute indicates the data type that the element may contain. Possible types include XML Schema–defined types (e.g., `string`, `double`) and user-defined types (e.g., `BooksType`, which is defined in lines 11–16). Figure 24.11 lists several of XML Schema's many built-in types. For a complete list of built-in types, see Section 3 of the specification found at `www.w3.org/TR/xmlschema-2`.

In this example, `books` is defined as an element of type `deitel:BooksType` (line 9). `BooksType` is a user-defined type (Fig. 24.10, lines 11–16) in the `http://www.deitel.com/booklist` namespace and therefore must have the namespace prefix `deitel`. It's not an existing XML Schema type. Two categories of types exist in XML Schema—**simple types** and **complex types**. They differ only in that simple types cannot contain attributes or child elements and complex types can.

A user-defined type that contains attributes or child elements must be defined as a complex type. Lines 11–16 use element **`complexType`** to define `BooksType` as a complex type that has a child element named `book`. The `sequence` element (lines 12–15) allows you to specify the sequential order in which child elements must appear. The `element` (lines 13–14) nested within the `complexType` element indicates that a `BooksType` element (e.g., `books`) can contain child elements named `book` of type `deitel:SingleBookType` (defined in lines 18–22). Attribute **`minOccurs`** (line 14), with value `1`, specifies that elements of type `BooksType` must contain a minimum of one `book` element. Attribute **`maxOccurs`** (line 14), with value **`unbounded`**, specifies that elements of type `BooksType` may have any number of `book` child elements. Both of these attributes have default values of `1`.

Lines 18–22 define the complex type `SingleBookType`. An element of this type contains a child element named `title`. Line 20 defines element `title` to be of simple type `string`. Recall that elements of a simple type cannot contain attributes or child elements. The `schema` end tag (`</schema>`, line 23) declares the end of the XML Schema document.

A Closer Look at Types in XML Schema

Every element in XML Schema has a type. Types include the *built-in types* provided by XML Schema (Fig. 24.11) or *user-defined types* (e.g., `SingleBookType` in Fig. 24.10).

Type	Description	Ranges or structures	Examples
`string`	A character string		`hello`
`boolean`	True or false	`true`, `false`	`true`
`decimal`	A decimal numeral	`i * (10`^{n}`)`, where `i` is an integer and `n` is an integer that is less than or equal to zero	`5`, `-12`, `-45.78`
`float`	A floating-point number	`m * (2`^{e}`)`, where `m` is an integer whose absolute value is less than 2^{24} and `e` is an integer in the range `-149` to `104`. Plus three additional numbers: positive infinity (`INF`), negative infinity (`-INF`) and not-a-number (`NaN`)	`0`, `12`, `-109.375`, `NaN`

Fig. 24.11 | Some XML Schema types. (Part 1 of 2.)

Type	Description	Ranges or structures	Examples
double	A floating-point number	$m * (2^e)$, where m is an integer whose absolute value is less than 2^{53} and e is an integer in the range -1075 to 970. Plus three additional numbers: positive infinity, negative infinity and not-a-number	0, 12, -109.375, NaN
long	A whole number	-9223372036854775808 to 9223372036854775807, inclusive	1234567890, -1234567890
int	A whole number	-2147483648 to 2147483647, inclusive	1234567890, -1234567890
short	A whole number	-32768 to 32767, inclusive	12, -345
date	A date consisting of a year, month and day	yyyy-mm with an optional dd and an optional time zone, where yyyy is four digits long and mm and dd are two digits long. The time zone is specified as +hh:mm or -hh:mm, giving an offset in hours and minutes	2013-07-25+01:00
time	A time consisting of hours, minutes and seconds	hh:mm:ss with an optional time zone, where hh, mm and ss are two digits long	16:30:25-05:00

Fig. 24.11 | Some XML Schema types. (Part 2 of 2.)

Every *simple type* defines a **restriction** on an XML Schema-defined type or a restriction on a user-defined type. Restrictions limit the possible values that an element can hold.

Complex types are divided into two groups—those with **simple content** and those with **complex content**. Both can contain attributes, but only complex content can contain child elements. Complex types with simple content must extend or restrict some other existing type. Complex types with complex content do not have this limitation. We demonstrate complex types with each kind of content in the next example.

XML Schema with Simple and Complext Types

The schema in Fig. 24.12 creates simple types and complex types. The XML document in Fig. 24.13 (`laptop.xml`) follows the structure defined in Fig. 24.12 to describe parts of a laptop computer. A document such as `laptop.xml` that conforms to a schema is known as an **XML instance document**—the document is an instance (i.e., example) of the schema.

```
<?xml version = "1.0"?>
<!-- Fig. 24.12: computer.xsd -->
<!-- W3C XML Schema document -->

<schema xmlns = "http://www.w3.org/2001/XMLSchema"
   xmlns:computer = "http://www.deitel.com/computer"
   targetNamespace = "http://www.deitel.com/computer">
```

Fig. 24.12 | XML Schema document defining simple and complex types. (Part 1 of 2.)

```
8
9      <simpleType name = "gigahertz">
10        <restriction base = "decimal">
11           <minInclusive value = "2.1"/>
12        </restriction>
13     </simpleType>
14
15     <complexType name = "CPU">
16        <simpleContent>
17           <extension base = "string">
18              <attribute name = "model" type = "string"/>
19           </extension>
20        </simpleContent>
21     </complexType>
22
23     <complexType name = "portable">
24        <all>
25           <element name = "processor" type = "computer:CPU"/>
26           <element name = "monitor" type = "int"/>
27           <element name = "CPUSpeed" type = "computer:gigahertz"/>
28           <element name = "RAM" type = "int"/>
29        </all>
30        <attribute name = "manufacturer" type = "string"/>
31     </complexType>
32
33     <element name = "laptop" type = "computer:portable"/>
34  </schema>
```

Fig. 24.12 | XML Schema document defining simple and complex types. (Part 2 of 2.)

Opening `schema` *Tag*

Line 5 (Fig. 24.12) declares the default namespace as the standard XML Schema namespace—any elements without a prefix are assumed to be in the XML Schema namespace. Line 6 binds the namespace prefix `computer` to the namespace `http://www.deitel.com/computer`. Line 7 identifies this namespace as the `targetNamespace`—the namespace being defined by the current XML Schema document.

`simpleType` *Element* `gigahertz`

To design the XML elements for describing laptop computers, we first create a simple type in lines 9–13 using the **`simpleType`** element. We name this `simpleType` `gigahertz` because it will be used to describe the clock speed of the processor in gigahertz. Simple types are restrictions of a type typically called a **base type**. For this `simpleType`, line 10 declares the base type as `decimal`, and we restrict the value to be at least `2.1` by using the **`minInclusive`** element in line 11.

`complexType` *Element* `CPU`

Next, we declare a `complexType` named `CPU` that has **`simpleContent`** (lines 16–20). Remember that a complex type with simple content can have attributes but not child elements. Also recall that complex types with simple content must extend or restrict some XML Schema type or user-defined type. The **`extension`** element with attribute **`base`** (line 17) sets the base type to `string`. In this `complexType`, we extend the base type `string` with an attribute. The **`attribute`** element (line 18) gives the `complexType` an attribute of type `string` named `model`. Thus an element of type `CPU` must contain `string` text (because the base type is `string`) and may contain a `model` attribute that is also of type `string`.

`complexType` Element `portable`

Last, we define type `portable`, which is a `complexType` with complex content (lines 23–31). Such types are allowed to have child elements and attributes. The element **`all`** (lines 24–29) encloses elements that must each be included once in the corresponding XML instance document. These elements can be included in any order. This complex type holds four elements—`processor`, `monitor`, `CPUSpeed` and `RAM`. They're given types `CPU`, `int`, `gigahertz` and `int`, respectively. When using types `CPU` and `gigahertz`, we must include the namespace prefix `computer`, because these user-defined types are part of the `computer` namespace (`http://www.deitel.com/computer`)—the namespace defined in the current document (line 7). Also, `portable` contains an attribute defined in line 30. The `attribute` element indicates that elements of type `portable` contain an attribute of type `string` named `manufacturer`.

Line 33 declares the actual element that uses the three types defined in the schema. The element is called `laptop` and is of type `portable`. We must use the namespace prefix `computer` in front of `portable`.

Using the `laptop` Element

We have now created an element named `laptop` that contains child elements `processor`, `monitor`, `CPUSpeed` and `RAM`, and an attribute `manufacturer`. Figure 24.13 uses the `laptop` element defined in the `computer.xsd` schema. We used Visual Studio's built-in schema validation to ensure that this XML instance document adheres to the schema's structural rules.

```
1  <?xml version = "1.0"?>
2  <!-- Fig. 24.13: laptop.xml              -->
3  <!-- Laptop components marked up as XML -->
4
5  <computer:laptop xmlns:computer = "http://www.deitel.com/computer"
6     manufacturer = "IBM">
7
8     <processor model = "Centrino">Intel</processor>
9     <monitor>17</monitor>
10    <CPUSpeed>2.4</CPUSpeed>
11    <RAM>256</RAM>
12 </computer:laptop>
```

Fig. 24.13 | XML document using the `laptop` element defined in `computer.xsd`.

Line 5 declares namespace prefix `computer`. The `laptop` element requires this prefix because it's part of the `http://www.deitel.com/computer` namespace. Line 6 sets the laptop's `manufacturer` attribute, and lines 8–11 use the elements defined in the schema to describe the laptop's characteristics.

Automatically Creating Schemas using Visual Studio

Visual Studio includes a tool that allows you to create a schema from an existing XML document, using the document as a template. With an XML document open, select **XML >**

Create Schema to use this feature. A new schema file opens that conforms to the standards of the XML document. You can now save it and add it to the project.

Good Programming Practice 24.2

The schema generated by Visual Studio is a good starting point, but you should refine the restrictions and types it specifies so they're appropriate for your XML documents.

24.7 Extensible Stylesheet Language and XSL Transformations

Extensible Stylesheet Language (**XSL**) documents specify how programs are to render XML document data. XSL is a group of three technologies—**XSL-FO** (**XSL Formatting Objects**), **XPath** (**XML Path Language**) and **XSLT** (**XSL Transformations**). XSL-FO is a vocabulary for specifying formatting, and XPath is a string-based language of expressions used by XML and many of its related technologies for effectively and efficiently locating structures and data (such as specific elements and attributes) in XML documents.

The third portion of XSL—XSL Transformations (XSLT)—is a technology for transforming XML documents into other documents—i.e., transforming the structure of the XML document data to another structure. XSLT provides elements that define rules for transforming one XML document to produce a different XML document. This is useful when you want to use data in multiple applications or on multiple platforms, each of which may be designed to work with documents written in a particular vocabulary. For example, XSLT allows you to convert a simple XML document to an **XHTML** (**Extensible HyperText Markup Language**) document that presents the XML document's data (or a subset of the data) formatted for display in a web browser. (See Fig. 24.14 for a sample "before" and "after" view of such a transformation.)

Transforming an XML document using XSLT involves two tree structures—the **source tree** (i.e., the XML document to be transformed) and the **result tree** (i.e., the XML document to be created). XPath is used to locate parts of the source-tree document that match **templates** defined in an **XSL style sheet**. When a match occurs (i.e., a node matches a template), the matching template executes and adds its result to the result tree. When there are no more matches, XSLT has transformed the source tree into the result tree. The XSLT does not analyze every node of the source tree; it selectively navigates the source tree using XSLT's `select` and `match` attributes. For XSLT to function, the source tree must be properly structured. Schemas, DTDs and validating parsers can validate document structure before using XPath and XSLTs.

A Simple XSL Example

Figure 24.14 lists an XML document that describes various sports. The output shows the result of the transformation (specified in the XSLT template of Fig. 24.15) rendered by Internet Explore. Rright click with the page open in Internet Explorer and select **View Source** to view the generated XHTML.

To perform transformations, an XSLT processor is required. For a list of some XSLT processors, visit `en.wikipedia.org/wiki/XSL_Transformations`. The XML document shown in Fig. 24.14 is transformed into an XHTML document by Internet Explorer when the document is loaded.

```
1  <?xml version = "1.0"?>
2  <?xml-stylesheet type = "text/xsl" href = "sports.xsl"?>
3
4  <!-- Fig. 24.14: sports.xml -->
5  <!-- Sports Database -->
6
7  <sports>
8     <game id = "783">
9        <name>Cricket</name>
10
11       <paragraph>
12          More popular among Commonwealth nations.
13       </paragraph>
14    </game>
15
16    <game id = "239">
17       <name>Baseball</name>
18
19       <paragraph>
20          More popular in America.
21       </paragraph>
22    </game>
23
24    <game id = "418">
25       <name>Soccer (Futbol)</name>
26
27       <paragraph>
28          Most popular sport in the world.
29       </paragraph>
30    </game>
31 </sports>
```

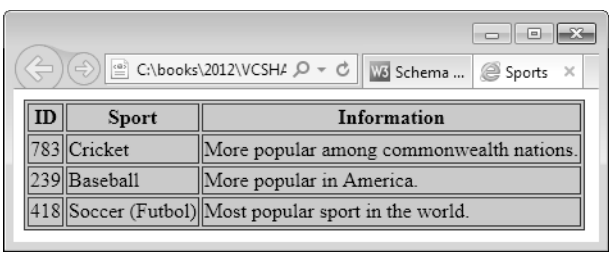


Fig. 24.14 | XML document that describes various sports.

Line 2 (Fig. 24.14) is a **processing instruction (PI)** that references the XSL style sheet `sports.xsl` (Fig. 24.15). A processing instruction is embedded in an XML document and provides application-specific information to whichever XML processor the application uses. In this particular case, the processing instruction specifies the location of an XSLT document with which to transform the XML document. The characters **<?** and **?>** (Fig. 24.14, line 2) delimit a processing instruction, which consists of a **PI target** (e.g., `xml-stylesheet`) and a **PI value** (e.g., `type = "text/xsl" href = "sports.xsl"`). The PI value's `type` attribute specifies that `sports.xsl` is a `text/xsl` file (i.e., a text file containing XSL content). The `href` attribute specifies the name and location of the style sheet to apply—in this case, `sports.xsl` in the current directory.

Software Engineering Observation 24.5

XSL enables document authors to separate data presentation (specified in XSL documents) from data description (specified in XML documents).

XSL for Transforming `sports.xml`

Figure 24.15 shows the XSL document for transforming the structured data of the XML document of Fig. 24.14 into an XHTML document for presentation. By convention, XSL documents have the file-name extension **`.xsl`**.

```
<?xml version = "1.0"?>
<!-- Fig. 24.15: sports.xsl -->
<!-- A simple XSLT transformation -->

<!-- reference XSL style sheet URI -->
<xsl:stylesheet version = "1.0"
   xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">

   <xsl:output method = "xml" omit-xml-declaration = "no"
      doctype-system =
         "http://www.w3c.org/TR/xhtml11/DTD/xhtml11-strict.dtd"
      doctype-public = "-//W3C//DTD XHTML 1.0 Strict//EN"/>

   <xsl:template match = "/"> <!-- match root element -->

   <html xmlns = "http://www.w3.org/1999/xhtml">
      <head>
         <title>Sports</title>
      </head>

      <body>
         <table border = "1" style = "background-color: turquoise">
            <thead>
               <tr>
                  <th>ID</th>
                  <th>Sport</th>
                  <th>Information</th>
               </tr>
            </thead>

            <!-- insert each name and paragraph element value -->
            <!-- into a table row. -->
            <xsl:for-each select = "/sports/game">
               <tr>
                  <td><xsl:value-of select = "@id"/></td>
                  <td><xsl:value-of select = "name"/></td>
                  <td><xsl:value-of select = "paragraph"/></td>
               </tr>
            </xsl:for-each>
```

Fig. 24.15 | XSLT that creates elements and attributes in an XHTML document. (Part 1 of 2.)

```
40            </table>
41         </body>
42      </html>
43
44      </xsl:template>
45   </xsl:stylesheet>
```

Fig. 24.15 | XSLT that creates elements and attributes in an XHTML document. (Part 2 of 2.)

`stylesheet` *Start Tag*

Lines 6–7 (Fig. 24.15) begin the XSL style sheet with the **`stylesheet`** start tag. Attribute **`version`** specifies the XSLT version to which this document conforms. Line 7 binds namespace prefix **`xsl`** to the W3C's XSLT URI (i.e., `http://www.w3.org/1999/XSL/Transform`).

`xsl:output` *Element*

Lines 9–12 use element **`xsl:output`** to write an XHTML document type declaration (`DOCTYPE`) to the result tree (i.e., the XML document to be created). The `DOCTYPE` identifies XHTML as the type of the resulting document. Attribute `method` is assigned `"xml"`, which indicates that XML is being output to the result tree. (Recall that XHTML is a type of XML.) Attribute **`omit-xml-declaration`** specifies whether the transformation should write the XML declaration to the result tree. In this case, we do not want to omit the XML declaration, so we assign to this attribute the value `"no"`. Attributes `doctype-system` and `doctype-public` write the `DOCTYPE` DTD information to the result tree.

`xsl:template` *Element*

XSLT uses **templates** (i.e., **`xsl:template`** elements) to describe how to transform particular nodes from the source tree to the result tree. A template is applied to nodes that are specified in the `match` attribute. Line 14 uses the **`match`** attribute to select the **document root** (i.e., the conceptual part of the document that contains the root element and everything below it) of the XML source document (i.e., `sports.xml`). The **XPath character `/`** (a forward slash) is used as a separator between element names. Recall that XPath is a string-based language used to locate parts of an XML document easily. In XPath, a leading forward slash specifies that we are using **absolute addressing** (i.e., we are starting from the root and defining paths down the source tree). In the XML document of Fig. 24.14, the child nodes of the document root are the two processing-instruction nodes (lines 1–2), the two comment nodes (lines 4–5) and the `sports` element node (lines 7–31). The template in Fig. 24.15, line 14, matches a node (i.e., the document root), so the contents of the template are now added to the result tree.

`xsl:for-each` *Element*

The XSLT processor writes the XHTML in lines 16–29 (Fig. 24.15) to the result tree exactly as it appears in the XSL document. Now the result tree consists of the `DOCTYPE` definition and the XHTML code from lines 16–29. Lines 33–39 use element **`xsl:for-each`** to iterate through the source XML document, searching for `game` elements. The `xsl:for-each` element is similar to C#'s `foreach` statement. Attribute **`select`** is an XPath expression that specifies the nodes (called the **node set**) on which the `xsl:for-each` operates. Again, the first forward slash means that we are using absolute addressing. The forward slash between `sports` and `game` indicates that `game` is a child node of `sports`. Thus, the `xsl:for-each` finds `game` nodes that are children of the `sports` node. The XML document `sports.xml` contains only one `sports` node, which is also the document root element. After finding the elements that match the selection criteria, the `xsl:for-each` processes each element with the code in lines 34–38 (these lines produce one row in an XHTML table each time they execute) and places the result of lines 34–38 in the result tree.

Line 35 uses element **`value-of`** to retrieve attribute `id`'s value and place it in a `td` element in the result tree. The XPath symbol `@` specifies that `id` is an attribute node of the `game` **context node** (i.e., the current node being processed). Lines 36–37 place the `name` and `paragraph` element values in `td` elements and insert them in the result tree. When an XPath expression has no beginning forward slash, the expression uses **relative addressing**. Omitting the beginning forward slash tells the **`xsl:value-of select`** statements to search for `name` and `paragraph` elements that are children of the context node, not the root node. Owing to the last XPath expression selection, the current context node is `game`, which indeed has an `id` attribute, a `name` child element and a `paragraph` child element.

Using XSLT to Sort and Format Data

Figure 24.16 presents an XML document (`sorting.xml`) that marks up information about a book. Several elements of the markup describing the book appear out of order (e.g., the element describing Chapter 3 appears before the element describing Chapter 2). We arranged them this way purposely to demonstrate that the XSL style sheet referenced in line 5 (`sorting.xsl`) can sort the XML file's data for presentation purposes.

```
1  <?xml version = "1.0"?>
2  <!-- Fig. 24.16: sorting.xml -->
3  <!-- XML document containing book information -->
4
5  <?xml-stylesheet type = "text/xsl" href = "sorting.xsl"?>
6
7  <book isbn = "999-99999-9-X">
8     <title>Deitel&apos;s XML Primer</title>
9
10    <author>
11       <firstName>Jane</firstName>
12       <lastName>Blue</lastName>
13    </author>
14
15    <chapters>
16       <frontMatter>
17          <preface pages = "2" />
18          <contents pages = "5" />
19          <illustrations pages = "4" />
20       </frontMatter>
21
22       <chapter number = "3" pages = "44">Advanced XML</chapter>
23       <chapter number = "2" pages = "35">Intermediate XML</chapter>
24       <appendix number = "B" pages = "26">Parsers and Tools</appendix>
25       <appendix number = "A" pages = "7">Entities</appendix>
26       <chapter number = "1" pages = "28">XML Fundamentals</chapter>
27    </chapters>
```

Fig. 24.16 | XML document containing book information. (Part 1 of 2.)

```

   <media type = "CD" />
</book>
```

Fig. 24.16 | XML document containing book information. (Part 2 of 2.)

Figure 24.17 presents an XSL document (`sorting.xsl`) for transforming `sorting.xml` (Fig. 24.16) to XHTML. Recall that an XSL document navigates a source tree and builds a result tree. In this example, the source tree is XML, and the output tree is XHTML. Line 14 of Fig. 24.17 matches the root element of the document in Fig. 24.16. Line 15 (Fig. 24.17) outputs an `html` start tag to the result tree. The `<xsl:apply-templates/>` element (line 16) specifies that the XSLT processor is to apply the `xsl:templates` defined in this XSL document to the current node's (i.e., the document root's) children. The content from the applied templates is output in the `html` element that ends at line 17. Lines 21–86 specify a template that matches element `book`. The template indicates how to format the information contained in `book` elements of `sorting.xml` (Fig. 24.16) as XHTML.

```
1  <?xml version = "1.0"?>
2  <!-- Fig. 24.17: sorting.xsl -->
3  <!-- Transformation of book information into XHTML -->
4
5  <xsl:stylesheet version = "1.0" xmlns = "http://www.w3.org/1999/xhtml"
6     xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
7
8     <!-- write XML declaration and DOCTYPE DTD information -->
9     <xsl:output method = "xml" omit-xml-declaration = "no"
10       doctype-system = "http://www.w3.org/TR/xhtml11/DTD/xhtml11.dtd"
11       doctype-public = "-//W3C//DTD XHTML 1.1//EN"/>
12
13    <!-- match document root -->
14    <xsl:template match = "/">
15       <html>
16          <xsl:apply-templates/>
17       </html>
18    </xsl:template>
19
20    <!-- match book -->
21    <xsl:template match = "book">
22       <head>
23          <title>ISBN <xsl:value-of select = "@isbn"/> -
24             <xsl:value-of select = "title"/></title>
25       </head>
26
27       <body>
28          <h1 style = "color: blue"><xsl:value-of select = "title"/></h1>
29          <h2 style = "color: blue">by
30             <xsl:value-of select = "author/firstName"/>
31             <xsl:text> </xsl:text>
```

Fig. 24.17 | XSL document that transforms `sorting.xml` into XHTML. (Part 1 of 3.)

```
            <xsl:value-of select = "author/lastName"/>
         </h2>

         <table style = "border-style: groove; background-color: gold">

            <xsl:for-each select = "chapters/frontMatter/*">
               <tr>
                  <td style = "text-align: right">
                     <xsl:value-of select = "name()"/>
                  </td>

                  <td>
                     ( <xsl:value-of select = "@pages"/> pages )
                  </td>
               </tr>
            </xsl:for-each>

            <xsl:for-each select = "chapters/chapter">
               <xsl:sort select = "@number" data-type = "number"
                    order = "ascending"/>
               <tr>
                  <td style = "text-align: right">
                     Chapter <xsl:value-of select = "@number"/>
                  </td>

                  <td>
                     <xsl:value-of select = "text()"/>
                     ( <xsl:value-of select = "@pages"/> pages )
                  </td>
               </tr>
            </xsl:for-each>

            <xsl:for-each select = "chapters/appendix">
               <xsl:sort select = "@number" data-type = "text"
                  order = "ascending"/>
               <tr>
                  <td style = "text-align: right">
                     Appendix <xsl:value-of select = "@number"/>
                  </td>

                  <td>
                     <xsl:value-of select = "text()"/>
                     ( <xsl:value-of select = "@pages"/> pages )
                  </td>
               </tr>
            </xsl:for-each>
         </table>

         <p style = "color: blue">Pages:
            <xsl:variable name = "pagecount"
               select = "sum(chapters//*/@pages)"/>
            <xsl:value-of select = "$pagecount"/>
```

Fig. 24.17 | XSL document that transforms `sorting.xml` into XHTML. (Part 2 of 3.)

```
84             <br />Media Type: <xsl:value-of select = "media/@type"/></p>
85          </body>
86       </xsl:template>
87    </xsl:stylesheet>
```

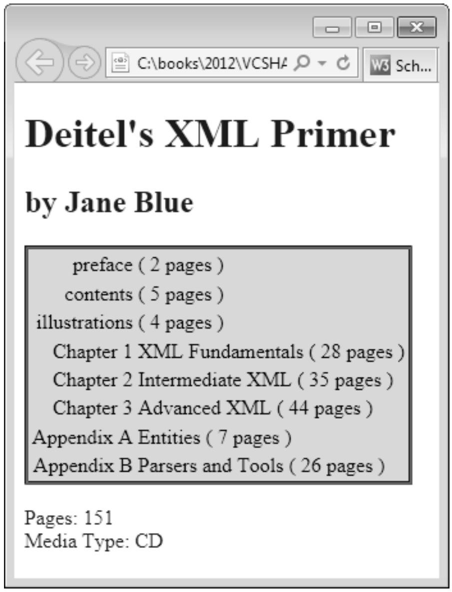


Fig. 24.17 | XSL document that transforms `sorting.xml` into XHTML. (Part 3 of 3.)

Lines 23–24 create the title for the XHTML document. We use the `book`'s ISBN (from attribute `isbn`) and the contents of element `title` to create the string that appears in the browser window's title bar (**ISBN 999-99999-9-X - Deitel's XML Primer**).

Line 28 creates a header element that contains the book's title. Lines 29–33 create a header element that contains the book's author. Because the *context node* (i.e., the node being processed) is `book`, the XPath expression `author/lastName` selects the author's last name, and the expression `author/firstName` selects the author's first name. The **`xsl:text`** element (line 31) is used to insert literal text. Because XML (and therefore XSLT) ignores whitespace, the author's name would appear as **JaneBlue** without inserting the explicit space.

Line 37 selects each element (indicated by an asterisk) that is a child of element `frontMatter`. Line 40 calls **node-set function `name`** to retrieve the current node's element name (e.g., `preface`). The current node is the context node specified in the `xsl:for-each` (line 37). Line 44 retrieves the value of the `pages` attribute of the current node.

Line 49 selects each `chapter` element. Lines 50–51 use element **`xsl:sort`** to sort chapters by number in *ascending* order. Attribute **`select`** selects the value of attribute `number` in context node `chapter`. Attribute **`data-type`**, with value `"number"`, specifies a numeric sort, and attribute **`order`**, with value `"ascending"`, specifies ascending order. Attribute `data-type` also accepts the value `"text"` (line 65), and attribute `order` also accepts the value `"descending"`. Line 58 uses **node-set function `text`** to obtain the text between the `chapter` start and end tags (i.e., the name of the chapter). Line 59 retrieves the value of the `pages` attribute of the current node. Lines 64–77 perform similar tasks for each appendix.

Lines 81–82 use an **XSL variable** to store the value of the book's total page count and output the page count to the result tree. Such variables cannot be modified after they're initialized. Attribute **`name`** specifies the variable's name (i.e., `pagecount`), and attribute `select` assigns a value to the variable. Function **`sum`** (line 82) totals the values for all `page` attribute values. The two slashes between `chapters` and `*` indicate a **recursive descent**—the XSLT processor will search for elements that contain an attribute named `pages` in all descendant nodes of `chapters`. The XPath expression

```
//*
```

selects all the nodes in an XML document. Line 83 retrieves the value of the newly created XSL variable `pagecount` by placing a dollar sign in front of its name.

Performance Tip 24.1

Selecting all nodes in a document when it's not necessary slows XSLT processing.

Summary of XSL Style-Sheet Elements

This section's examples used several predefined XSL elements to perform various operations. Figure 24.18 lists commonly used XSL elements. For more information on these elements and XSL in general, see `www.w3.org/Style/XSL`.

Element	Description
`<xsl:apply-templates>`	Applies the templates of the XSL document to the children of the current node.
`<xsl:apply-templates match = "`*expression*`">`	Applies the templates of the XSL document to the children of the nodes matching *expression*. The value of the attribute match (i.e., *expression*) must be an XPath expression that specifies elements.
`<xsl:template>`	Contains rules to apply when a specified node is matched.
`<xsl:value-of select = "`*expression*`">`	Selects the value of an XML element or attribute and adds it to the output tree of the transformation. The required `select` attribute contains an XPath expression.
`<xsl:for-each select = "`*expression*`">`	Applies a template to every node selected by the XPath specified by the `select` attribute.
`<xsl:sort select = "`*expression*`">`	Used as a child element of an `<xsl:apply-templates>` or `<xsl:for-each>` element. Sorts the nodes selected by the `<xsl:apply-template>` or `<xsl:for-each>` element so that the nodes are processed in sorted order.
`<xsl:output>`	Has various attributes to define the format (e.g., XML, XHTML), version (e.g., 1.0, 2.0), document type and MIME type of the output document. This tag is a top-level element—it can be used only as a child element of an `xsl:stylesheet`.
`<xsl:copy>`	Adds the current node to the output tree.

Fig. 24.18 | XSL style-sheet elements.

This section introduced Extensible Stylesheet Language (XSL) and showed how to create XSL transformations to convert XML documents from one format to another. We showed how to transform XML documents to XHTML documents for display in a web browser. In most business applications, XML documents are transferred between business partners and are transformed to other XML vocabularies programmatically. In Section 24.11, we demonstrate how to perform XSL transformations using the `XslCompiledTransform` class provided by the .NET Framework.

24.8 LINQ to XML: Document Object Model (DOM)

Although an XML document is a text file, retrieving data from the document using traditional sequential file-processing techniques is not practical, especially for adding and removing elements dynamically.

On successfully parsing a document, some XML parsers store document data as *trees* in memory. Figure 24.19 illustrates the tree structure for the document `article.xml` discussed in Fig. 24.2. This hierarchical tree structure is called a **Document Object Model** (**DOM**) **tree**, and an XML parser that creates such a tree is known as a **DOM parser**. DOM gets its name from the conversion of an XML document's tree structure into a tree of objects that are then manipulated using an object-oriented programming language such as C#. Each element name (e.g., `article`, `date`, `firstName`) is represented by a node. A node that contains other nodes (called **child nodes** or children) is called a **parent node** (e.g., `author`). A parent node can have *many* children, but a child node can have *only one* parent node. Nodes that are *peers* (e.g., `firstName` and `lastName`) are called **sibling nodes**. A node's **descendant nodes** include its children, its children's children and so on. A node's **ancestor nodes** include its parent, its parent's parent and so on.

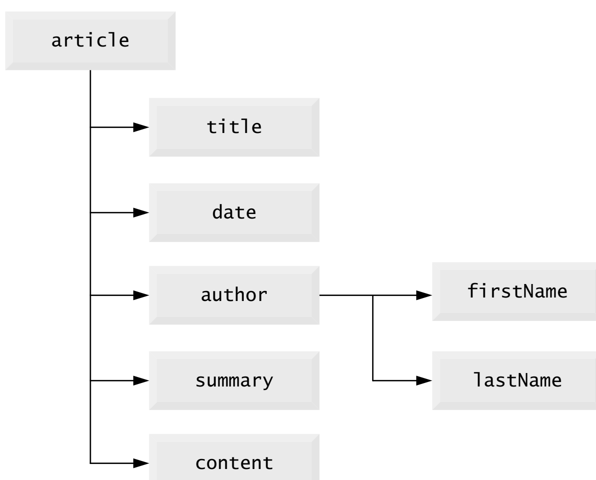


Fig. 24.19 | Tree structure for the document `article.xml`.

The DOM tree has a single **root node**, which contains all the other nodes in the document. For example, the root node of the DOM tree that represents `article.xml`

(Fig. 24.2) contains a node for the XML declaration (line 1), two nodes for the comments (lines 2–3) and a node for the XML document's root element `article` (line 5).

Classes for creating, reading and manipulating XML documents are located in the **`System.Xml`** namespace, which also contains additional namespaces that provide other XML-related operations.

Reading an XML Document with an `XDocument`

Namespace **`System.Xml.Linq`** contains the classes used to manipulate a DOM in .NET. Though LINQ query expressions are not required to use them, the technologies used are collectively referred to as **LINQ to XML**. Previous versions of the .NET Framework used a different DOM implementation in the `System.Xml` namespace. These classes (such as `XmlDocument`) should generally be avoided in favor of LINQ to XML. In LINQ to XML, the **`XElement`** class represents a DOM element node—an XML document is represented by a tree of `XElement` objects. The **`XDocument`** class represents an entire XML document. Unlike `XElements`, `XDocuments` cannot be nested. Figure 24.20 uses these classes to load the `article.xml` document (Fig. 24.2) and display its data in a `TextBox`. The program displays a formatted version of its input XML file. If `article.xml` were poorly formatted, such as being all on one line, this application would allow you to convert it into a form that is much easier to understand.

To create an `XDocument` from an existing XML document, we use `XDocument`'s `static` **`Load` method**, giving the location of the document as an argument (Fig. 24.20, line 20). The returned `XDocument` contains a tree representation of the loaded XML file, which is used to navigate the file's contents. The `XDocument`'s **`Root` property** (line 24) returns an `XElement` representing the root element of the XML file.

Method `PrintElement` (lines 28–56) displays an `XElement` in `outputTextBox`. Because nested elements should be at different indentation levels, `PrintElement` takes an `int` specifying the amount of indentation to use in addition to the `XElement` it's displaying. Variable `indentLevel` is passed as an argument to the `IndentOutput` method (lines 59–63) to add the correct amount of spacing before the begin (line 35) and end (line 55) tags are displayed.

```
1  // Fig. 24.20: XDocumentTestForm.cs
2  // Reading an XML document and displaying it in a TextBox.
3  using System;
4  using System.Xml.Linq;
5  using System.Windows.Forms;
6
7  namespace XDocumentTest
8  {
9     public partial class XDocumentTestForm : Form
10    {
11       public XDocumentTestForm()
12       {
13          InitializeComponent();
14       } // end constructor
```

Fig. 24.20 | Reading an XML document and displaying it in a `TextBox`. (Part 1 of 3.)

```

      // read XML document and display its content
      private void XDocumentTestForm_Load( object sender, EventArgs e )
      {
         // load the XML file into an XDocument
         XDocument xmlFile = XDocument.Load( "article.xml" );
         int indentLevel = 0; // no indentation for root element

         // print elements recursively
         PrintElement( xmlFile.Root, indentLevel );
      } // end method XDocumentTestForm_Load

      // display an element (and its children, if any) in the TextBox
      private void PrintElement( XElement element, int indentLevel )
      {
         // get element name without namespace
         string name = element.Name.LocalName;

         // display the element's name within its tag
         IndentOutput( indentLevel ); // indent correct amount
         outputTextBox.AppendText( '<' + name + ">\n" );

         // check for child elements and print value if none contained
         if ( element.HasElements )
         {
            // print all child elements at the next indentation level
            foreach ( var child in element.Elements() )
               PrintElement( child, indentLevel + 1 );
         } // end if
         else
         {
            // increase the indentation amount for text elements
            IndentOutput( indentLevel + 1 );

            // display the text inside this element
            outputTextBox.AppendText( element.Value.Trim() + '\n' );
         } // end else

         // display end tag
         IndentOutput( indentLevel );
         outputTextBox.AppendText( "</" + name + ">\n" );
      } // end method PrintElement

      // add the specified amount of indentation to the current line
      private void IndentOutput( int number )
      {
         for ( int i = 0; i < number; ++i )
            outputTextBox.AppendText( "   " );
      } // end method IndentOutput
   } // end class XDocumentTestForm
} // end namespace XDocumentTest
```

Fig. 24.20 | Reading an XML document and displaying it in a `TextBox`. (Part 2 of 3.)

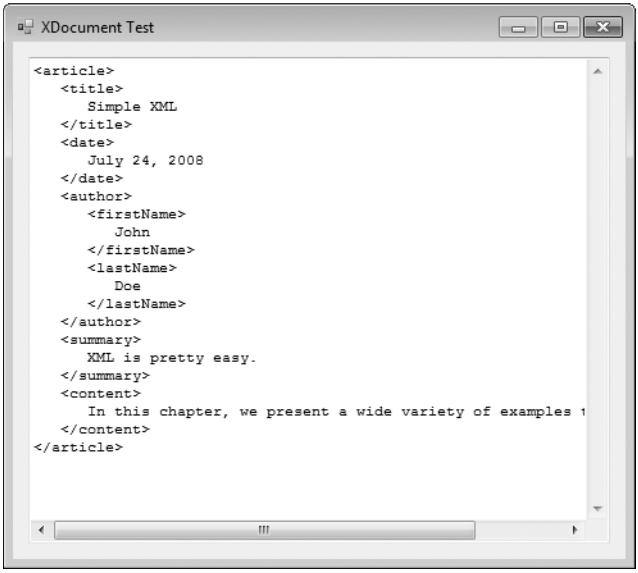


Fig. 24.20 | Reading an XML document and displaying it in a `TextBox`. (Part 3 of 3.)

As you've seen in previous sections, tag and attribute names often have a namespace prefix. Because the full names consist of two parts (the prefix and name), tag and attribute names are stored not simply as `string`s, but as objects of class **`XName`**. The **`Name` property** of an `XElement` (line 31) returns an `XName` object containing the tag name and namespace—we are not interested in the namespace for this example, so we retrieve the unqualified name using the `XName`'s **`LocalName` property**.

`XElement`s with and without children are treated differently in the program—this test is performed using the **`HasElements` property** (line 38). For `XElement`s with children, we use the **`Elements` method** (line 41) to obtain the children, then iterate through them and recursively print their children by calling `PrintElement` (line 42). For `XElement`s that do not have children, the text they contain is displayed using the **`Value` property** (line 50). If used on an element with children, the `Value` property returns all of the text contained within its descendants, with the tags removed. For simplicity, elements with attributes and those with both elements and text as children are not handled. The indentation is increased by one in both cases to allow for proper formatting.

24.9 LINQ to XML Class Hierarchy

As you saw in the previous section, `XElement` objects provide several methods for quickly traversing the DOM tree they represent. LINQ to XML provides many other classes for representing different parts of the tree. Figure 24.21 demonstrates the use of these additional classes to navigate the structure of an XML document and display it in a `TreeView` control. It also shows how to use these classes to get functionality equivalent to the XPath strings introduced in Section 24.7. The file used as a data source (`sports.xml`) is shown in Fig. 24.14.

```
// Fig. 24.21: PathNavigatorForm.cs
// Document navigation using XNode.
using System;
using System.Collections.Generic;
using System.Linq;
using System.Xml; // for XmlNodeType enumeration
using System.Xml.Linq; // for XNode and others
using System.Xml.XPath; // for XPathSelectElements
using System.Windows.Forms;

namespace PathNavigator
{
   public partial class PathNavigatorForm : Form
   {
      private XNode current; // currently selected node
      private XDocument document; // the document to navigate
      private TreeNode tree; // TreeNode used by TreeView control

      public PathNavigatorForm()
      {
         InitializeComponent();
      } // end PathNavigatorForm

      // initialize variables and TreeView control
      private void PathNavigatorForm_Load( object sender, EventArgs e )
      {
         document = XDocument.Load( "sports.xml" ); // load sports.xml

         // current node is the entire document
         current = document;

         // create root TreeNode and add to TreeView
         tree = new TreeNode( NodeText( current ) );
         pathTreeView.Nodes.Add( tree ); // add TreeNode to TreeView
         TreeRefresh(); // reset the tree display
      } // end method PathNavigatorForm_Load

      // print the elements of the selected path
      private void locateComboBox_SelectedIndexChanged(
         object sender, EventArgs e )
      {
         // retrieve the set of elements to output
         switch ( locateComboBox.SelectedIndex )
         {
            case 0: // print all sports elements
               PrintElements( document.Elements( "sports" ) );
               break;
            case 1: // print all game elements
               PrintElements( document.Descendants( "game" ) );
               break;
            case 2: // print all name elements
               PrintElements( document.XPathSelectElements( "//name" ) );
               break;
```

Fig. 24.21 | Document navigation using `XNode`. (Part 1 of 6.)

```
            case 3: // print all paragraph elements
               PrintElements( document.Descendants( "game" )
                  .Elements( "paragraph" ) );
               break;
            case 4: // print game elements with name element of "Cricket"
               // use LINQ to XML to retrieve the correct node
               var cricket =
                  from game in document.Descendants( "game" )
                  where game.Element( "name" ).Value == "Cricket"
                  select game;
               PrintElements( cricket );
               break;
            case 5: // print all id attributes of game
               PrintIDs( document.Descendants( "game" ) );
               break;
         } // end switch
      } // end method locateComboBox_SelectedIndexChanged

      // traverse to first child
      private void firstChildButton_Click( object sender, EventArgs e )
      {
         // try to convert to an XContainer
         var container = current as XContainer;

         // if container has children, move to first child
         if ( container != null && container.Nodes().Any() )
         {
            current = container.Nodes().First(); // first child

            // create new TreeNode for this node with correct label
            var newNode = new TreeNode( NodeText( current ) );
            tree.Nodes.Add( newNode ); // add node to TreeNode Nodes list
            tree = newNode; // move current selection to newNode
            TreeRefresh(); // reset the tree display
         } // end if
         else
         {
            // current node is not a container or has no children
            MessageBox.Show( "Current node has no children.", "Warning",
               MessageBoxButtons.OK, MessageBoxIcon.Information );
         } // end else
      } // end method firstChildButton_Click

      // traverse to node's parent
      private void parentButton_Click( object sender, EventArgs e )
      {
         // if current node is not the root, move to parent
         if ( current.Parent != null )
            current = current.Parent; // get parent node
         else // node is at top level: move to document itself
            current = current.Document;

```

Fig. 24.21 | Document navigation using XNode. (Part 2 of 6.)

```
         // move TreeView if it is not already at the root
         if ( tree.Parent != null )
         {
            tree = tree.Parent; // get parent in tree structure
            tree.Nodes.Clear(); // remove all children
            TreeRefresh(); // reset the tree display
         } // end if
      } // end method parentButton_Click

      // traverse to previous node
      private void previousButton_Click( object sender, EventArgs e )
      {
         // if current node is not first, move to previous node
         if ( current.PreviousNode != null )
         {
            current = current.PreviousNode; // move to previous node
            var treeParent = tree.Parent; // get parent node
            treeParent.Nodes.Remove( tree ); // delete current node
            tree = treeParent.LastNode; // set current display position
            TreeRefresh(); // reset the tree display
         } // end if
         else // current element is first among its siblings
         {
            MessageBox.Show( "Current node is first sibling.", "Warning",
               MessageBoxButtons.OK, MessageBoxIcon.Information );
         } // end else
      } // end method previousButton_Click

      // traverse to next node
      private void nextButton_Click( object sender, EventArgs e )
      {
         // if current node is not last, move to next node
         if ( current.NextNode != null )
         {
            current = current.NextNode; // move to next node

            // create new TreeNode to display next node
            var newNode = new TreeNode( NodeText( current ) );
            var treeParent = tree.Parent; // get parent TreeNode
            treeParent.Nodes.Add( newNode ); // add to parent node
            tree = newNode; // set current position for display
            TreeRefresh(); // reset the tree display
         } // end if
         else // current node is last among its siblings
         {
            MessageBox.Show( "Current node is last sibling.", "Warning",
               MessageBoxButtons.OK, MessageBoxIcon.Information );
         } // end else
      } // end method nextButton_Click

      // update TreeView control
      private void TreeRefresh()
      {
```

Fig. 24.21 | Document navigation using XNode. (Part 3 of 6.)

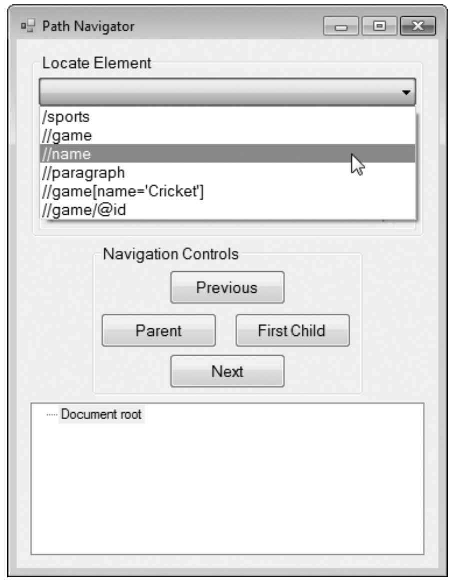
```
         pathTreeView.ExpandAll(); // expand tree node in TreeView
         pathTreeView.Refresh(); // force TreeView update
         pathTreeView.SelectedNode = tree; // highlight current node
      } // end method TreeRefresh

      // print values in the given collection
      private void PrintElements( IEnumerable< XElement > elements )
      {
         locateTextBox.Clear(); // clear the text area

         // display text inside all elements
         foreach ( var element in elements )
            locateTextBox.AppendText( element.Value.Trim() + '\n' );
      } // end method PrintElements

      // print the ID numbers of all games in elements
      private void PrintIDs( IEnumerable< XElement > elements )
      {
         locateTextBox.Clear(); // clear the text area

         // display "id" attribute of all elements
         foreach ( var element in elements )
            locateTextBox.AppendText(
               element.Attribute( "id" ).Value.Trim() + '\n' );
      } // end method PrintIDs

      // returns text used to represent an element in the tree
      private string NodeText( XNode node )
      {
         // different node types are displayed in different ways
         switch ( node.NodeType )
         {
            case XmlNodeType.Document:
               // display the document root
               return "Document root";
            case XmlNodeType.Element:
               // represent node by tag name
               return '<' + ( node as XElement ).Name.LocalName + '>';
            case XmlNodeType.Text:
               // represent node by text stored in Value property
               return ( node as XText ).Value;
            case XmlNodeType.Comment:
               // represent node by comment text
               return ( node as XComment ).ToString();
            case XmlNodeType.ProcessingInstruction:
               // represent node by processing-instruction text
               return ( node as XProcessingInstruction ).ToString();
            default:
               // all nodes in this example are already covered;
               // return a reasonable default value for other nodes
               return node.NodeType.ToString();
         } // end switch
      } // end method NodeText
```

Fig. 24.21 | Document navigation using XNode. (Part 4 of 6.)

```
    } // end class PathNavigatorForm
} // end namespace PathNavigator
```

a) **Path Navigator** form upon loading

b) The **//name** path is selected



c) The **//name** path displays all `name` elements in the document

d) The **//game[name='Cricket']** path displays `game` elements with a `name` element containing "Cricket"

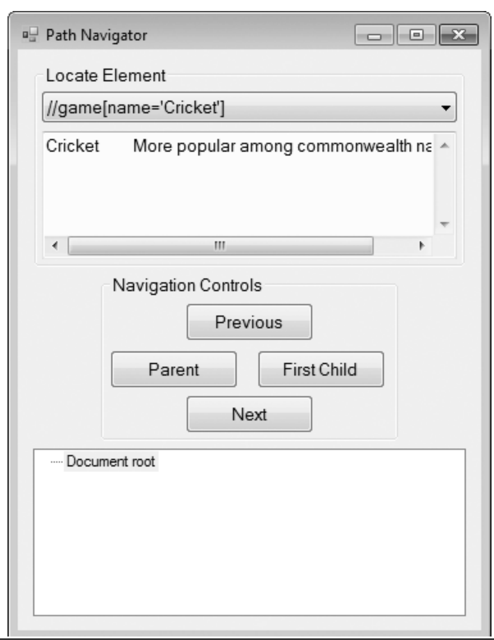


Fig. 24.21 | Document navigation using `XNode`. (Part 5 of 6.)

e) The **First Child** button expands the tree to show the first element in that group

f) The **Next** button lets you view siblings of the current element

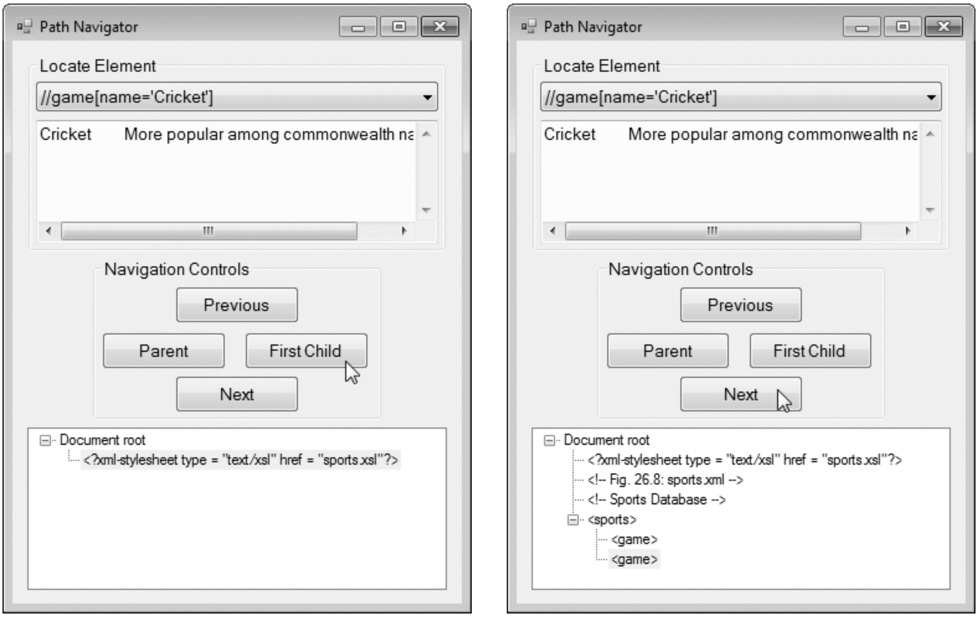


Fig. 24.21 | Document navigation using `XNode`. (Part 6 of 6.)

The interface for this example allows the user to display selected elements in the `TextBox`, or to navigate through the DOM tree in the lower `TreeView`. Initially, the `TextBox` is blank, and the `TreeView` is initialized to show the root of the tree. The `ComboBox` at the top of the `Form` contains XPath expressions. These are not used directly—instead, the example uses the LINQ to XML DOM classes and a LINQ query to retrieve the same results. As in the previous example, the `XDocument`'s `Load` method (line 27) is used to load the contents of the XML file into memory. Instance variable `current`, which points to the current position in the DOM, is initialized to the document itself (line 30). Line 33 creates a `TreeNode` for the `XElement` with the correct text, which is then inserted into the `TreeView` (lines 34–35). The `TreeRefresh` method (lines 157–162) refreshes the `pathTreeView` control so that the user interface updates correctly.

`locateComboBox_SelectedIndexChanged` Event Handler

The `SelectedIndexChanged` event handler of `locateComboBox` (lines 39–70) fills the `TextBox` with the elements corresponding to the path the user selected. The first `case` (lines 45–47) uses the `Elements` method of the `XDocument` object `document`. The `Elements` method is overloaded—one version has no parameter and returns all child elements. The second version returns only elements with the given tag name. Recall from the previous example that `XElement` also has an `Elements` method. This is because the method is actually defined in the **`XContainer` class**, the base class of `XDocument` and `XElement`. `XContainer` represents nodes in the DOM tree that can contain other nodes. The results of the call to the method `Elements` are passed to the `PrintElements` method (lines 165–172). The

PrintElements method uses the XElement's Value property (line 171) introduced in the previous example. The Value property returns all text in the current node and its descendants. The text is displayed in locateTextBox.

The second case (lines 48–50) uses the **Descendants method**—another XContainer method common to XElement and XDocument—to get the same results as the XPath double slash (//) operator. In other words, the Descendants method returns all descendant elements with the given tag name, not just direct children. Like Elements, it's overloaded and has a version with no parameter that returns all descendants.

The third case (lines 51–53) uses extension method **XPathSelectElements** from namespace **System.Xml.XPath** (imported at line 8). This method allows you to use an XPath expression to navigate XDocument and XElement objects. It returns an IEnumerable<XElement>. There's also an XPathSelectElement method that returns a single XElement.

The fourth case (lines 54–57) also uses the Descendants method to retrieve all game elements, but it then calls the Elements method to retrieve the child paragraph elements. Because the Descendants method returns an IEnumerable<XElement>, the Elements method is not being called on the XContainer class that we previously stated contains the Elements method. Calling the Elements method in this way is allowed because there's an extension method in the System.Xml.Linq namespace that returns an IEnumerable<XElement> containing the children of all elements in the original collection. To match the interface of the XContainer class, there's also a Descendants extension method, and both have versions that do not take an argument.

In a document where a specific element appears at multiple nesting levels, you may need to use chained calls of the Elements method explicitly to return only the elements in which you are interested. Using the Descendants method in these cases can be a source of subtle bugs—if the XML document's structure changes, your code could silently accept input that the program should not treat as valid. The Descendants method is best used for tags that can appear at any nesting level within the document, such as formatting tags in XHTML, which can occur in many distinct parts of the text.

The fifth case (lines 58–65) retrieves only the game elements with a name element containing "Cricket". To do this, we use a LINQ query (lines 61–63). The Descendants and Element methods return an IEnumerable<XElement>, so they can be used as the subject of a LINQ query. The where clause (line 62) uses the Element method to retrieve all name elements that are children of the game element the range variable represents. The **Element method**, a member of the XContainer class, returns the first child element with the given tag name or null if no such element exists. The where clause uses the Value property to retrieve the text contained in the element. We do not check for Element returning null because we know that all game elements in sports.xml contain name elements.

PrintIDs Method

The PrintIDs method (lines 175–183) displays the id attributes of the XElement objects passed to it—specifically, the game elements in the document (line 67). To do this, it uses the **Attribute method** of the XElement class (line 182). The Attribute method returns an XAttribute object matching the given attribute name or null if no such object exists. The **XAttribute class** represents an XML attribute—it holds the attribute's name and value. Here, we access its Value property to get a string that contains the attribute's value—it can also be used as an *lvalue* to modify the value.

LINQ to XML Class Hierarchy

The `Click` event handlers for the `Buttons` in the example are used to update the data displayed in the `TreeView`. These methods introduce many other classes from the namespace `System.Xml.Linq`. The entire LINQ to XML class hierarchy is shown in the UML class diagram of Fig. 24.22. `XNamespace` will be covered in the next section, and **`XDocumentType`** holds a DTD, which may be defined directly in an XML file rather than externally referenced (as we did in Fig. 24.4, `letter.xml`).

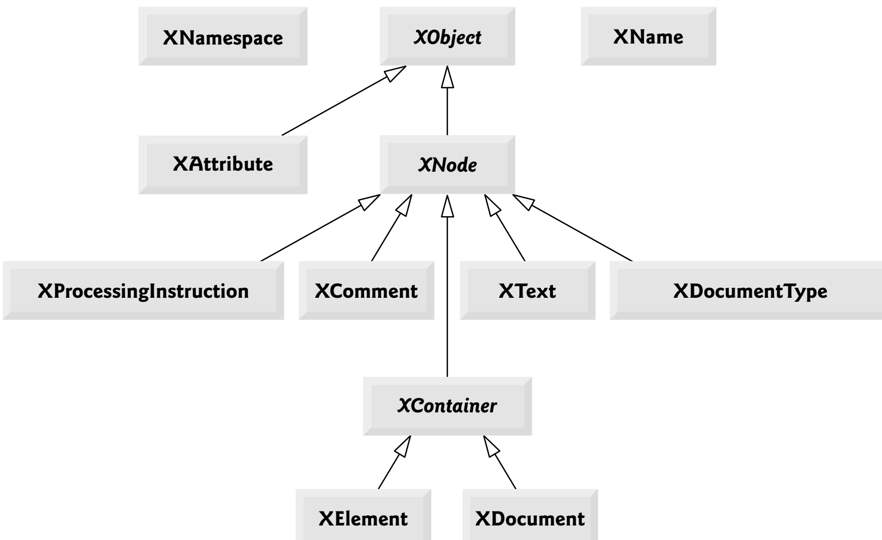


Fig. 24.22 | LINQ to XML class hierarchy diagram.

As you can see from the diagram, the **`XNode` class** is a common abstract base class of all the node types in an XML document—including elements, text and processing instructions. Because all DOM node classes inherit from `XNode`, an `XNode` object can be used to keep track of our current location as we navigate the DOM tree.

`firstChildButton_Click` *Event Handler*

The `firstChildButton_Click` event handler (Fig. 24.21, lines 73–95) uses the `as` operator to determine whether the current node is an `XContainer` (line 76). Recall that the `as` operator attempts to cast the reference to another type, and returns `null` if it cannot. If `current` is an `XContainer` and has children (line 79), we move `current` to its first child (line 81). These operations use the **`Nodes` method** of class `XContainer`, which returns a reference to an object of type `IEnumerable<XNode>` containing all children of the given `XContainer`. Line 79 uses the `Any` extension method introduced in Chapter 9—all of the standard LINQ to Objects methods may be used with the LINQ to XML classes. The event handler then inserts a `TreeNode` into the `TreeView` to display the child element that `current` now references (lines 84–87).

NodeText Method

Line 84 uses the NodeText method (lines 186–211) to determine what text to display in the TreeNode. It uses the **NodeType property**, which returns a value of the **XmlNodeType enumeration** from the System.Xml namespace (imported at line 6) indicating the object's node type. Although we call it on an XNode, the NodeType property is actually defined in the **XObject class**. XObject is an abstract base class for all nodes and attributes. The NodeType property is overridden in the concrete subclasses to return the correct value.

After the node's type has been determined, it's converted to the appropriate type using the as operator, then the correct text is retrieved. For the entire document, it returns the text **Document root** (line 193). For elements, NodeText returns the tag name enclosed in angle brackets (line 196). For text nodes, it uses the contained text. It retrieves this by converting the XNode to an XText object—the **XText class** holds the contents of a text node. XText's **Value property** returns the contained text (line 199)—we could also have used its ToString method. Comments, represented by the **XComment class**, are displayed just as they're written in the XML file using the ToString method of XComment (line 202). The ToString methods of all subclasses of XNode return the XML they and their children (if any) represent with proper indentation. The last type handled is processing instructions, stored in the **XProcessingInstruction class** (line 205)—in this example, the only processing instruction is the XML declaration at the beginning of the file. A default case returning the name of the node type is included for other node types that do not appear in sports.xml (line 209).

Other Button Event Handlers

The event handlers for the other Buttons are structured similarly to firstChildButton_Click—each moves current and updates the TreeView accordingly. The parentButton_Click method (lines 98–113) ensures that the current node has a parent—that is, it's not at the root of the XDocument—before it tries to move current to the parent (line 102). It uses the **Parent property** of XObject, which returns the parent of the given XObject or null if the parent does not exist. For nodes at the root of the document, including the root element, XML declaration, header comments and the document itself, Parent with return null. We want to move up to the document root in this case, so we use the **Document property** (also defined in XObject) to retrieve the XDocument representing the document root (line 104). The Document property of an XDocument returns itself. This is consistent with most file systems—attempting to move up a directory from the root will succeed, but not move.

The event handlers for the **Previous** (lines 116–132) and **Next** (lines 135–154) Buttons use the **PreviousNode** (lines 119 and 121) and **NextNode** (lines 138 and 140) properties of XNode, respectively. As their names imply, they return the previous or next sibling node in the tree. If there's no previous or next node, the properties return null.

24.10 LINQ to XML: Namespaces and Creating Documents

As you know, XML namespaces provide a technique for preventing collisions between tag names used for different purposes. LINQ to XML provides the **XNamespace class** to enable creation and manipulation of XML namespaces.

Using LINQ to XML to navigate data already stored in an XML document is a common operation, but sometimes it's necessary to create an XML document from scratch. Figure 24.23 uses these features to update an XML document to a new format and combine the data in it with data from a document already in the new format. Figures 24.24 and 24.25 contain the XML files in the old and new formats, respectively. Figure 24.26 displays the file output by the program.

```
// Fig. 24.23: XMLCombine.cs
// Transforming an XML document and splicing its contents with another.
using System;
using System.Linq;
using System.Xml.Linq;

class XMLCombine
{
   // namespaces used in XML files
   private static readonly XNamespace employeesOld =
      "http://www.deitel.com/employeesold";
   private static readonly XNamespace employeesNew =
      "http://www.deitel.com/employeesnew";

   static void Main( string[] args )
   {
      // load files from disk
      XDocument newDocument = XDocument.Load( "employeesNew.xml" );
      XDocument oldDocument = XDocument.Load( "employeesOld.xml" );

      // convert from old to new format
      oldDocument = TransformDocument( oldDocument );

      // combine documents and write to output file
      SaveFinalDocument( newDocument, oldDocument );

      // tell user we have finished
      Console.WriteLine( "Documents successfully combined." );
   } // end Main

   // convert the given XDocument in the old format to the new format
   private static XDocument TransformDocument( XDocument document )
   {
      // use a LINQ query to fill the new XML root with the correct data
      var newDocumentRoot = new XElement( employeesNew + "employeelist",
         from employee in document.Root.Elements()
         select TransformEmployee( employee ) );

      return new XDocument( newDocumentRoot ); // return new document
   } // end method TransformDocument

   // transform a single employee's data from old to new format
   private static XElement TransformEmployee( XElement employee )
   {
```

Fig. 24.23 | Transforming an XML document and splicing its contents with another. (Part 1 of 2.)

```
         // retrieve values from old-format XML document
         XNamespace old = employeesOld; // shorter name
         string firstName = employee.Element( old + "firstname" ).Value;
         string lastName = employee.Element( old + "lastname" ).Value;
         string salary = employee.Element( old + "salary" ).Value;

         // return new-format element with the correct data
         return new XElement( employeesNew + "employee",
            new XAttribute( "name", firstName + " " + lastName ),
            new XAttribute( "salary", salary ) );
      } // end method TransformEmployee

      // take two new-format XDocuments and combine
      // them into one, then save to output.xml
      private static void SaveFinalDocument( XDocument document1,
         XDocument document2 )
      {
         // create new root element
         var root = new XElement( employeesNew + "employeelist" );

         // fill with the elements contained in the roots of both documents
         root.Add( document1.Root.Elements() );
         root.Add( document2.Root.Elements() );

         root.Save( "output.xml" ); // save document to file
      } // end method SaveFinalDocument
   } // end class XMLCombine
```

Fig. 24.23 | Transforming an XML document and splicing its contents with another. (Part 2 of 2.)

```
<?xml version="1.0"?>
<!-- Fig. 24.24: employeesOld.xml -->
<!-- Sample old-format input for the XMLCombine application. -->
<employees xmlns="http://www.deitel.com/employeesold">
   <employeelisting>
      <firstname>Christopher</firstname>
      <lastname>Green</lastname>
      <salary>1460</salary>
   </employeelisting>
   <employeelisting>
      <firstname>Michael</firstname>
      <lastname>Red</lastname>
      <salary>1420</salary>
   </employeelisting>
</employees>
```

Fig. 24.24 | Sample old-format input for the `XMLCombine` application.

```
<?xml version="1.0"?>
<!-- Fig. 24.25: employeesNew.xml -->
<!-- Sample new-format input for the XMLCombine application. -->
```

Fig. 24.25 | Sample new-format input for the `XMLCombine` application. (Part 1 of 2.)

```
<employeelist xmlns="http://www.deitel.com/employeesnew">
   <employee name="Jenn Brown" salary="2300"/>
   <employee name="Percy Indigo" salary="1415"/>
</employeelist>
```

Fig. 24.25 | Sample new-format input for the `XMLCombine` application. (Part 2 of 2.)

```
<?xml version="1.0" encoding="utf-8"?>
<employeelist xmlns="http://www.deitel.com/employeesnew">
  <employee name="Jenn Brown" salary="2300" />
  <employee name="Percy Indigo" salary="1415" />
  <employee name="Christopher Green" salary="1460" />
  <employee name="Michael Red" salary="1420" />
</employeelist>
```

Fig. 24.26 | XML file generated by `XMLCombine` (Fig. 24.23).

Lines 10–13 of Fig. 24.23 define `XNamespace` objects for the two namespaces used in the input XML documents. There's an implicit conversion from `string` to `XNamespace`.

The `TransformDocument` method (lines 32–40) converts an XML document from the old format to the new format. It creates a new `XElement newDocumentRoot`, passing the desired name and child elements as arguments. It then creates and returns a new `XDocument`, with `newDocumentRoot` as its root element.

The first argument (line 35) creates an `XName` object for the tag name using the `XNamespace`'s overloaded + operator—the `XName` contains the `XNamespace` from the left operand and the local name given by the `string` in the right operand. Recall that you can use `XName`'s `LocalName` property to access the element's unqualified name. The **`Namespace` property** gives you access to the contained `XNamespace` object. The second argument is the result of a LINQ query (lines 36–37), which uses the `TransformEmployee` method to transform each `employeelisting` entry in the old format (returned by calling the `Elements` method on the root of the old document) into an `employee` entry in the new format. When passed a collection of `XElements`, the `XElement` constructor adds all members of the collection as children.

The `TransformEmployee` method (lines 43–55) reformats the data for one employee. It does this by retrieving the text contained in the child elements of each of the `employeelisting` entries, then creating a new `employee` element and returning it. The expressions passed to the `Element` method use `XNamespaces`—this is necessary because the elements they're retrieving are in the old namespace. Passing just the tag's local name would cause the `Element` method to return `null`, creating a `NullReferenceException` when the `Value` property was accessed.

Once we've retrieved the values from the original XML document, we add them as attributes to an `employee` element. This is done by creating new `XAttribute` objects with the attribute's name and value, and passing these to the `XElement` constructor (lines 52–54).

The `SaveFinalDocument` method (lines 59–70) merges the two documents and saves them to disk. It first creates a new root element in the correct namespace (line 63). Then it adds the `employee` elements from both documents as children using the **`Add` method** defined in the `XContainer` class (lines 66–67). The `Add` method, like `XElement`'s constructor, will add all elements if passed a collection. After creating and filling the new root, we save it to disk (line 69).

24.11 XSLT with Class XslCompiledTransform

Recall from Section 24.7 that XSL elements define rules for transforming one type of XML document to another type of XML document. We showed how to transform XML documents into XHTML documents and displayed the results in Internet Explorer. The XSLT processor built into Internet Explorer performed the transformations. We now perform a similar task in a C# program.

Performing an XSL Transformation in C# Using the .NET Framework

Figure 24.27 applies the style sheet `sports.xsl` (Fig. 24.15) to the XML document `sports.xml` (Fig. 24.14) programmatically. The result of the transformation is written to an XHTML file on disk and displayed in a text box. Figure 24.27(c) shows the resulting XHTML document (`sports.html`) when you view it in Internet Explorer.

```
// Fig. 24.27: TransformTestForm.cs
// Applying an XSLT style sheet to an XML Document.
using System;
using System.IO;
using System.Windows.Forms;
using System.Xml.Xsl; // contains class XslCompiledTransform

namespace TransformTest
{
   public partial class TransformTestForm : Form
   {
      public TransformTestForm()
      {
         InitializeComponent();
      } // end constructor

      // applies the transformation
      private XslCompiledTransform transformer;

      // initialize variables
      private void TransformTestForm_Load( object sender, EventArgs e )
      {
         transformer = new XslCompiledTransform(); // create transformer

         // load and compile the style sheet
         transformer.Load( "sports.xsl" );
      } // end TransformTestForm_Load

      // transform data on transformButton_Click event
      private void transformButton_Click( object sender, EventArgs e )
      {
         // perform the transformation and store the result in new file
         transformer.Transform( "sports.xml", "sports.html" );
```

Fig. 24.27 | Applying an XSLT style sheet to an XML document. (Part 1 of 2.)

```
34
35            // read and display the XHTML document's text in a TextBox
36            consoleTextBox.Text = File.ReadAllText( "sports.html" );
37         } // end method transformButton_Click
38      } // end class TransformTestForm
39   } // end namespace TransformTest
```

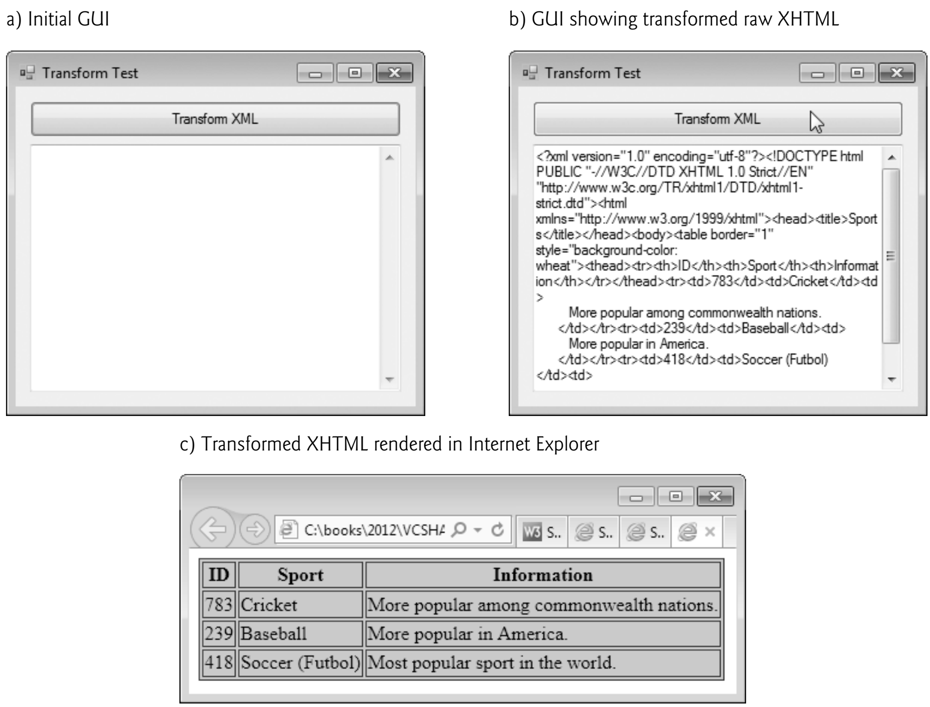


Fig. 24.27 | Applying an XSLT style sheet to an XML document. (Part 2 of 2.)

Line 6 imports the **`System.Xml.Xsl`** namespace, which contains class **`XslCompiledTransform`** for applying XSL style sheets to XML documents. Line 18 declares `XslCompiledTransform` object `transformer`, which serves as an XSLT processor to transform XML data from one format to another.

In event handler `TransformTestForm_Load` (lines 21–27), line 23 creates and initializes `transformer`. Line 26 calls the `XslCompiledTransform` object's **`Load`** method, which loads and parses the style sheet that this application uses. This method takes an argument specifying the name and location of the style sheet—`sports.xsl` (Fig. 24.15) located in the current directory.

The event handler `transformButton_Click` (lines 30–37) calls the **`Transform`** method of class `XslCompiledTransform` to apply the style sheet (`sports.xsl`) to `sports.xml` (line 33). This method takes two `string` arguments—the first specifies the XML file to which the style sheet should be applied, and the second specifies the file in which the result of the transformation should be stored on disk. Thus the `Transform` method call in line 33 transforms `sports.xml` to XHTML and writes the result to disk as the file `sports.html`. Figure 24.27(c) shows the new XHTML document rendered in Internet Explorer. The output is identical to that of Fig. 24.14—in the current example, though, the XHTML is stored on disk rather than generated dynamically.

After applying the transformation, the program displays the content of the new file `sports.html` in `consoleTextBox`, as shown in Fig. 24.27(b). Line 36 obtains the text of the file by passing its name to method `ReadAllText` of the `System.IO.File` class, which simplifies file-processing tasks on the local system.

24.12 Wrap-Up

In this chapter, we introduced XML and several related technologies. We discussed how to create DTDs and schemas for specifying and validating the structure of an XML document. We showed how to use various tools to confirm whether XML documents are valid (i.e., conform to a DTD or schema).

You learned how to create and use XSL documents to specify rules for converting XML documents between formats. Specifically, you learned how to format and sort XML data and output it as XHTML for display in a web browser.

The final sections of the chapter presented more advanced uses of XML in C# applications. We demonstrated how to retrieve and display data from an XML document using various .NET classes. We illustrated how a DOM tree represents each element of an XML document as a node in the tree. The chapter also demonstrated loading data from an XML document using the `Load` method of the `XDocument` class. We demonstrated the tools LINQ to XML provides for working with namespaces. Finally, we showed how to use the `XslCompiledTransform` class to perform XSL transformations.

Summary

Section 24.1 Introduction

- XML is a widely supported standard for describing data that is commonly used to exchange that data between applications over the Internet.
- The .NET Framework uses XML extensively. Many of the internal files that Visual Studio creates, such as those that represent project settings, are formatted as XML.
- XML is used heavily in serialization.
- XAML (from WPF) is an XML vocabulary used for creating user interfaces.
- LINQ to XML provides a convenient way to extract data from XML documents using the same LINQ syntax used on arrays and collections.
- LINQ to XML also provides a set of classes for easily navigating and creating XML documents in your code.

Section 24.2 XML Basics

- XML documents should be readable by both humans and machines.
- XML permits document authors to create custom markup for any type of information. This enables document authors to create entirely new markup languages that describe specific types of data, including mathematical formulas, chemical molecular structures, music and recipes.

- An XML parser is responsible for identifying components of XML documents (typically files with the `.xml` extension) and then storing those components in a data structure for manipulation.
- An XML document can optionally reference a Document Type Definition (DTD) or W3C XML Schema that defines the XML document's structure.
- An XML document that conforms to a DTD/schema is valid.
- If an XML parser can process an XML document successfully, that document is well formed.

Section 24.3 Structuring Data

- An XML document begins with an optional XML declaration. The `version` attribute specifies the version of XML syntax used in the document. The `encoding` attribute specifies what character encoding is used in the document.
- XML comments begin with `<!--` and end with `-->`.
- An XML document contains text that represents its content (that is, data) and elements that specify its structure. XML documents delimit an element with start and end tags.
- The root element of an XML document encompasses all its other elements.
- XML element names can be of any length and can contain letters, digits, underscores, hyphens and periods. However, they must begin with either a letter or an underscore, and they should not begin with "`xml`" in any combination of uppercase and lowercase letters, as this is reserved for use in the XML standards.
- When a user loads an XML document in Internet Explorer, the browser parses the document, and Internet Explorer uses a style sheet to format the data for display.
- Internet Explorer displays minus (**–**) or plus (**+**) signs next to all container elements. A minus sign indicates that all child elements are being displayed. When clicked, a minus sign becomes a plus sign (which collapses the container element and hides all the children), and vice versa.
- Data can be placed between tags or in attributes (name/value pairs that appear within the angle brackets of start tags). Elements can have any number of attributes, but attribute names within a single element must be unique.

Section 24.4 XML Namespaces

- XML allows document authors to create their own markup, and as a result, naming collisions (that is, two different elements that have the same name) can occur. XML namespaces provide a means for document authors to prevent collisions.
- Each namespace prefix is bound to a uniform resource identifier (URI) that uniquely identifies the namespace. A URI is a series of characters that differentiates namespaces. Document authors create their own namespace prefixes. Any name can be used as a namespace prefix, but the namespace prefix `xml` is reserved for use in XML standards.
- To eliminate the need to place a namespace prefix in each element, authors can specify a default namespace for an element and its children. We declare a default namespace using keyword `xmlns` with a URI (Uniform Resource Identifier) as its value.
- Document authors commonly use URLs (Uniform Resource Locators) for URIs, because domain names (for example, `deitel.com`) in URLs must be unique.

Section 24.5 Document Type Definitions (DTDs)

- DTDs and schemas specify documents' element types and attributes and their relationships to one another.
- DTDs and schemas enable an XML parser to verify whether an XML document is valid (i.e., its elements contain the proper attributes and appear in the proper sequence).

- A DTD expresses the set of rules for document structure by specifying what attributes and other elements may appear inside a given element.
- In a DTD, an `ELEMENT` element type declaration defines the rules for an element. An `ATTLIST` attribute-list declaration defines attributes for a particular element.

Section 24.6 W3C XML Schema Documents

- Unlike DTDs, schemas use XML syntax and are themselves XML documents that programs can manipulate.
- Unlike DTDs, XML Schema documents can specify what type of data (e.g., numeric, text) an element can contain.
- An XML document that conforms to a schema document is schema valid.
- Two categories of types exist in XML Schema: simple types and complex types. Simple types cannot contain attributes or child elements; complex types can.
- Every simple type defines a restriction on an XML Schema–defined schema type or on a user-defined type.
- Complex types can have either simple content or complex content. Both simple content and complex content can contain attributes, but only complex content can contain child elements.
- Whereas complex types with simple content must extend or restrict some other existing type, complex types with complex content do not have this limitation.

Section 24.7 Extensible Stylesheet Language and XSL Transformations

- XSL can convert XML into any text-based document. XSL documents have the extension `.xsl`.
- XPath is a string-based language of expressions used by XML and many of its related technologies for effectively and efficiently locating structures and data (such as specific elements and attributes) in XML documents.
- XPath is used to locate parts of the source-tree document that match templates defined in an XSL style sheet. When a match occurs (i.e., a node matches a template), the matching template executes and adds its result to the result tree. When there are no more matches, XSLT has transformed the source tree into the result tree.
- XSLT selectively navigates the source tree using the `select` and `match` attributes.
- For XSLT to function, the source tree must be properly structured. Schemas, DTDs and validating parsers can validate document structure before using XPath and XSLT.
- XSL style sheets can be connected directly to an XML document by adding an `xml-stylesheet` processing instruction to the XML document.
- Two tree structures are involved in transforming an XML document using XSLT—the source tree (the document being transformed) and the result tree (the result of the transformation).
- The XPath character `/` (a forward slash) always selects the document root. In XPath, a leading forward slash specifies that we are using absolute addressing.
- An XPath expression with no beginning forward slash uses relative addressing.
- XSL element `value-of` retrieves an attribute's or element's value. The `@` symbol specifies an attribute node.
- XSL node-set function `name` retrieves the current node's element name.
- XSL node-set function `text` retrieves the text between the current node's start and end tags.
- The XPath expression `//*` selects all the nodes in an XML document.

Section 24.8 LINQ to XML: Document Object Model (DOM)

- Retrieving data from an XML document using traditional sequential file-processing techniques is not practical.
- On successfully parsing a document, some XML parsers store document data as trees in memory. This hierarchical tree structure is called a Document Object Model (DOM) tree, and an XML parser that creates such a tree is known as a DOM parser.
- In the DOM, each element name is represented by a node. A node that contains children is called a parent node. A parent node can have many children, but a child node can have only one parent node. Nodes that are peers are called sibling nodes.
- A node's descendant nodes include its children, its children's children and so on. A node's ancestor nodes include its parent, its parent's parent and so on.
- The DOM tree has a single root node, which contains all the other nodes in the document.
- Classes for creating, reading and manipulating XML documents are located in namespace `System.Xml`, which also contains additional namespaces that provide other XML-related operations.
- Namespace `System.Xml.Linq` contains the LINQ to XML classes used to manipulate a DOM.
- The `XElement` class represents a DOM element node.
- Class `XDocument` represents an XML document. Unlike `XElements`, `XDocuments` cannot be nested.
- To create an `XDocument` from an existing XML document, we use its `static` `Load` method, giving the location of the document as an argument. The returned `XDocument` contains a tree representation of the loaded XML file, which is used to navigate the file's contents.
- The `XDocument`'s `Root` property returns an `XElement` representing the root element of the XML file.
- Tag and attribute names are stored not simply as `strings`, but as objects of class `XName`. The `Name` property of an `XElement` returns an `XName` object containing the tag name and namespace.
- The unqualified name can be retrieved using `XName`'s `LocalName` property.
- The `HasElements` property of `XElement` can be used to determine whether it has children.
- The `Elements` method of `XElement` returns all child elements.
- The text contained in an `XElement` can be retrieved using the `Value` property. If used on an element with children, the `Value` property returns all of the text contained within its descendants, with the tags removed.

Section 24.9 LINQ to XML Class Hierarchy

- `XContainer`, the base class of `XDocument` and `XElement`, represents nodes in the DOM tree that can contain other nodes.
- The `Elements` method of `XContainer` is overloaded—one version has no parameter and returns all child elements. The second version returns only elements with the given tag name.
- `XContainer`'s `Descendants` method returns all descendant elements with the given tag name, not just direct children. Like `Elements`, it's overloaded and has a version with no parameter that returns all descendants.
- Extension method `XPathSelectElements` (namespace `System.Xml.XPath`) allows you to use an XPath expression to navigate `XDocument` and `XElement` objects. It returns an `IEnumerable<XElement>`—there's also an `XPathSelectElement` method that returns a single `XElement`.
- There are `Elements` and `Descendants` extension methods defined for `IEnumerable<XElement>` that return the children or descendants of all elements in the collection.

- Using the `Descendants` method when a specific element appears at multiple nesting levels can be a source of subtle bugs—if the XML document's structure changes, your code could silently accept input that the program should not treat as valid.
- Because the `Descendants` and `Elements` methods return an `IEnumerable<XElement>`, they can be used as the subject of a LINQ query.
- The `Element` method of the `XContainer` class returns the first child element with the given tag name or `null` if no such element exists.
- `XElement`'s `Attribute` method returns an `XAttribute` object matching the given attribute name or `null` if no such object exists.
- The `XAttribute` class represents an XML attribute—it holds the attribute's name and value. Its `Value` property returns a `string` that contains the attribute's value—it can also be used as an *lvalue* to modify the value.
- `XDocumentType` holds a DTD, which may be defined directly in an XML file rather than externally referenced.
- The `XNode` class is a common base class between all nodes in an XML document—including elements, text and processing instructions.
- The `Nodes` method of class `XContainer` returns an `IEnumerable<XNode>` containing all children of the given `XContainer`.
- `XObject`'s `NodeType` property returns a value of the `XmlNodeType` enumeration from the `System.Xml` namespace indicating what type of node that object is.
- `XObject` is an abstract base class for all nodes as well as attributes.
- Class `XText` holds the contents of a text node. `XText`'s `Value` property returns the contained text.
- Comments are represented by the `XComment` class.
- The `ToString` methods of all subclasses of `XNode` return the XML they and their children (if any) represent with proper indentation.
- Processing instructions are stored in the `XProcessingInstruction` class.
- The `Parent` property of `XObject` returns the parent of the given `XObject` or `null` if the parent does not exist. For nodes at the root of the document, including the root element, XML declaration, header comments and the document itself, `Parent` with return `null`.
- `XObject`'s `Document` property retrieves the `XDocument` representing the document root. The `Document` property of an `XDocument` returns itself.
- The `PreviousNode` and `NextNode` properties of `XNode`, as their names imply, return the previous or next sibling node in the tree. If there's no previous or next node, the properties return `null`.

Section 24.10 LINQ to XML: Namespaces and Creating Documents

- Class `XNamespace` enables creation and manipulation of XML namespaces.
- Using LINQ to XML to navigate data already stored in an XML document is a common operation, but sometimes it's necessary to create an XML document from scratch. The LINQ to XML classes were designed to make document creation as easy as document navigation.
- There's an implicit conversion from `string` to `XNamespace`.
- An `XName` object can be created for the tag name using the overloaded + operator—the `XName` contains the `XNamespace` given on the left side and the local name given by the `string` on the right.
- The `Namespace` property of `XName` gives you access to the contained `XNamespace` object.
- `XElement`'s constructor adds all members of its collection argument as children.

- When accessing elements with a namespace using the `Element`, `Elements` or `Descendants` methods, you must use an `XName` with a proper namespace or the access will fail.
- Attributes are placed into a document by creating new `XAttribute` objects and passing them to the `XElement` constructor.
- `XContainer` method `Add` adds items to a container. Like `XElement`'s constructor, `Add` will add all elements if it receives a collection as an argument.

Section 24.11 XSLT with Class `XslCompiledTransform`

- The `System.Xml.Xsl` namespace contains class `XslCompiledTransform` for applying XSLT style sheets to XML documents.
- The `XslCompiledTransform` method `Load` loads and compiles a style sheet.
- The `XslCompiledTransform` method `Transform` applies the compiled style sheet to a specified XML document. This method takes two `string` arguments: the name of the XML file to which the style sheet should be applied and the name of the file to store the transformation result.

Terminology

Sections 24.1–24.7

/ forward slash character (XPath)
@ XPath attribute symbol
<? and ?> XML delimiters
absolute addressing
`all` element
asterisk (*) occurrence indicator
`ATTLIST` attribute-list declaration
automatic schema generation
`base` attribute of element `extension`
`base` attribute of element `restriction`
base type
`CDATA` keyword
character data
character entity reference
complex content in XML Schema
complex type
`complexType` element
context node
`data-type` attribute of `xsl:sort` element
Document Type Definition (DTD)
`element` element (XML Schema)
`ELEMENT` element type declaration
`EMPTY` keyword
Extensible HyperText Markup Language (XHTML)
`extension` element
`#FIXED` keyword
`#IMPLIED` keyword
LINQ to XML
`match` attribute of `xsl:template` element
`maxOccurs` attribute of `element` element
`minInclusive` element
`minOccurs` attribute of `element` element
`name` attribute of `element` element
`name` node-set function
node-set function
node set of an `xsl:for-each` element
occurrence indicator
`order` attribute of `xsl:sort` element
parsed character data
parser
`#PCDATA` keyword
PI target
PI value
plus sign (+) occurrence indicator
processing instruction (PI)
prolog of an XML document
question mark (?) occurrence indicator
recursive descent
relative addressing
`#REQUIRED` keyword
restriction on built-in schema type
result tree (XSLT)
schema
`schema` element
schema-invalid XML document
schema repository
schema-valid XML document
`select` attribute of `xsl:for-each` element
simple content in XML Schema

simple type
simpleContent XML Schema element
simpleType XML Schema element
source tree (XSLT)
stylesheet start tag
sum function (XSL)
targetNamespace attribute of schema element
text node-set function
type attribute in a processing instruction
type attribute of element element
unbounded value of attribute maxOccurs
version attribute of xsl:stylesheet element
W3C XML Schema
World Wide Web Consortium (W3C)
XML instance document
XML Path Language (XPath)
XML Schema
XML Validator
.xsd file-name extension
.xsl file-name extension
XSL Formatting Objects (XSL-FO)
XSL style sheet
XSL template
XSL Transformations (XSLT)
XSL variable
xsl:for-each element
xsl:output element
xsl:sort element
xsl:stylesheet element
xsl:template element
xsl:text element
xsl:value-of element

Sections 24.8–24.11

Add method of class XContainer
ancestor node
Attribute method of class XElement
child node
descendant node
Descendants extension method of IEnumerable<XElement>
Descendants method of class XContainer
Document Object Model (DOM)
Document property of class XObject
document root
DOM parser
Element method of class XContainer
Elements extension method of IEnumerable<XElement>
Elements method of class XContainer
ExpandAll method of class TreeView
HasElements property of class XElement
Load method of class XDocument
Load method of class XslCompiledTransform
LocalName property of class XName
LINQ to XML
Name property of class XElement
Namespace property of class XName
NextNode property of class XNode
Nodes method of class XContainer
NodeType property of class XObject
parent node
Parent property of class TreeNode
Parent property of class XObject
PreviousNode property of class XNode
Refresh method of class TreeView
root node
Root property of class XDocument
sibling node
System.Xml namespace
System.Xml.Linq namespace
System.Xml.XPath namespace
System.Xml.Xsl namespace
TreeNode class
TreeView control
transformations using LINQ
Transform method of class XslCompiledTransform
Value property of class XElement
Value property of class XText
XAttribute class
XComment class
XContainer class
XDocument class
XDocumentType class
XElement class
XmlNodeType enumeration
XName class
XNamespace class
XNode class
XObject class
XPathSelectElements extension method of class XNode
XProcessingInstruction class
XslCompiledTransform class
XText class

Self-Review Exercises

24.1 Which of the following are valid XML element names? (Select all that apply.)
- a) `yearBorn`
- b) `year.Born`
- c) `year Born`
- d) `year-Born1`
- e) `2_year_born`
- f) `_year_born_`

24.2 State whether each of the following is *true* or *false*. If *false*, explain why.
- a) XML is a technology for creating markup languages called XML vocabularies.
- b) XML markup is delimited by forward and backward slashes (`/` and `\`).
- c) All XML start tags must have corresponding end tags.
- d) Parsers check an XML document's syntax.
- e) XML does not support namespaces.
- f) When creating XML elements, document authors must use the set of standard XML tags provided by the W3C.

24.3 In Fig. 24.2, we subdivided the `author` element into more detailed pieces. How might you subdivide the `date` element? Use the date May 5, 2013, as an example.

24.4 Fill in the blanks for each of the following:
- a) __________ embed application-specific information into an XML document.
- b) XSL element __________ writes a `DOCTYPE` to the result tree.
- c) XML Schema documents have root element __________.
- d) XSL element __________ is the root element in an XSL document.
- e) XSL element __________ selects specific XML elements using repetition.

24.5 State whether each of the following is *true* or *false*. If *false*, explain why.
- a) XML Schemas are better than DTDs, because DTDs lack a way of indicating what specific type of data (e.g., numeric, text) an element can contain and DTDs are not themselves XML documents.
- b) A DTD cannot indicate that an element is optional.
- c) Schema is a technology for locating information in an XML document.

24.6 Write a processing instruction that includes style sheet `wap.xsl` for use in Internet Explorer.

24.7 Write an XPath expression that locates `contact` nodes in `letter.xml` (Fig. 24.4).

24.8 Describe the `Elements` and `Descendants` methods used in this chapter.

24.9 Write the C# code necessary to create an `XElement` with a local name of `"name"` and a namespace of `"http://www.example.com"`.

Answers to Self-Review Exercises

24.1 a, b, d, f. [Choice c is incorrect because it contains a space. Choice e is incorrect because the first character is a digit.]

24.2 a) True. b) False. In an XML document, markup text is delimited by tags enclosed in angle brackets (< and >) with a forward slash just after the < in the end tag or before the > in an empty element. c) True. d) True. e) False. XML does support namespaces. f) False. When creating tags, document authors can use any valid name but should avoid ones that begin with the reserved word `xml` (also `XML`, `Xml`, and so on).

24.3
```
<date>
    <month>May</month>
    <day>5</day>
    <year>2013</year>
</date>.
```

24.4 a) Processing instructions. b) `xsl:output`. c) `schema`. d) `xsl:stylesheet`. e) `xsl:for-each`.

24.5 a) True. b) False. DTDs specify optional elements using the question mark (`?`) occurrence indicator, which indicates that an element may appear at most once, or the asterisk (`*`) occurrence indicator, which indicates the element may appear zero or more times. c) False. XPath is a technology for locating information in an XML document. XML Schema provides a means for type checking XML documents and verifying their validity.

24.6
```
<?xml-stylesheet type = "text/xsl" href = "wap.xsl"?>
```

24.7 `/letter/contact`.

24.8 The `Elements` and `Descendants` methods of `XContainer` are both overloaded—the version that takes no arguments returns all applicable elements, and the version that takes an `XName` returns only those elements with the given name. The `Elements` method returns only direct children, while the `Descendants` method also returns grandchildren, great-grandchildren, and so on. There are also extension methods for `IEnumerable<XElement>` that return the children or descendants of all elements in the collection.

24.9
```
XNamespace example = "http://www.example.com";
XElement element = new XElement( example + "name" );
```

Exercises

24.10 *(Nutrition Information XML Document)* Create an XML document that marks up the nutrition facts for a package of Grandma White's cookies. A package of cookies has a serving size of 28 grams and the following nutritional value per serving: 140 calories, 60 fat calories, 8 grams of fat, 2 grams of saturated fat, 5 milligrams of cholesterol, 110 milligrams of sodium, 15 grams of total carbohydrates, 2 grams of fiber, 15 grams of sugars and 1 gram of protein. Name this document `nutrition.xml`. Load the XML document into Internet Explorer. [*Hint:* Your markup should contain individual elements describing the product name, serving size, calories, sodium, cholesterol, proteins and so on. Mark up each nutrition fact/ingredient listed above.]

24.11 *(Nutrition-Information XML Schema)* Write an XML Schema document (`nutrition.xsd`) specifying the structure of the XML document created in Exercise 24.10.

24.12 *(Sorting XSLT Modification)* Modify Fig. 24.17 (`sorting.xsl`) to sort by the number of pages rather than by chapter number. Save the modified document as `sorting_byPage.xsl`.

24.13 *(Nutrition Information XHTML Conversion)* Using the file you created in Exercise 24.10, write a program that creates an XHTML document with a table containing each nutritional value. Save the resulting XHTML document.

24.14 *(`XMLCombine` Format Checking)* Create a GUI application based on the `XMLCombine` application in Fig. 24.23. Instead of hard-coding the file names, create two sets of radio buttons that allow the user to choose the two input files (Fig. 24.28). Each set should let the user choose between the `employeesOld.xml` and `employeesNew.xml` from Section 24.10, and the `employeesExtra.xml` included in the `Exercises` folder with this chapter's examples. If either file is in the old format, convert it to the new format, then merge the entries in the two files. Do not worry about duplicate entries. Use the file's structure, not the selected radio button, to determine whether it's in the old or new format.

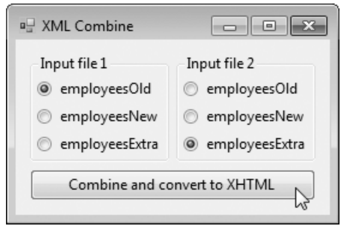


Fig. 24.28 | XML Combine GUI application.

24.15 *(Nutrition XHTML Modification)* Modify your program from Exercise 24.13 to also read file `nutrition2.xml` (included in the `Exercises` folder) and combine its elements with those of `nutrition.xml`. Then, sort all of the elements by their local name before outputting them as XHTML. Use the product title of the first document when writing the final document's title.