CHAPTER 8: DATABASE APPLICATION DEVELOPMENT

Modern Database Management

12th Edition

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OBJECTIVES

- Define terms
- Explain three components of client/server systems: presentation, processing, and storage
- Distinguish between two-tier and three-tier architectures
- Describe how to connect to databases in 2-tier systems using VB.NET and Java
- Describe key components and information flow in Web applications
- Describe how to connect to databases in 3-tier applications using JSP, PHP, and ASP .NET
- Explain the purpose of XML
- See how XQuery can be used to query XML documents
- Explain how XML fosters Web services and SOAs

CLIENT/SERVER ARCHITECTURES

- Networked computing model
- Processes distributed between clients and servers
- Client–Workstation (PC, smartphone, tablet) that requests and uses a service
- Server– Powerful computer (PC/mini/mainframe) that provides a service
- For DBMS, server is a database server
- For the Internet, server is a web server

APPLICATION LOGIC IN C/S SYSTEMS

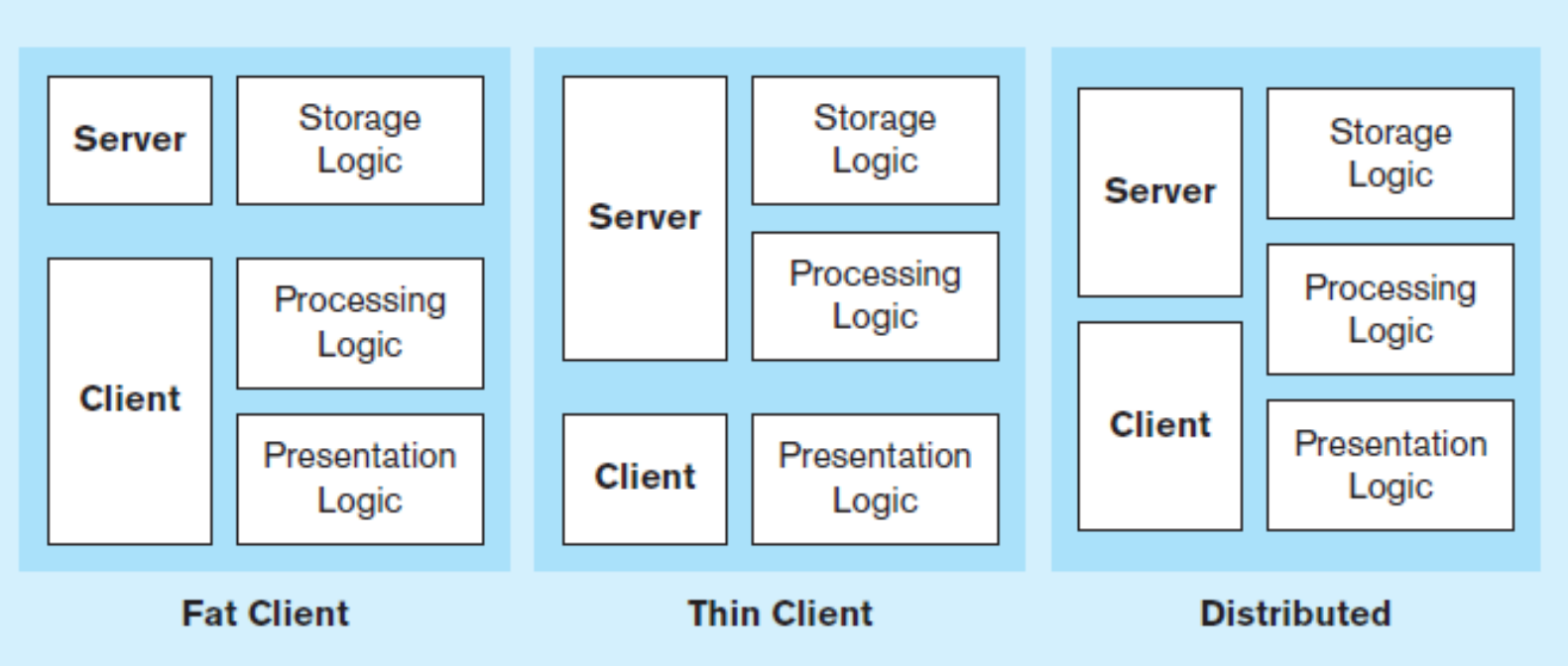
Presentation Logic ▪ Input–keyboard/mouse ▪ Output–monitor/printer	**GUI Interface**
Processing Logic ▪ I/O processing ▪ Business rules ▪ Data management	**Procedures, functions, programs**
Storage Logic ▪ Data storage/retrieval	**DBMS activities**

APPLICATION PARTITIONING

- Placing portions of the application code in different locations (client vs. server) after it is written
- Advantages
  - Improved performance
  - Improved interoperability
  - Balanced workloads

FIGURE 8-2 COMMON LOGIC DISTRIBUTIONS

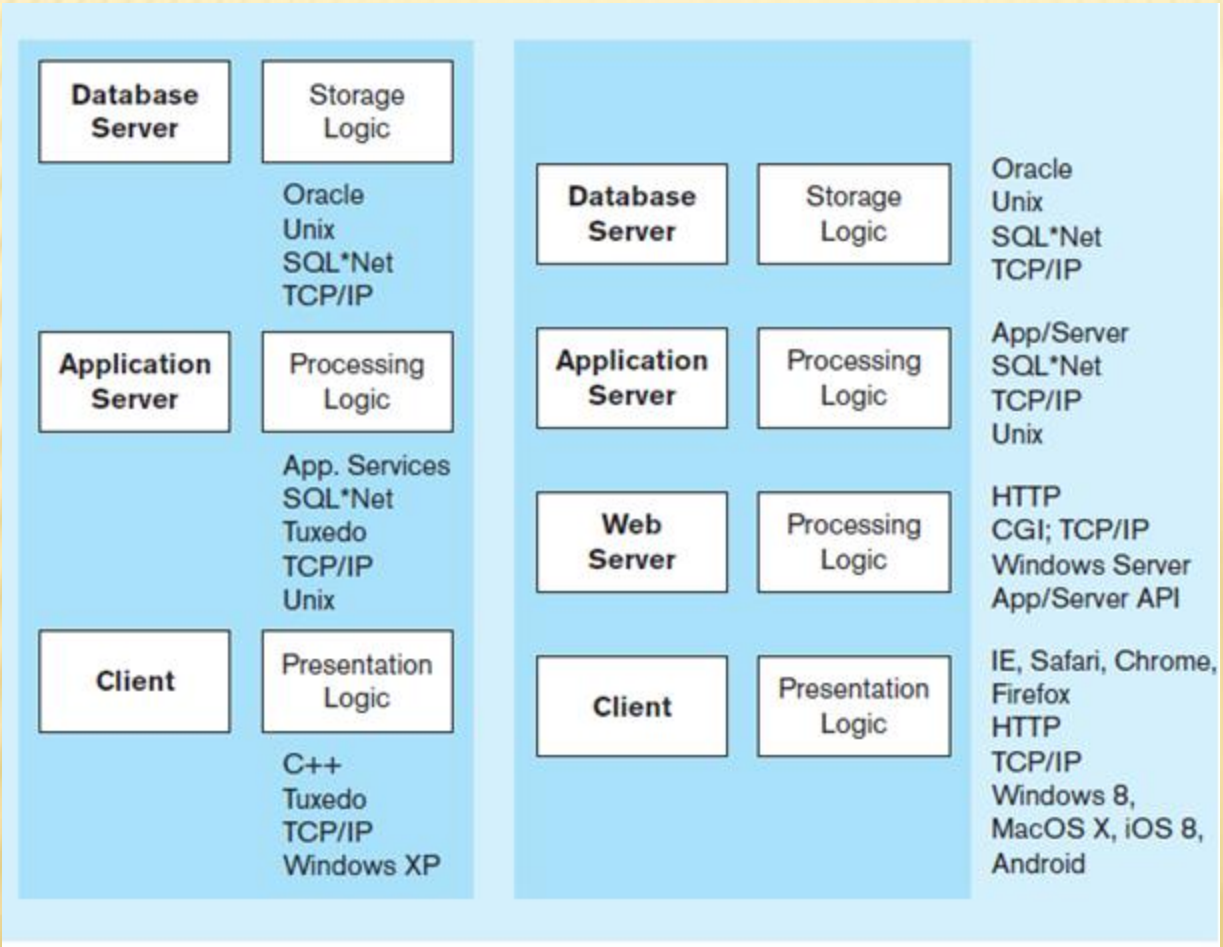
a) Two-tier client-server environments



Processing logic could be at client (fat client), server (thin client), or both (distributed environment).

FIGURE 8-2 COMMON LOGIC DISTRIBUTIONS

b) Three-tier and *n*-tier client-server environments



Processing logic will be at application server or Web server.

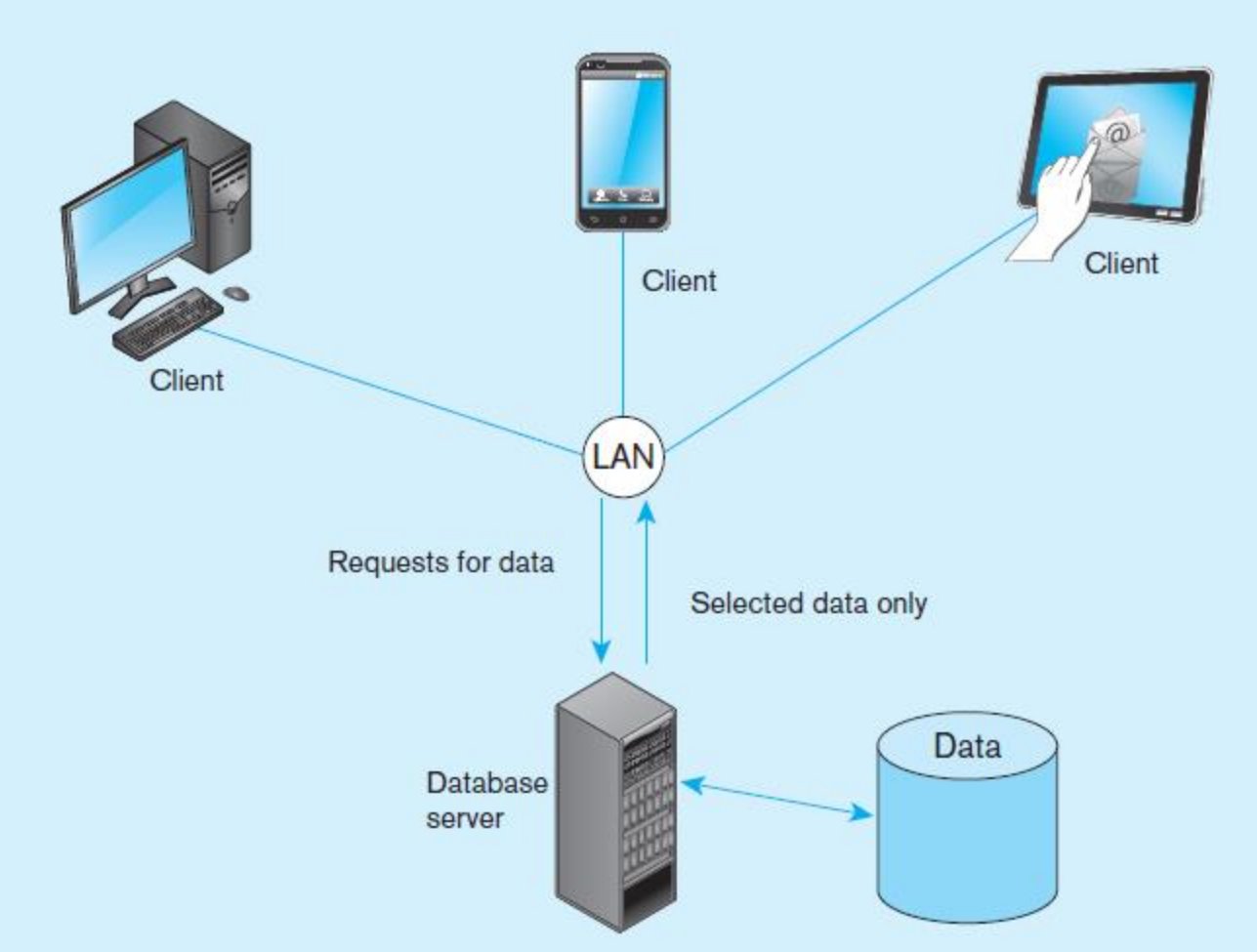
TWO-TIER DATABASE SERVER ARCHITECTURES

- Client workstation is responsible for
  - Presentation logic
  - Data processing logic
  - Business rules logic
- Server performs all data storage, access, and processing
  - Typically called a ***database server***

DBMS is only on server

Figure 8-3 Database server architecture (two-tier architecture)

Front-end programs



Back-end functions

CHARACTERISTICS OF TWO-TIER CLIENT/SERVER SYSTEMS

- Departmental in scope (few users)
- Not mission-critical
- Low transaction volumes
- Common programming languages:
  - Java, VB .NET, C#
- Interface database via middleware, APIs

MIDDLEWARE AND APIS

- **Middleware** – software that allows an application to interoperate with other software without requiring user to understand and code low-level operations
- **Application Program Interface (API)** – routines that an application uses to direct the performance of procedures by the computer's operating system
- Common database APIs – ODBC, ADO .NET, JDBC

STEPS FOR USING DATABASES VIA MIDDLEWARE APIS

1. Identify and register a database driver.
2. Open a connection to a database.
3. Execute a query against the database.
4. Process the results of the query.
5. Repeat steps 3–4 as necessary.
6. Close the connection to the

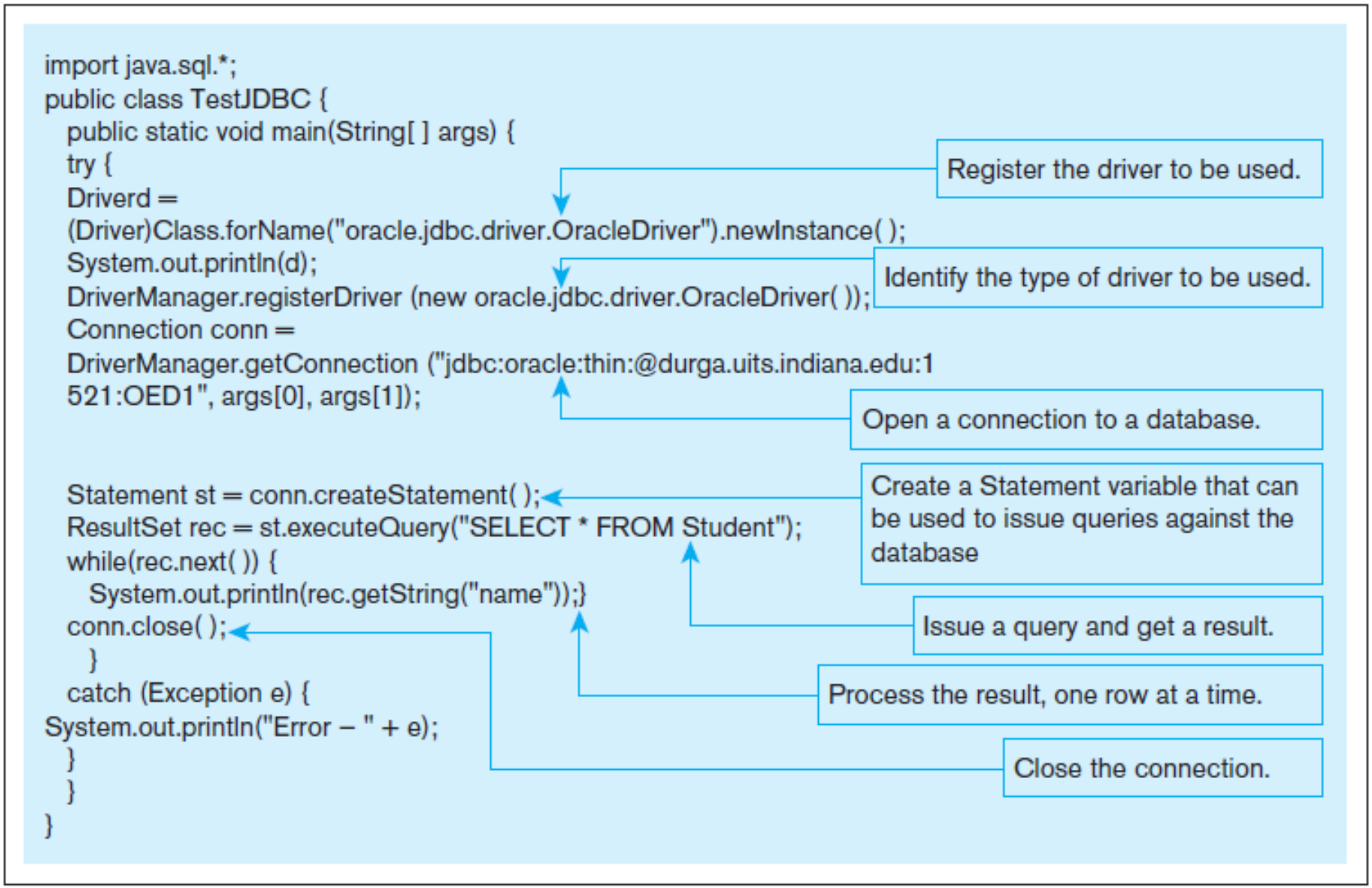


FIGURE 8-5 Database access from a Java program

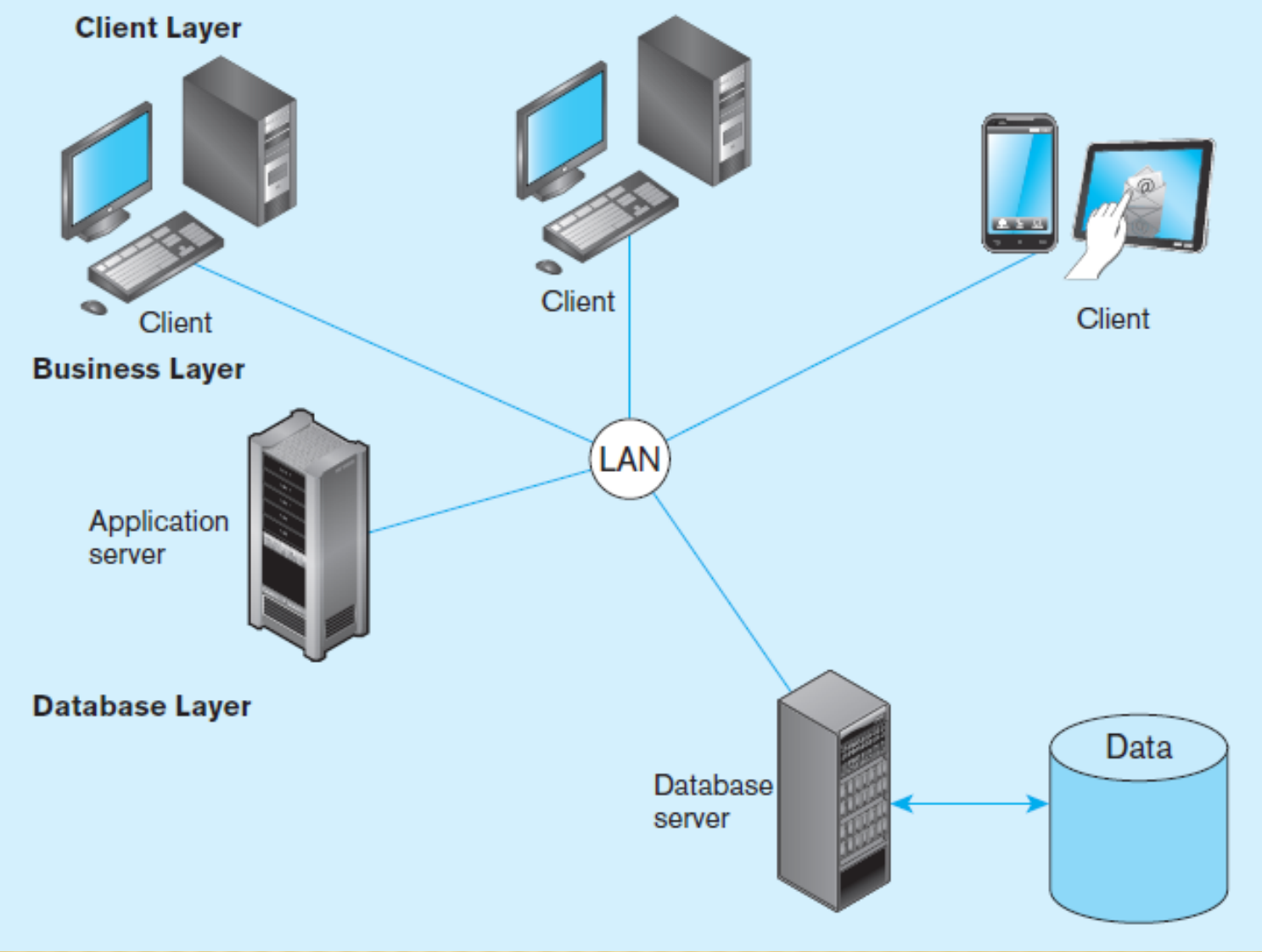
THREE-TIER ARCHITECTURES

Client	**GUI interface (I/O processing)**	***Browser, Mobile App***
Application server	**Business rules**	***Web Server***
Database server	**Data storage**	***DBMS***

Thin Client

- PC just for user interface and a little application processing. Limited or no data storage (sometimes no hard drive)

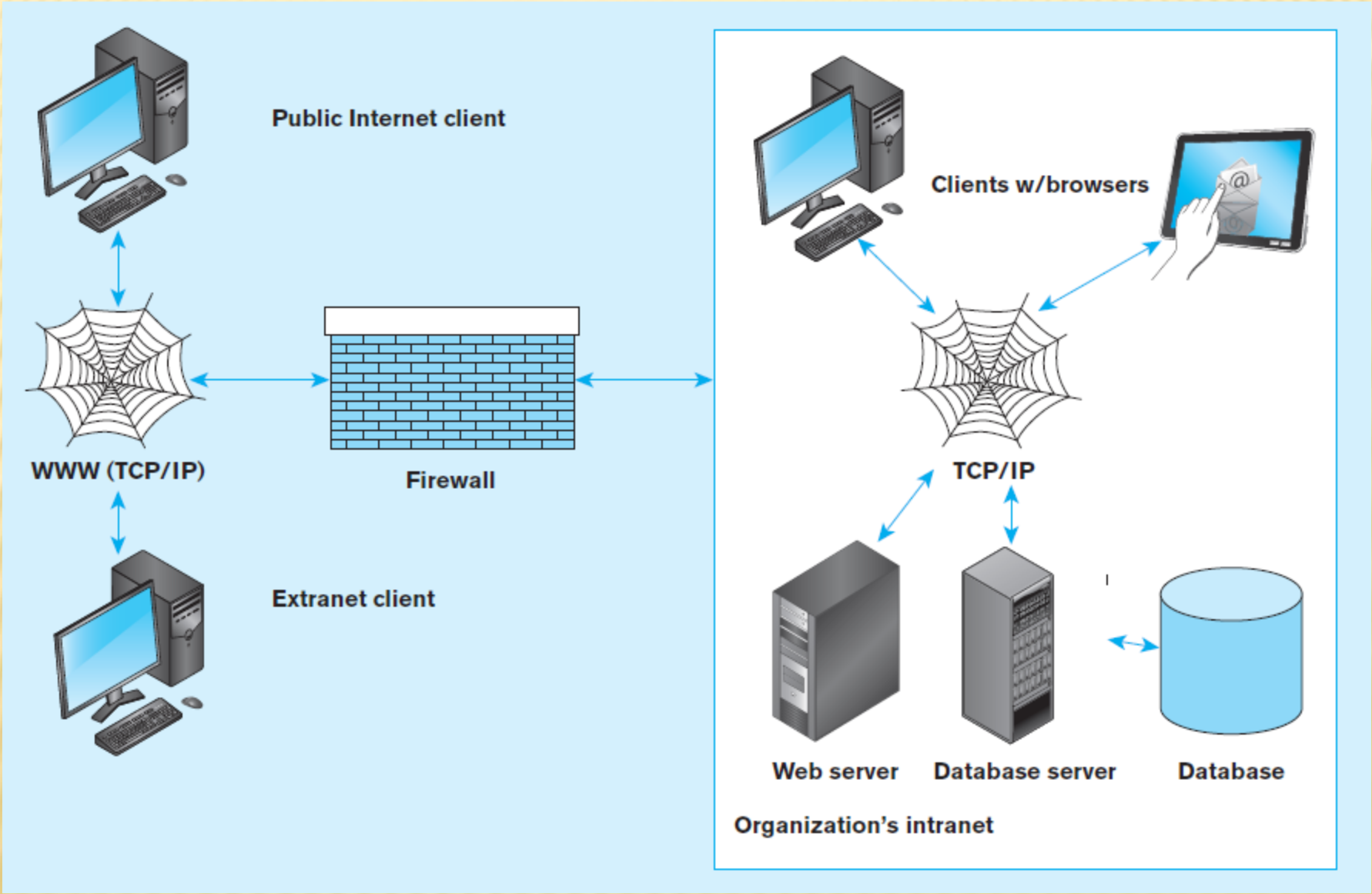
Figure 8-6a Generic three-tier architecture



THIN CLIENT

- An application where the client accessing the application primarily provides the user interfaces and some application processing, usually with no or limited local data storage.
- Usually, thin client application is a Web browser and the 3-tier architecture involves a Web application.

Figure 8-7 A database-enabled intranet/Internet environment



WEB APPLICATION COMPONENTS

- Database server – hosts the DBMS
  - e.g. Oracle, SQL Server, Informix, MS Access, MySql
- Web server – receives and responds to browser requests using HTTP protocol
  - e.g. Apache, Internet Information Services (IIS)
- Application server – software building blocks for creating dynamic web sites
  - e.g. MS ASP .NET framework, Java EE, ColdFusion, PHP
- Web browser – client program that sends web requests and receives web pages
  - e.g. Internet Explorer, Firefox, Safari, Google Chrome

LANGUAGES FOR CREATING WEB PAGES

- **Hypertext Markup Language (HTML)**
  - Markup language specifically for Web pages
- **Standard Generalized Markup Language (SGML)**
  - Markup language standard
- **Extensible Markup Language (XML)**
  - Markup language allowing customized tags
- **XHTML**
  - XML-compliant extension of HTML
- **JavaScript/VBScript**
  - Scripting languages that enable interactivity in HTML documents
- **Cascading Style Sheets (CSS)**
  - Control appearance of Web elements in an HML document
- **XSL and XSLT**
  - XMS style sheet and transformation to HTML

Standards and Web conventions established by **World Wide Web Consortium (W3C)**

PROCESSING IN 3-TIER APPLICATIONS

- Static page requests
  - .htm or .html requests handled by the Web server
- Dynamic page requests
  - .jsp, .aspx, and .php requests are routed to the application server
  - Server-side processing by JSP servlet (Java), ASP .NET application (C# or VB), ColdFusion, or PHP
  - Database access via JDBC, ADO .NET, or other database middleware

Figure 8-9 Information flow in a three-tier architecture

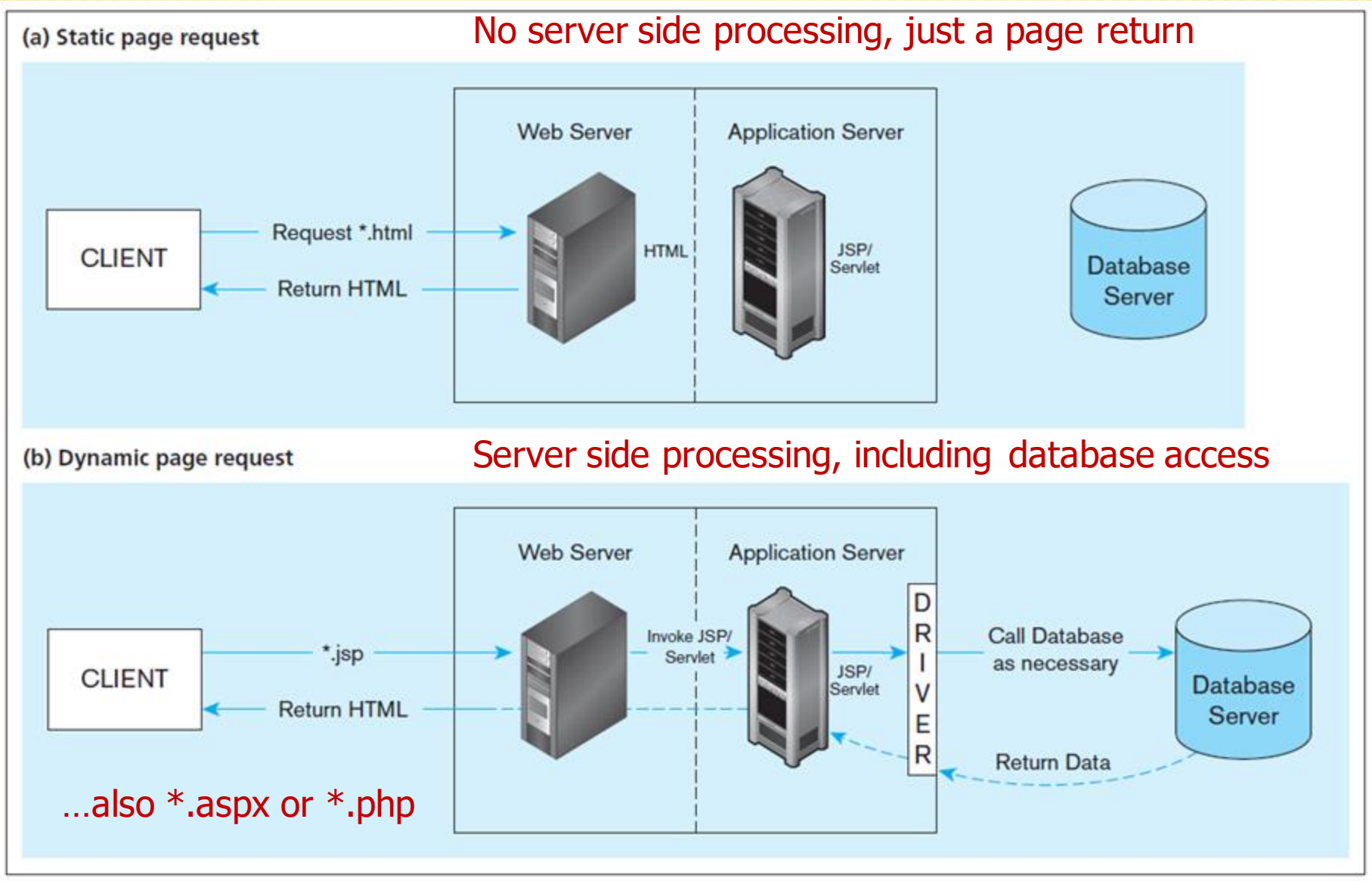


Figure 8-12 A registration page written in ASP .NET

a) Sample ASP .NET code for user registration

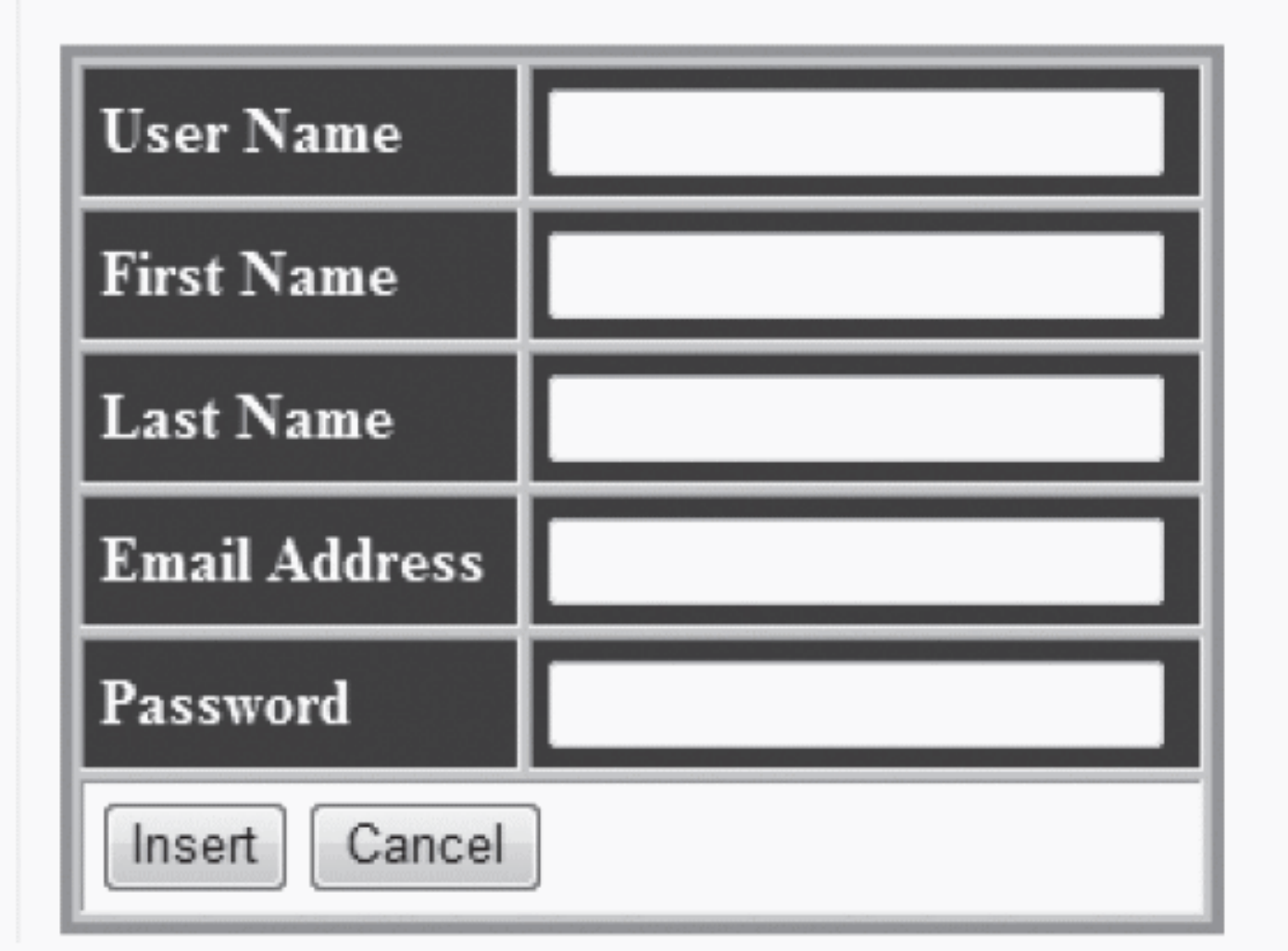
```
<%@ Page Language="C#" AutoEventWireup="true" CodeFile="users.aspx.cs" Inherits="users" %>
<html xmlns="http://www.w3.org/1999/xhtml" >
<head runat="server">
   <title>Register</title>
</head>
<body>
<form id="form1" runat="server">
<div>
<asp:DetailsView ID="manageUsers" runat="server" DataSourceID="usersDataSource">
        <Fields>
                <asp:BoundField DataField="username" HeaderText="User Name" />
                <asp:BoundField DataField="first_name" HeaderText="First Name" />
                <asp:BoundField DataField="last_name" HeaderText="Last Name" />
                <asp:BoundField DataField="email" HeaderText="Email Address" />
                <asp:BoundField DataField="password" HeaderText="Password" />
                <asp:CommandField ShowInsertButton="True" ButtonType="Button" />
        </Fields>
        </asp:DetailsView>
<asp:SqlDataSource ID="usersDataSource" runat="server"
        ConnectionString="<%$ ConnectionStrings:StudentConnectionString %>"
        InsertCommand="INSERT INTO users(username, first_name, last_name, email, password,
        registration_date) VALUES (@username, @first_name, @last_name, @email, @password, GETDATE())"
        SelectCommand="SELECT [username], [first_name], [last_name], [email], [password] FROM [users]">
</asp:SqlDataSource>
</div>
</form>
</body>
</html>
```

A **DetailsView** is a type of Web control

Web controls can be databound to data sources, including **SqlDataSource**.

Figure 8-12 A registration page written in ASP .NET

b) Form for the ASP .NET application



CONSIDERATIONS IN 3-TIER APPLICATIONS

- Stored procedures
  - Code logic embedded in DBMS
  - Improve performance, but proprietary
- Transactions
  - Involve many database updates
  - Either all must succeed, or none should occur
- Database connections
  - Maintaining an open connection is resource-intensive
  - Use of connection pooling

ADVANTAGES AND DISADVANTAGES OF STORED PROCEDURES

- Advantages
  - Performance improves for compiled SQL statements
  - Reduced network traffic
  - Improved security
  - Improved data integrity
  - Thinner clients
- Disadvantages
  - Programming takes more time
  - Proprietary, so algorithms are not portable

BENEFITS OF THREE-TIER ARCHITECTURES

- Scalability
- Technological flexibility
- Long-term cost reduction
- Better match of systems to business needs
- Improved customer service
- Competitive advantage
- Reduced risk

CLOUD COMPUTING

- A model for creating ubiquitous, convenient, on-demand access to network services
- Characteristics: on-demand, broad network access, resource pooling, rapid elasticity, measured service
- Types of cloud computing:
  - Infrastructure-as-a-service (IaaS)
  - Platform-as-a-service (PaaS)
  - Software-as-a-service (SaaS)

EXTENSIBLE MARKUP LANGUAGE (XML)

- A text-based markup language (like HTML)
  - Uses elements, tags, attributes
  - Includes document type declarations (DTDs), XML schemas, comments, and entity references
- Revolutionizes the way data are exchanged over the Internet
- Document Structure Declarations (DSD), XML Schema (XSD) and Relax NG replacing DTDs for validating XML document structure
- XSD – language for defining XML databases, recommended by the W3C.

SIMPLE XML EXAMPLE

```
<?xml version = "1.0"/>
<furniturecompany>
    <product ID="1">
        <description>End Table</description>
        <finish>Cherry</finish>
        <standard price>175.00</standard price>
        <line>1</line>
    </product>
</furniturecompany>
```

SAMPLE XML SCHEMA (XSD)

```
<?xml version="1.0" encoding="utf-8" ?>
<xsd:schema id="salespersonSchema"
xmlns:xsd="http://www.w3.org/2001/XMLSchema">
  <xsd:element name="Salesperson" type="SalespersonType" />
  <xsd:complexType name="SalespersonType">
      <xsd:sequence>
          <xsd:elementname="SalespersonID"
                  type="xsd:integer"/>
          <xsd:elementname="SalespersonName"
                  type="xsd:string" />
          <xsd:element name="SalespersonTelephone"
                  type="PhoneNumberType">
          <xsd:element name="SalespersonFax"
                  type="PhoneNumber" minOccurs="0" />
          </xsd:element>
      </xsd:sequence>
  </xsd:complexType>
  <xsd:simpleType name="PhoneNumberType">
      <xsd:restriction base="xsd:string">
          <xsd:length value="12" />
          <xsd:pattern value="\d{3}-\d{3}-\d{4}" />
      </xsd:restriction>
  </xsd:simpleType>
</xsd:schema>
```

Schema is a record definition, analogous to the Create SQL statement, and therefore provides metadata.

SAMPLE XML DOCUMENT DATA

```
<?xml version="1.0" encoding="utf-8" ?>
<Salesperson xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
xsi:noNamespaceSchemaLocation="salespersonSchema.xsd">
    <SalespersonID>1</SalespersonID>
    <SalespersonName>Doug Henny</SalespersonName>
    <SalespersonTelephone>813-444-5555</SalespersonTelephone>
</Salesperson>
```

This XML data conforms to the XML schema of the previous slide, and involves elements and attributes defined in the schema.

This is analogous to a record in a database.

STORING XML DOCUMENTS

- Storing as files introduces the same file processing problems stated in Ch 1
- Four common options:
  - Store XML data in a relational database by shredding the XML document
  - Store entire XML document in a large field (BLOB or CLOB)
  - Store the XML document using special XML columns
  - Store the XML document using a native XML database (non-relational)

RETRIEVING XML DOCUMENTS

- XPath – One of a set of XML technologies supporting XQuery development, locating data in XML documents
- XQuery – An XML transformation language that allows applications to query both relational databases and XML data
- Sample XQuery expression:

```
for $p in doc("PVFC.xml")/furniture company/product
where $p/standardprice>300.00
order by $p/description
return $p/description
```

DISPLAYING XML DATA

- Extensible Stylesheet Language Transformation (XSLT) – A language used to transform complex XML documents and also used to create HTML pages from XML documents

- XSLT can translate a single XML document into both standard HTML and WAP/WML for cell phones without the necessity for two different pages

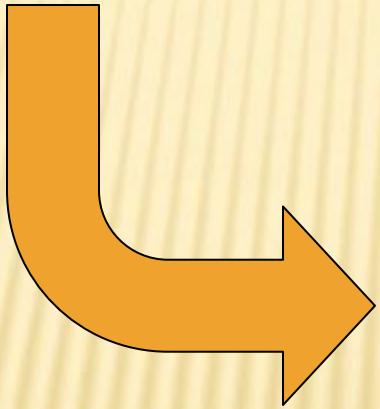
FIGURE 8-15B – XSLT CODE

```
<?xml version = "1.0"?>
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
<xsl:template match="/">
    <html>
        <body>
        <h2>Product Listing</h2>
        <table border="1">
        <tr bgcolor="orange">
                <th>Description</th>
                <th>Finish</th>
                <th>Price</th>
        </tr>
        <xsl:for-each select="furniturecompany/product">
        <tr>
            <td><xsl:value-of select="description"/></td>
            <td><xsl:value-of select="finish"/></td>
            <td><xsl:value-of select="price"/></td>
        </tr>
        </xsl:for-each>
        </table>
        </body>
    </html>
</xsl:template>
</xsl:stylesheet>
```

```
<furniture company>
    <product ID="1">
        <description>End Table</description>
        <finish>Cherry</finish>
        <standard price>175.00</standard price>
        <line>1</line>
    </product>
    <product ID="2">
        <description>Coffee Table</description>
        <finish>Natural Ash</finish>
        <standard price>200.00</standard price>
        <line>2</line>
    </product>
</furniture company>
```

Extracted from Figures 8-15a and 8-15c

When applied to the above XML data, the XSLT code from Figure 8-15b produces the display on the right.



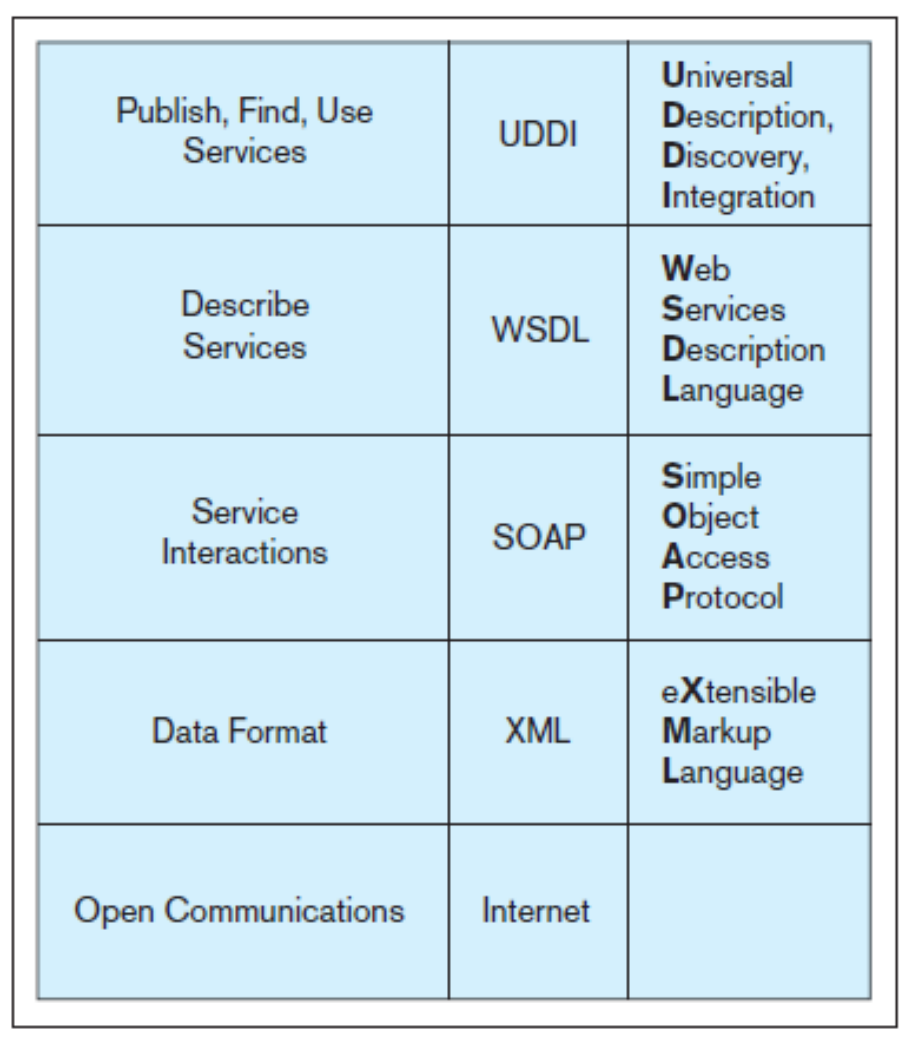
Product Listing

Description	Finish	Price
End Table	Cherry	175.00
Coffee Table	Natural Ash	200.00

XML AND WEB SERVICES

- Web Services – a set of emerging JSON/XML-based standards that define protocols for automatic communication between software programs over the Web
- Universal Description, Discovery, and Integration (UDDI) – standard for creating a distributed registry of Web services
- Web Services Description Language (WSDL) – XML-based grammar for describing a Web Service and specifying its public interface
- Simple Object Access Protocol (SOAP) – XML-based communication protocol for sending messages between applications over the Internet

Figure 8-17 Web Services protocol stack



Publish, Find, Use Services	UDDI	**U**niversal **D**escription, **D**iscovery, **I**ntegration
Describe Services	WSDL	**W**eb **S**ervices **D**escription **L**anguage
Service Interactions	SOAP	**S**imple **O**bject **A**ccess **P**rotocol
Data Format	XML	e**X**tensible **M**arkup **L**anguage
Open Communications	Internet	

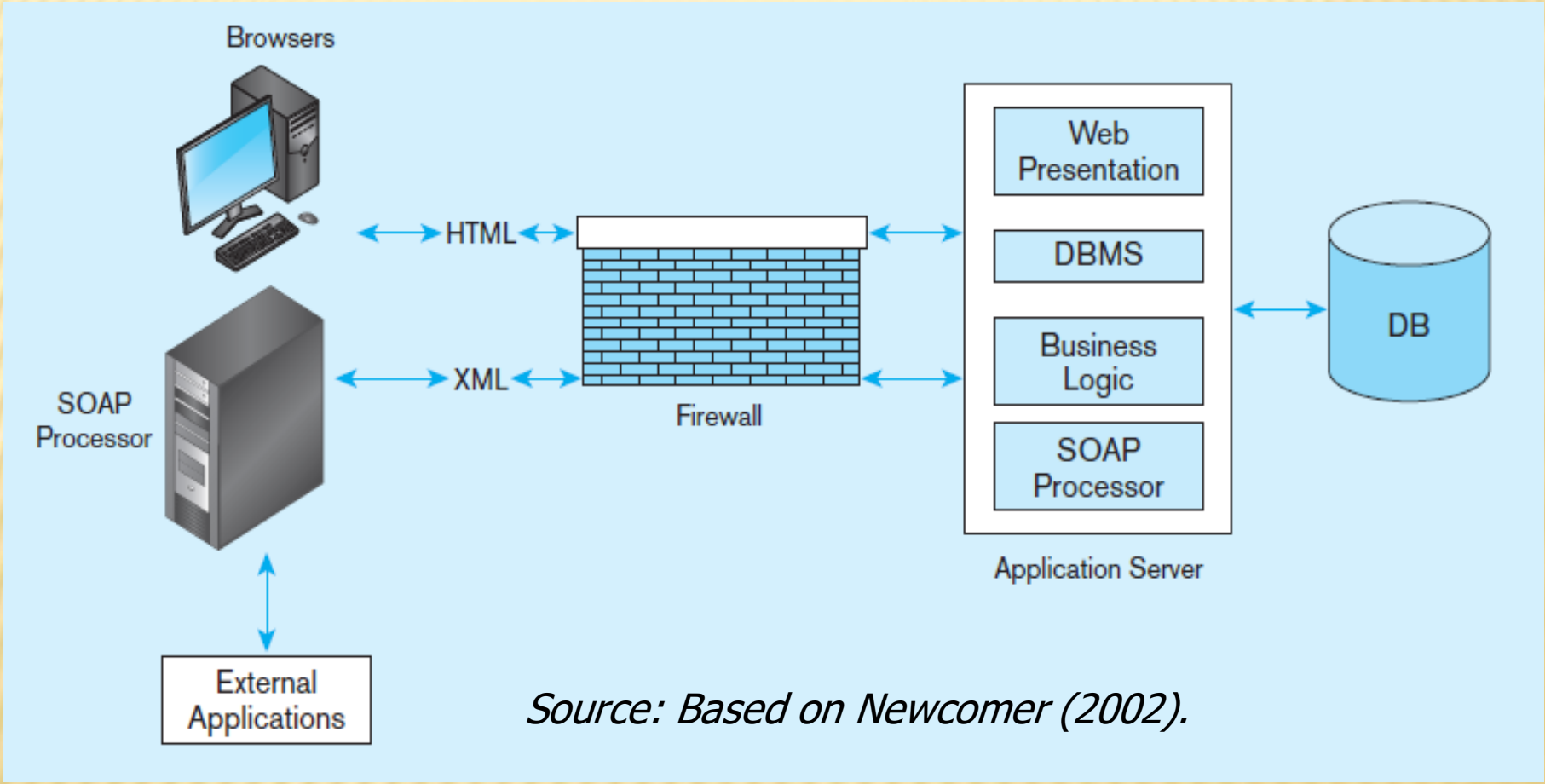
SOAP request sent from customer to supplier

```
<soap:Envelope xmlns:soap=http://schemas.xmlsoap.org/soap/envelope/>
  <soap:Body>
    <getProductDetails xmlns=http://supplier.example.com/ws
      <productID>32879</productID>
    </getProductDetails>
  </soap:Body>
</soap:Envelope>
```

SOAP response sent from supplier to customer

```
<soap:Envelope xmlns:soap=http://schemas.xmlsoap.org/soap/envelope/>
  <soap:Body>
    <getProductDetailsResponse xmlns="suppliers.example.com/ws">
      <getProductDetailsResult>
       <productName>Dining Table</productName>
       <Finish>Natural Ash</Finish>
       <Price>800</Price>
       <inStock>True</inStock>
       </getProductDetailsResult>
    </getProductDetailsResponse>
  </soap:Body>
</soap:Envelope>
```

Figure 8-18 Web services deployment



Source: Based on Newcomer (2002).

SERVICE ORIENTED ARCHITECTURE (SOA)

- A collection of services that communicate with each other, usually by passing data or coordinating a business activity
- A new paradigm for IT application development, based mostly on Web services
- Loosely coupled, highly interoperable components
- Leads to flexibility and shorter development time