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Fundamentals of
WEB DEVELOPMENT

Third Edition



Fundamentals of Web Development

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Fundamentals of Web Development

Third Edition

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To all whose lives have been afflicted by the COVID-19 pandemic and especially for the loved ones that have been lost to it.

Randy Connolly

To every student working to build a better world.

Ricardo Hoar

Brief Table of Contents

Chapter 1	Introduction to Web Development	1
Chapter 2	How the Web Works	42
Chapter 3	HTML 1: Introduction	73
Chapter 4	CSS 1: Selectors and Basic Styling	122
Chapter 5	HTML 2: Tables and Forms	189
Chapter 6	Web Media	240
Chapter 7	CSS 2: Layout	282
Chapter 8	JavaScript 1: Language Fundamentals	348
Chapter 9	JavaScript 2: Using JavaScript	418
Chapter 10	JavaScript 3: Additional Features	480
Chapter 11	JavaScript 4: React	545

Chapter 12	Server-Side Development 1: PHP	603
Chapter 13	Server-Side Development 2: Node.js	673
Chapter 14	Working with Databases	711
Chapter 15	Managing State	778
Chapter 16	Security	813
Chapter 17	DevOps and Hosting	880
Chapter 18	Tools and Traffic	932

Table of Contents

Preface xxix

Acknowledgments xxxv

Chapter 1 Introduction to Web Development 1

- 1.1 A Complicated Ecosystem** 2
- 1.2 Definitions and History** 4
 - A Short History of the Internet 4
 - The Birth of the Web 7
 - Web Applications in Comparison to Desktop Applications 8
 - From Static to Dynamic (and Back to Static) 10
- 1.3 The Client-Server Model** 15
 - The Client 17
 - The Server 17
 - Server Types 17
 - Real-World Server Installations 19
 - Cloud Servers 23
- 1.4 Where Is the Internet?** 24
 - From the Computer to Outside the Home 25
 - From the Home to the Ocean's Edge 26
 - How the Internet Is Organized Today 28
- 1.5 Working in Web Development** 31
 - Roles and Skills 32
 - Types of Web Development Companies 36
- 1.6 Chapter Summary** 40
 - Key Terms 40
 - Review Questions 41
 - References 41

Chapter 2 How the Web Works 42

- 2.1 Internet Protocols** 43
 - A Layered Architecture 43
 - Link Layer 43
 - Internet Layer 44
 - Transport Layer 47
 - Application Layer 48
- 2.2 Domain Name System** 49
 - Name Levels 51
 - Name Registration 53
 - Address Resolution 55
- 2.3 Uniform Resource Locators** 58
 - Protocol 58
 - Domain 58
 - Port 58
 - Path 59
 - Query String 59
 - Fragment 59
- 2.4 Hypertext Transfer Protocol** 60
 - Headers 61
 - Request Methods 62
 - Response Codes 64
- 2.5 Web Browsers** 64
 - Fetching a Web Page 65
 - Browser Rendering 65
 - Browser Caching 67
 - Browser Features 68
 - Browser Extensions 68
- 2.6 Web Servers** 69
 - Operating Systems 69
 - Web Server Software 70
 - Database Software 70
 - Scripting Software 70

2.7 Chapter Summary 71

Key Terms 71

Review Questions 72

References 72

Chapter 3 HTML 1: Introduction 73

3.1 What Is HTML and Where Did It Come From? 74

XHTML 76

HTML5 78

3.2 HTML Syntax 79

Elements and Attributes 79

Nesting HTML Elements 80

3.3 Semantic Markup 81**3.4 Structure of HTML Documents** 84

DOCTYPE 85

Head and Body 85

3.5 Quick Tour of HTML Elements 87

Headings 87

Paragraphs and Divisions 91

Links 92

URL Relative Referencing 92

Inline Text Elements 95

Images 95

Character Entities 98

Lists 99

3.6 HTML5 Semantic Structure Elements 102

Header and Footer 103

Navigation 104

Main 105

Articles and Sections 106

Figure and Figure Captions 106

Aside	108
Details and Summary	109
Additional Semantic Elements	110
3.7 Chapter Summary	116
Key Terms	116
Review Questions	116
Hands-On Projects	117

Chapter 4 CSS 1: Selectors and Basic Styling 122

4.1 What Is CSS?	123
Benefits of CSS	123
CSS Versions	123
Browser Adoption	124
4.2 CSS Syntax	125
Selectors	126
Properties	126
Values	127
4.3 Location of Styles	130
Inline Styles	130
Embedded Style Sheet	131
External Style Sheet	131
4.4 Selectors	132
Element Selectors	133
Class Selectors	133
Id Selectors	135
Attribute Selectors	136
Pseudo-Element and Pseudo-Class Selectors	136
Contextual Selectors	139
4.5 The Cascade: How Styles Interact	142
Inheritance	143
Specificity	145
Location	146

4.6 The Box Model	149
Block versus Inline Elements	149
Background	153
Borders and Box Shadow	155
Margins and Padding	156
Box Dimensions	159
4.7 CSS Text Styling	165
Font Family	165
Font Sizes	167
Font Weight	171
Paragraph Properties	172
4.8 CSS Frameworks and Variables	174
What is a CSS Framework?	175
CSS Variables	181
4.9 Chapter Summary	183
Key Terms	183
Review Questions	183
Hands-On Practice	184
References	188

Chapter 5 HTML 2: Tables and Forms 189

5.1 HTML Tables	190
Basic Table Structure	190
Spanning Rows and Columns	191
Additional Table Elements	191
Using Tables for Layout	194
5.2 Styling Tables	195
Table Borders	195
Boxes and Zebras	197
5.3 Introducing Forms	199
Form Structure	199
How Forms Work	200

Query Strings	201
The <form> Element	202
5.4 Form Control Elements	204
Text Input Controls	204
Choice Controls	205
Button Controls	209
Specialized Controls	209
Date and Time Controls	213
5.5 Table and Form Accessibility	215
Accessible Tables	216
Accessible Forms	217
5.6 Styling and Designing Forms	218
Styling Form Elements	219
Form Design	220
5.7 Validating User Input	222
Types of Input Validation	222
Notifying the User	223
How to Reduce Validation Errors	224
Where to Perform Validation	227
5.8 Chapter Summary	234
Key Terms	234
Review Questions	234
Hands-On Practice	235
Chapter 6 Web Media	240
<hr/>	
6.1 Representing Digital Images	241
Image Types	241
Color Models	242
6.2 Image Concepts	250
Color Depth	250
Image Size	251
Display Resolution	254

- 6.3 File Formats** 258
 - JPEG 258
 - GIF 259
 - PNG 264
 - SVG 264
 - Other Formats 265
- 6.4 Audio and Video** 268
 - Media Concepts 268
 - Browser Video Support 269
 - Browser Audio Support 271
- 6.5 Working with Color** 273
 - Picking Colors 274
 - Define Shades 275
- 6.6 Chapter Summary** 277
 - Key Terms 277
 - Review Questions 277
 - Hands-On Practice 278

Chapter 7 CSS 2: Layout 282

- 7.1 Older Approaches to CSS Layout** 283
 - Floating Elements 283
 - Positioning Elements 284
 - Overlapping and Hiding Elements 288
- 7.2 Flexbox Layout** 292
 - Flex Containers and Flex Items 293
 - Use Cases for Flexbox 294
- 7.3 Grid Layout** 298
 - Specifying the Grid Structure 299
 - Explicit Grid Placement 300
 - Cell Properties 302
 - Nested Grids 302
 - Grid Areas 306
 - Grid and Flexbox Together 306

- 7.4 Responsive Design** 310
 - Setting Viewports 313
 - Media Queries 314
 - Scaling Images 318
- 7.5 CSS Effects** 321
 - Transforms 322
 - Filters 324
 - Transitions 324
 - Animations 329
- 7.6 CSS Preprocessors** 332
 - The Basics of Sass 333
 - Mixins and Functions 335
 - Modules 336
- 7.7 Chapter Summary** 340
 - Key Terms 340
 - Review Questions 340
 - Hands-On Practice 341
 - References 347

Chapter 8 JavaScript 1: Language Fundamentals 348

- 8.1 What Is JavaScript and What Can It Do?** 349
 - Client-Side Scripting 350
 - JavaScript's History 352
 - JavaScript and Web 2.0 353
 - JavaScript in Contemporary Software Development 354
- 8.2 Where Does JavaScript Go?** 356
 - Inline JavaScript 356
 - Embedded JavaScript 356
 - External JavaScript 358
 - Users without JavaScript 359
- 8.3 Variables and Data Types** 359
 - JavaScript Output 362
 - Data Types 364

	Built-In Objects	366
	Concatenation	368
8.4	Conditionals	369
	Truthy and Falsy	371
8.5	Loops	372
	While and do ... while Loops	373
	For Loops	373
8.6	Arrays	375
	Iterating an array using for ... of	378
	Array Destructuring	378
8.7	Objects	380
	Object Creation Using Object Literal Notation	380
	Object Creation Using Object Constructor	381
	Object Destructuring	382
	JSON	385
8.8	Functions	388
	Function Declarations vs. Function Expressions	388
	Nested Functions	391
	Hoisting in JavaScript	392
	Callback Functions	394
	Objects and Functions Together	396
	Function Constructors	397
	Arrow Syntax	399
8.9	Scope and Closures in JavaScript	403
	Scope in JavaScript	403
	Closures in JavaScript	408
8.10	Chapter Summary	411
	Key Terms	412
	Review Questions	412
	Hands-On Practice	413
	References	417

Chapter 9 JavaScript 2: Using JavaScript 418

9.1 The Document Object Model (DOM) 419

Nodes and NodeLists 420

Document Object 420

Selection Methods 422

Element Node Object 424

9.2 Modifying the DOM 427

Changing an Element's Style 427

InnerHTML vs textContent vs DOM Manipulation 429

DOM Manipulation Methods 430

DOM Timing 433

9.3 Events 436

Implementing an Event Handler 436

Page Loading and the DOM 439

Event Object 440

Event Propagation 440

Event Delegation 444

Using the Dataset Property 446

9.4 Event Types 448

Mouse Events 448

Keyboard Events 448

Form Events 450

Media Events 451

Frame Events 451

9.5 Forms in JavaScript 456

Responding to Form Movement Events 458

Responding to Form Changes Events 458

Validating a Submitted Form 458

Submitting Forms 462

9.6 Regular Expressions 463

Regular Expression Syntax 463

Extended Example 465

9.7 Chapter Summary 472

Key Terms 472

Review Questions 473

Hands-On Practice 473

References 479

Chapter 10 JavaScript 3: Additional Features 480

10.1 Array Functions 481

forEach 481

Find, Filter, Map, and Reduce 482

Sort 484

10.2 Prototypes, Classes, and Modules 485

Using Prototypes 487

Classes 491

Modules 493

10.3 Asynchronous Coding with JavaScript 499

Fetching Data from a Web API 503

Promises 514

Async and Await 518

10.4 Using Browser APIs 524

Web Storage API 524

Web Speech API 526

Geolocation 527

10.5 Using External APIs 529

Google Maps 529

Charting with Plotly.js 531

10.6 Chapter Summary 539

Key Terms 539

Review Questions 539

Hands-On Practice 540

References 544

Chapter 11	JavaScript 4: React	545
11.1	JavaScript Front-End Frameworks	546
	Why Do We Need Frameworks?	546
	React, Angular, and Vue	547
11.2	Introducing React	551
	React Components	553
11.3	Props, State, Behavior, and Forms	557
	Props	557
	State	561
	Behaviors	563
	Forms in React	568
	Component Data Flow	570
11.4	React Build Approach	577
	Build Tools	577
	Create React App	579
	Other React Build Approaches	582
11.5	React Lifecycle	582
	Fetching Data	583
11.6	Extending React	584
	Routing	584
	CSS in React	587
	Other Approaches to State	588
11.7	Chapter Summary	596
	Key Terms	597
	Review Questions	597
	Hands-On Practice	597
	References	602
Chapter 12	Server-Side Development 1: PHP	603
12.1	What Is Server-Side Development?	604
	Front End versus Back End	604
	Common Server-Side Technologies	605

12.2	PHP Language Fundamentals	611
	PHP Tags	611
	Variables and Data Types	613
	Writing to Output	614
	Concatenation	615
12.3	Program Control	620
	if ... else	620
	switch ... case	621
	while and do ... while	622
	for	623
	Alternate Syntax for Control Structures	624
	Include Files	624
12.4	Functions	627
	Function Syntax	627
	Invoking a Function	628
	Parameters	629
	Variable Scope within Functions	632
12.5	Arrays	635
	Defining and Accessing an Array	635
	Multidimensional Arrays	636
	Iterating through an Array	639
	Adding and Deleting Elements	640
12.6	Classes and Objects	643
	Terminology	643
	Defining Classes	644
	Instantiating Objects	644
	Properties	645
	Constructors	645
	Method	646
	Visibility	648
	Static Members	649
	Inheritance	651

- 12.7 \$ _GET and \$ _POST Superglobal Arrays** 652
 - Superglobal Arrays 652
 - Determining If Any Data Sent 655
 - Accessing Form Array Data 658
 - Using Query Strings in Hyperlinks 659
 - Sanitizing Query Strings 660
- 12.8 Working with the HTTP Header** 664
 - Redirecting Using Location Header 664
 - Setting the Content-Type Header 664
- 12.9 Chapter Summary** 666
 - Key Terms 667
 - Review Questions 667
 - Hands on Practice 667
 - Reference 672

Chapter 13 Server-Side Development 2: Node.js 673

- 13.1 Introducing Node.js** 674
 - Node Advantages 674
 - Node Disadvantages 679
- 13.2 First Steps with Node** 682
 - Simple Node Application 682
 - Adding Express 685
 - Environment Variables 686
- 13.3 Creating an API in Node** 687
 - Simple API 687
 - Adding Routes 689
 - Separating Functionality into Modules 690
- 13.4 Creating a CRUD API** 692
 - Passing Data to an API 694
 - API Testing Tools 695
- 13.5 Working with Web Sockets** 696
- 13.6 View Engines** 700

- 13.7 Serverless Approaches** 702
 - What Is Serverless? 702
 - Benefits of Serverless Computing 704
 - Serverless Technologies 704
- 13.8 Chapter Summary** 706
 - Key Terms 707
 - Review Questions 707
 - Hands-On Practice 707
 - References 710

Chapter 14 Working with Databases 711

- 14.1 Databases and Web Development** 712
 - The Role of Databases in Web Development 712
- 14.2 Managing Databases** 715
 - Command-Line Interface 716
 - phpMyAdmin 716
 - MySQL Workbench 718
 - SQLite Tools 719
 - MongoDB Tools 719
- 14.3 SQL** 720
 - Database Design 720
 - SELECT Statement 724
 - INSERT, UPDATE, and DELETE Statements 727
 - Transactions 727
 - Data Definition Statements 731
 - Database Indexes and Efficiency 732
- 14.4 Working with SQL in PHP** 733
 - Connecting to a Database 734
 - Handling Connection Errors 737
 - Executing the Query 738
 - Processing the Query Results 739

Freeing Resources and Closing Connection	743
Working with Parameters	744
Using Transactions	747
Designing Data Access	751
14.5 NoSQL Databases	754
Why (and Why Not) Choose NoSQL?	756
Types of NoSQL Systems	757
14.6 Working with MongoDB in Node	761
MongoDB Features	761
MongoDB Data Model	762
Working with the MongoDB Shell	764
Accessing MongoDB Data in Node.js	764
14.7 Chapter Summary	771
Key Terms	772
Review Questions	772
Hands-On Practice	773
References	777
Chapter 15 Managing State	778
<hr/>	
15.1 The Problem of State in Web Applications	779
15.2 Passing Information in HTTP	781
Passing Information via the URL	781
Passing Information via HTTP Header	782
15.3 Cookies	785
How Do Cookies Work?	786
Using Cookies in PHP	787
Using Cookies in Node and Express	789
Persistent Cookie Best Practices	789
15.4 Session State	792
How Does Session State Work?	793
Session Storage and Configuration	794
Session State in PHP	796
Session State in Node	798

- 15.5 Caching** 799
 - Page Output Caching 800
 - Application Data Caching 800
 - Redis as Caching Service 803
- 15.6 Chapter Summary** 808
 - Key Terms 808
 - Review Questions 808
 - Hands-On Practice 808
 - References 812

Chapter 16 Security 813

- 16.1 Security Principles** 814
 - Information Security 814
 - Risk Assessment and Management 815
 - Security Policy 818
 - Business Continuity 818
 - Secure by Design 821
 - Social Engineering 823
 - Authentication Factors 824
- 16.2 Approaches to Web Authentication** 825
 - Basic HTTP Authentication 826
 - Form-Based Authentication 827
 - HTTP Token Authentication 829
 - Third-Party Authentication 830
- 16.3 Cryptography** 834
 - Substitution Ciphers 835
 - Public Key Cryptography 838
 - Digital Signatures 840
- 16.4 Hypertext Transfer Protocol Secure (HTTPS)** 840
 - SSL/TLS Handshake 842
 - Certificates and Authorities 842
 - Migrating to HTTPS 846

16.5	Security Best Practices	848
	Credential Storage	849
	Monitor Your Systems	858
	Audit and Attack Thyself	859
16.6	Common Threat Vectors	860
	Brute-Force Attacks	860
	SQL Injection	861
	Cross-Site Scripting (XSS)	863
	Cross-Site Request Forgery (CSRF)	868
	Insecure Direct Object Reference	869
	Denial of Service	870
	Security Misconfiguration	871
16.7	Chapter Summary	874
	Key Terms	875
	Review Questions	875
	Hands-On Practice	876
	References	878
<hr/>		
Chapter 17	DevOps and Hosting	880
17.1	DevOps: Development and Operations	881
	Continuous Integration, Delivery, and Deployment	881
	Testing	882
	Infrastructure as Code	885
	Microservice Architecture	886
17.2	Domain Name Administration	888
	Registering a Domain Name	888
	Updating the Name Servers	891
	DNS Record Types	891
	Reverse DNS	894
17.3	Web Server Hosting Options	895
	Shared Hosting	895
	Dedicated Hosting	898

Collocated Hosting 898

Cloud Hosting 899

17.4 Virtualization 899

Server Virtualization 899

Cloud Virtualization 904

17.5 Linux and Web Server Configuration 905

Configuration 907

Starting and Stopping the Server 907

Connection Management 908

Data Compression 910

Encryption and SSL 911

Managing File Ownership and Permissions 913

17.6 Request and Response Management 914

Managing Multiple Domains on One Web Server 914

Handling Directory Requests 916

Responding to File Requests 917

URL Redirection 918

Managing Access with .htaccess 922

Server Caching 923

17.7 Web Monitoring 925

Internal Monitoring 925

External Monitoring 927

17.8 Chapter Summary 927

Key Terms 927

Review Questions 928

Hands-On Practice 928

References 930

Chapter 18 Tools and Traffic 932

18.1 The History and Anatomy of Search Engines 933

Search Engine Overview 933

18.2	Web Crawlers and Scrapers	935
	Scrapers	936
18.3	Indexing and Reverse Indexing	938
18.4	PageRank and Result Order	939
18.5	Search Engine Optimization	942
	Title	943
	Meta Tags	943
	URLs	945
	Site Design	947
	Sitemaps	948
	Anchor Text	949
	Images	949
	Content	950
	Black-Hat SEO	950
18.6	Social Networks	955
	How Did We Get Here?	956
18.7	Social Network Integration	958
	Basic Social Media Presence	959
	Facebook's Social Plugins	960
	Open Graph	964
	Twitter's Widgets	965
	Advanced Social Network Integration	969
18.8	Content Management Systems	970
	Components of a Managed Website	970
	Types of CMS	971
18.9	WordPress Overview	972
	Post and Page Management	973
	WYSIWYG Editors	975
	Template Management	976
	Menu Control	977
	User Management and Roles	977

User Roles	978
Workflow and Version Control	981
Asset Management	982
Search	983
Upgrades and Updates	983
18.10 WordPress Technical Overview	984
Installation	984
File Structure	984
WordPress Nomenclature	986
WordPress Template Hierarchy	987
18.11 Modifying Themes	988
Changing Theme Files	990
18.12 Web Advertising Fundamentals	991
Web Advertising 101	991
Web Advertising Economy	994
18.13 Support Tools and Analytics	995
Search Engine Webmaster Tools	995
Analytics	996
Third-Party Analytics	999
Performance Tuning and Rating	999
18.14 Chapter Summary	1005
Key Terms	1005
Review Questions	1006
Hands-On Practice	1006
References	1009
<i>Index</i>	<i>1011</i>
<i>Credits</i>	<i>1029</i>

Preface

Welcome to the *Fundamentals of Web Development*. This textbook is intended to cover the broad range of topics required for modern web development and is suitable for intermediate to upper-level computing students. A significant percentage of the material in this book has also been used by the authors to teach web development principles to first-year computing students and to non-computing students as well.

One of the difficulties that we faced when planning this book is that web development is taught in a wide variety of ways and to a diverse student audience. Some instructors teach a single course that focuses on server-side programming to third-year students; other instructors teach the full gamut of web development across two or more courses, while others might only teach web development indirectly in the context of a networking, HCI, or capstone project course. We have tried to create a textbook that supports learning outcomes in all of these teaching scenarios.

What Is Web Development?

Web development is a term that takes on different meanings depending on the audience and context. In practice, web development requires people with complementary but distinct expertise working together toward a single goal. Whereas a graphic designer might regard web development as the application of good graphic design strategies, a database administrator might regard it as a simple interface to an underlying database. Software engineers and programmers might regard web development as a classic software development task with phases and deliverables, where a system administrator sees a system that has to be secured from attackers. With so many different classes of users and meanings for the term, it's no wonder that web development is often poorly understood. Too often, in an effort to fully cover one aspect of web development, the other principles are ignored altogether, leaving students without a sense of where their skills fit into the big picture.

A true grasp of web development requires an understanding of multiple perspectives. As you will see, the design and layout of a website are closely related to the code and the database. The quality of the graphics is related to the performance and configuration of the server, and the security of the system spans every aspect of development. All of these seemingly independent perspectives are interrelated and,

therefore, a web developer (of any type) should have a foundational understanding of all aspects, even if he/she only possesses expertise in a handful of areas.

What's New in the Third Edition?

The first edition of this title was mainly written in the first half of 2013 and then published in early 2014. The second edition was mainly written in the first half of 2016 and then published in early 2017. This edition was mainly written in the first half of 2020.

The focus of the book has always been on the conceptual and practical fundamentals of web development. As such, many of the topics covered in the book are as important today as they were when we wrote the first edition in 2013. Nonetheless, the field of web development is constantly in flux, which has resulted in many changes in the underlying technologies of web development since the first and second editions were written. The third edition reflects both these recent changes as well as those enduring fundamental aspects of web development.

Over the past decade, the key technology stack within real-world web development has migrated away from back-end technologies such as PHP, JSP, and ASP.NET. While these technologies are still important, the front-end technology of JavaScript has become the focal practice of most web developers today. This edition reflects this transformation in real-world practices.

Some of the key changes in this edition include the following:

- Existing chapters have been revised based on user feedback. Instructor focus groups from 2018 provided helpful information on what content was missing or needed improvement. Emailed suggestions from other instructors and our own student feedback also informed changes to existing content.
- Updated, expanded, or new coverage of a wide-variety of topics that reflect current approaches to web development. Some of these topics include CSS preprocessors, CSS design principles, ES6+ language additions, web and browser APIs, React, Node, TypeScript, SQLite and NoSQL databases, GraphQL, serverless computing, caching, new security vulnerabilities, JWT authentication, DevOps, continuous integration/deployment, and microservice architectures.
- Enhanced coverage of contemporary JavaScript. This edition has five chapters on both front-end and back-end JavaScript (almost 300 pages versus the second edition's three chapters of 170 pages).
- Dedicated chapters on React and Node. Both of these have become an essential skill for contemporary web developers.
- New pedagogical features within most chapters. These include Test Your Knowledge exercises and Essential Solutions boxes. The former are short exercises for student to apply the knowledge in the section(s) they have

just read, while the latter provide quick guidance to the reader on how to accomplish common tasks.

- Updated art style throughout most of the book.
- Most of the end-of-chapter projects have been revised or replaced.

Features of the Book

To help students master the fundamentals of web development, this book has the following features:

- **Covers both the concepts and the practice of the entire scope of web development.** Web development can be a difficult subject to teach because it involves covering a wide range of theoretical material that is technology independent as well as practical material that is very specific to a particular technology. This book comprehensively covers both the conceptual and practical side of the entire gamut of the web development world.
- **Comprehensive coverage of a modern Internet development platform.** In order to create any kind of realistic Internet application, readers require detailed knowledge of and practice with a single specific Internet development platform. This book covers HTML, CSS, JavaScript, and two server-side stacks (PHP and MySQL, as well as Node and MongoDB). The book also covers the key concepts and infrastructures—such as web protocols and architecture, security, hosting provision, and server administration—that are important learning outcomes for any web development course.
- **Focused on the web development reality of today’s world and in anticipation of future trends.** The world of web development has changed remarkably in the past decade. Fewer and fewer sites are being created from scratch; instead, many developers make use of existing sophisticated frameworks and environments. This book includes coverage of essential frameworks such as Bootstrap, React, and WordPress.
- **Sophisticated, realistic, and engaging case studies.** Rather than using simplistic “Hello World” style web projects, this book makes extensive use of three case studies: an art store, a travel photo sharing community, a stock trading site, and a movie review site. For all the case studies, supporting material such as the visual design, images, and databases are included. We have found that students are more enthusiastic and thus work significantly harder with attractive and realistic cases.
- **Content presentation suitable for visually oriented learners.** As long-time instructors, the authors are well aware that today’s students are often extremely reluctant to read long blocks of text. As a result, we have tried to make the

content visually pleasing and to explain complicated ideas not only through text but also through diagrams.

- **Content that is the result of over 25 years of classroom experience** (in college, university, and adult continuing education settings) teaching web development. The book's content also reflects the authors' deep experience engaging in web development work for a variety of international clients.
- **Additional instructional content available online.** Rather than using long programming listings to teach ideas and techniques, this book uses a combination of illustrations, short color-coded listings, and separate lab exercises. These step-by-step tutorials are not contained within the book, but are available online at www.funwebdev.com. Code listings within book as well as starting files for projects are publicly available on GitHub.
- **Complete pedagogical features for the student.** Each chapter includes learning objectives, margin notes, links to step-by-step online labs, advanced tips, keyword highlights, test your knowledge exercises, essential solution boxes, end-of-chapter review questions, and three different case study exercises.

Organization of the Book

The chapters in *Fundamentals of Web Development* can be organized into three large sections.

- **Foundational client-side knowledge (Chapters 1–10).** These first chapters cover the foundational knowledge needed by any front-end web developer. This includes a broad introduction to web development (Chapter 1), how the web works (Chapter 2), HTML (Chapters 3 and 5), CSS (Chapters 4 and 7), web media (Chapter 6), and JavaScript (Chapters 8–11).
- **Essential server-side development (Chapters 12–16).** Despite the increasing importance of JavaScript-based development, learning server-side development is still the essential skill taught in most web development courses. The two most popular server-side environments are covered in Chapter 12 (PHP) and Chapter 13 (Node). Database-driven web development is covered in Chapter 14, while state management is covered in Chapter 15.
- **Specialized topics (Chapters 16–18).** Contemporary web development has become a very complex field, and different instructors will likely have different interest areas beyond the foundational topics. As such, our book provides specialized chapters that cover a variety of different interest areas. Chapter 16 covers the vital topic of web security. Chapter 17 focuses on the web server with topics such as DevOps, hosting options, and server configuration. Finally, Chapter 18 covers search, social media integration, content management, advertising, and support tools and analytics.

Pathways through this Book

There are many approaches to teach web development and our book is intended to work with most of these approaches. It should be noted that this book has more material than can be plausibly covered in a single semester course. This is by design as it allows different instructors to chart their own unique way through the diverse topics that make up contemporary web development.

We do have some suggested pathways through the materials (though you are welcome to chart your own course), which you can see illustrated in the pathway diagrams.

- **All the web in a single course.** Many computing programs only have space for a single course on web development. This is typically an intermediate or upper-level course in which students will be expected to do a certain amount of learning on their own. In this case, we recommend covering Chapters 1–5, 8, 9, 12 or 13, 14, and 16.
- **Client-focused course for introductory students.** Some computing programs have a web course with minimal programming that may be open to non-major students or which acts as an introductory course to web development for major students. For such a course, we recommend covering Chapters 1–7. You can use Chapters 8 and 9 to introduce client-side scripting if desired.
- **Front end focused course for intermediate students.** For courses that wish to focus on front-end development, you could cover Chapters 1–11 as well as Chapter 13 and parts of Chapter 14.
- **Infrastructure-focused course.** In some computing programs the emphasis is less on the particulars of web programming and more on integrating web technologies into the overall computing infrastructure within an organization. Such a course might cover Chapters 1, 2, 3, 4, 8, 13, 16, and 17 with an option to include some topics from Chapters 6, 14, 15, and 18.

For the Instructor

Web development courses have been called “unteachable” and indeed teaching web development has many challenges. We believe that using our book will make teaching web development significantly less challenging.

The following instructor resources are available at www.pearsonhighered.com/cs-resources/:

- Attractive and comprehensive PowerPoint presentations (one for each chapter).
- Images and databases for all the case studies.
- Solutions to end-of-chapter projects.
- Additional questions in exam bank.

Many of the code listings and examples used in the book are available on GitHub (github.com/funwebdev-3rd-ed).

For the Student

There are a variety of student resources available on GitHub (github.com/funwebdev-3rd-ed), the publisher's resource site (www.pearsonhighered.com/cs-resources/), and the book's website (www.funwebdev.com). These include:

- All code listings organized by chapter.
- Starting files, images, and database scripts for all end-of-chapter projects.
- Starting files and solutions to all Test Your Knowledge exercises.
- Instructions for lab exercises for each chapter.
- Starting files for all labs.
- Video lectures for a selection of chapter topics.

Why This Book?

The ACM computing curricula for computer science, information systems, information technology, and computing engineering all recommend at least a single course devoted to web development. As a consequence, almost every postsecondary computing program offers at least one course on web development.

Despite this universality, we could not find a suitable textbook for these courses that addressed both the theoretical underpinnings of the web together with modern web development practices. Complaints about this lack of breadth and depth have been well documented in published accounts in the computing education research literature. Although there are a number of introductory textbooks devoted to HTML and CSS, and, of course, an incredibly large number of trade books focused on specific web technologies, many of these are largely unsuitable for computing major students. Rather than illustrating how to create simple pages using HTML and JavaScript with very basic server-side capabilities, we believed that instructors increasingly need a textbook that guides students through the development of realistic, enterprise-quality web applications using contemporary Internet development platforms and frameworks.

This book is intended to fill this need. It covers the required ACM web development topics in a modern manner that is closely aligned with contemporary best practices in the real world of web development. It is based on our experience teaching a variety of different web development courses since 1997, our working professionally in the web development industry, our research in published accounts in the computing education literature, and in our corresponding with colleagues across the world. We hope that you find that this book does indeed satisfy your requirements for a web development textbook!

Acknowledgments

A book of this scale and scope incurs many debts of gratitude. We are first and foremost exceptionally grateful to Matt Goldstein, formerly the Acquisitions Editor at Pearson for the first two editions, championed the book and guided the overall process of bringing the book to market. Tracy Johnson, the Content Development Manager for Computer Science, navigated this edition through the complexities of the new electronic-first approach to textbook publishing. Louise Capulli was once again the very capable Project Manager who facilitated communication between the often finicky authors and the production team. Carole Synder from Pearson also contributed throughout the writing and production process. We would like to thank Pradeep Subramani and his team at Integra Software Services for the work they did on the postproduction side. We would also like to thank Rose Kernan, proofreader, who made sure that the words and illustrations actually work to tell a story that makes sense.

Reviewers help ensure that a textbook reflects more than just the authors' perspective. For this edition, the book was immeasurably improved by our talented and close-eyed reviewer, Jordan Pratt of Mount Royal University. A variety of very helpful students provided inspirational feedback on labs and lecture material. Some of these include: Farsos Bulsara, Raj Dutta, Hamid Hemani, Peter Huang, Jason Hutson, Andrews Juchem, Sarfaraz Kermali, Shuntian Li, Robert Martin, Brett Miller, Peter Morrison, and Renato Niro. Indeed, to be honest, we should list all of our students over the past five years here, as they have improved our insight and acted as non-voluntary guinea pigs in the evolution of our thinking on teaching web development.

There are many others who helped guide our thinking, provided suggestions, or made our administrative and teaching duties somewhat less onerous. While we cannot thank everyone, Randy Connolly is especially grateful to Brigitte Jellinek for inviting him to spend a semester in 2017 at Salzburg University of Applied Sciences, as it provided early inspiration for many of the changes made in this edition. We would also like to express our gratitude to all the instructors who took the time to email us about the first two editions. Their praise, suggestions for improvements, or their admonition for mistakes or omissions was always very welcome and hopefully resulted in a better third edition.

We are very appreciative of those who donated photos for the Travel case study used throughout the book: Robert Boschman, Alexander Connolly, Norman Connolly,

Mark Eagles, Sonya Flessati, Emily Girard, Mike Gouthro, Jordan Kidney, Roy Kuhnlein, and Jocelyn Sealy. For this edition, our Art case study was able to take advantage of the public-spirited and generous open content policies of the Rijksmuseum, the J. Paul Getty Museum, and the National Gallery of Art (Washington, DC).

From the early inception of the book in May of 2012 all the way to the conclusion of this edition in the late months of 2020, Dr. Janet Miller provided incredible and overwhelming encouragement, understanding, and feedback for which Randy Connolly will be always grateful. Joanne Hoar, holding a M.Sc. in computer science, has always been an inspiration for Ricardo Hoar, so he apologizes profusely for the systemic racism and sexism among computer science faculty that has excluded her, a brilliant programmer, from gainful employment in academia. Finally, we want to thank our children, Alexander Connolly, Benjamin Connolly, Mark Miller, Hann Miller, Archimedes Hoar, Curia Hoar, and Hypatia Hoar, who saw less of their fathers during this time but were always on our minds.

Visual Walkthrough

518 CHAPTER 10 JavaScript 3: Additional Features

```
// promised version of the transfer task
function transferToCloud(filename) {
  return new Promise((resolve, reject) => {
    // just have a made-up AWS url for now
    let cloudURL =
      "https://bucket.s3-aws-region.amazonaws.com/makebelieve.jpg";
    // if passed filename exists then upload ...
    if (!existsOnServer(filename)) {
      performTransfer(filename, cloudURL);
      resolve(cloudURL);
    } else {
      reject(new Error("filename does not exist"));
    }
  });
}
// use this function
transferToCloud(filename)
  .then(url => extractTags(url))
  .then(url => compressImage(url))
  .catch(err => logThisError(err));
```

LISTING 10.10 Creating Promises

The `Promise.all()` method is typically passed an array of `Promise` objects that can be satisfied in any order. Figure 10.20 illustrates how this approach can be used. Notice that it returns a `Promise`, thus the `then()` method needs to be passed a function that will get executed when all the passed `Promise` objects are resolved. That function will be passed an array containing, in the case of multiple fetches, multiple retrieved JSON data arrays.

Potentially, the `Promise.all()` approach can be more efficient when each individual fetch is independent of each other. Figure 10.21 contains screen captures of the Google Chrome Network Inspector status for two versions, one using nested fetches and one using the `Promise.all()` approach. With the nested approach, the browser can't make the next fetch request until the previous one is resolved (that is, the data has been returned); with the `Promise.all()` approach, all three fetches can be made simultaneously, which is more time efficient.

10.3.3 Async and Await

In the previous section, you learned how to use (and create) promises as a way of taming the code complexities of using asynchronous functions. While certainly a significant improvement over multiple nested callback functions, recent iterations of the JavaScript language have added additional language support for asynchronous operations, which further improves and simplifies the code needed for these operations.

Color-coded source code listings emphasize important elements and visually separate comments from the code.

Coverage of contemporary real-world web development topics.

Tables provide quick access to details.

Key terms are highlighted in consistent color.

Solutions to common problems are highlighted.

FIGURE 4.8 CSS 1: Selectors and Basic Styling

Property	Description
border	A combined shorthand property that allows you to set the style, width, and color of a border in one property. The order is important and must be: <code>border-width border-style border-color</code>
border-style	Specifies the line type of the border. Possible values are: <code>solid</code> , <code>dotted</code> , <code>dashed</code> , <code>double</code> , <code>groove</code> , <code>ridge</code> , <code>inset</code> , <code>outset</code> , <code>hidden</code> , and <code>none</code> .
border-width	The width of the border in a unit (but not percent). A variety of keywords (<code>thin</code> , <code>medium</code> , etc.) are also supported.
border-color	The color of the border in a color unit.
border-radius	The radius of a rounded corner.
border-image	The URI of an image to use as a border.
box-shadow	Adds a shadow effect to an element. The values are as follows: <code>offset-x offset-y blur-radius spread-radius color</code>

TABLE 4.8 Border Properties

The `box-shadow` property provides a way to add shadow effects around an element's box. To set the shadow, you specify x and y offsets, along with optional blur, spread, inset, and color settings.

4.6.4 Margins and Padding

Margins and padding are essential properties for adding white space to a web page, which can help differentiate one element from another. Figure 4.23 illustrates how these two properties can be used to provide spacing and element differentiation.

As you can see in Figures 4.17 and 4.23, margins add spacing around an element's content, while padding adds spacing within elements. Borders divide the margin area from the padding area.

ESSENTIAL SOLUTIONS

Centering an element horizontally within a container

```
<div id="element">content</div>
```

result in browser

```
element {
  margin: 0 auto;
  width: 200px; /* some value */
}
```

In chapter 7, you will learn how to use flexbox layout to position an element horizontally and vertically within a container.

Element

Test Your Knowledge sections provide opportunities for readers to apply their knowledge.

Separate hands-on lab exercises (available online) give readers opportunity to practically apply concepts and techniques covered in the text.

TEST YOUR KNOWLEDGE # 1

Modify lab07-test01.html by adding CSS in lab07-test01.css to implement the layout shown in Figure 7.16 (some of the styling as already been provided).

1. Set the background image on the <body> tag. Set the height to 100vh so it will always fill the entire viewport. Set the background-color and background-position properties (see Chapter 4 for a refresher if needed).
2. For the header, set its display to flex. Set justify-content to space-between and align-items to center. This will make the <h2> and the <nav> elements sit on the same line, but will expand to be aligned with the outside edges.
3. To center the form in the middle of the viewport, set the display of the <main> element to flex, and align-items and justify-content to center. Do the same for the <form> element.
4. Fine-tune the size of the form elements by setting the box-size of label to 16em, the search box to 36em, and the submit button to 10em. The final result should look similar to that shown in Figure 7.16.



FIGURE 7.16 Completed Test Your Knowledge #1

HANDS-ON EXERCISES

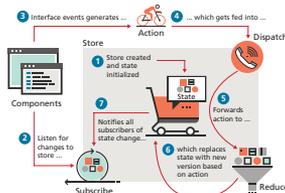
LAB 7
Using Grid
Nested Grids
Using calc()
Grid Areas
Grids and Flex Together

7.3 Grid Layout

Designers have long desired the ability to construct a layout based on a set number of rows and columns. In the early years of CSS, designers frequently made use of HTML tables as way to implement these types of. Unfortunately this not only added a lot of additional non-semantic markup, but also typically resulted in pages that didn't adapt to different sized monitors or browser widths. CSS Frameworks such as Bootstrap became popular partly because they provided a relatively painless and

Hundreds of illustrations help explain especially complicated processes.

Important algorithms are illustrated visually to help clarify understanding.



```

1 const initialState = {
  favorites: []
};
const store = createStore(reducer);

2 store.subscribe(() => {
  const state = store.getState();
  // update components with current state
  ...
});

3 AddFavClick() => {
  // create favorite object to add to store
  const f = { id: ..., title: ... };
  // dispatch add-to-fav action with the data
  store.dispatch( { type: 'ADD_TO_FAV', payload: f } );
};

4 store.dispatch( { type: 'ADD_TO_FAV', payload: f } );
};

6 const reducer = (state = initialState, action) => {
  if (action.type === 'ADD_TO_FAVS') {
    const newState = { ...state };
    newState.favorites.push(action.payload);
    return newState;
  } else if (action.type === 'REMOVE_FROM_FAVS') {
    ...
  } else {
    ...
  }
};

```

FIGURE 11.18 Redux architecture

Note and Pro Tip boxes emphasize important concepts and practical advice.

Probably the most common postloop operation is to increment a counter variable, as shown in Figure 8.11. An alternative way to increment this counter is to use `i++` instead of `i=i+1`. There are two additional, more specialized, variations of the basic `for` loop. There is a `for...in` loop and in ES6 and beyond, a `for...of` loop. The `for...in` loop is used for iterating through enumerable properties of an object, while the more useful `for...of` loop is used to iterate through iterable objects, and will be demonstrated in the next section on arrays.

NOTE
Infinite while loops can happen if you are not careful, and since the scripts are executing on the client computer, it can appear to them that the browser is "locked" while endlessly caught in a loop, processing. Some browsers will even try to terminate scripts that execute for too long a time to mitigate this unpleasantness.

DIVE DEEPER: ERRORS USING TRY AND CATCH
When the browser's JavaScript engine encounters a runtime error, it will throw an exception. These exceptions interrupt the regular, sequential execution of the program and can stop the JavaScript engine altogether. However, you can optionally catch these errors (and thus prevent the disruption) using the `try...catch` block as shown below.

```
try {
  nonexistentFunction("hello");
}
catch(err) {
  alert("An exception was caught!" + err);
}
```

In JavaScript errors, it messages. The `throw` built-in exceptions as

Tangential material has been moved into Dive Deeper sections, thereby keeping the main text more focused.

Tools Insight sections introduce many of the most essential tools used in web development.

TOOLS INSIGHT

JavaScript has become one of the most important programming languages in the world. As a result, there has been tremendous growth in the availability of tools to help with different aspects of JavaScript development. We could quite easily fill an entire chapter of this book examining just a small subset of these tools! In this Tools Insight section, we are going to look at just two JavaScript tools; subsequent JavaScript chapters will include additional Tools Insight sections that will introduce others.

The first, and most important, JavaScript tool is one that you have using, namely, your browser. All modern browsers now include sophisticated and profiling tools. Just as the authors' grandparents used to regale us in with stories of walking miles to school in the snow going uphill, there are authors sometimes tell our students what it used to be like in the late 1980s using JavaScript without having access to any type of debugger. Now it's a snap! Thankfully in today's more civilized and developed world, you can add step through code line by line, and inspect variables all within the browser, as shown in Figure 9.22.

Contemporary browsers provide additional tools that are essential for JavaScript development. As more and more functionality has migrated from the server to the client, it has become increasingly important to assess the performance of JavaScript code. Figure 9.23 illustrates the Profile view of a page's JavaScript performance. It allows a developer to pinpoint time-consuming functions or visualize performance as timeline charts.

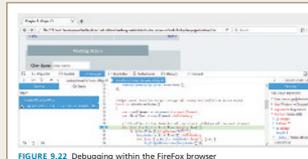


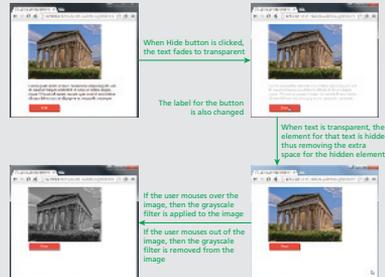
FIGURE 9.22 Debugging within the Firefox browser

Extended Example sections provide detailed guidance in the application of a chapter's content.

In JavaScript errors, it messages. The `throw` built-in exceptions as

EXTENDED EXAMPLE

Now that we have covered the basics of working with events and the DOM, we are going to put this knowledge to work in an extended example. In the `example.html` page, an image is displayed with some related text as well as a Hide button. Using some CSS filters and transitions along with some JavaScript event handling, the example will fade the text in and out of visibility when the user clicks on the button. Also, the example will apply or remove a grayscale filter to the image when the user moves the mouse in or out of the image.



(continued)

Key terms appear again at end of chapter.

Review questions at end of chapter provide opportunity for self-testing.

Projects contain step-by-step instructions of varying difficulty.

Attractive and realistic case studies help engage the readers' interest.

All images, starting files, database scripts, and other material for each of the end of chapter projects are available for download.

13.8 Chapter Summary 707

13.8.1 Key Terms

CommonJS	middleware	route
CRUD	module	serverless computing
Database-as-a-Service	Node	templates
Environment variables	nonblocking	V8
Express	npm	views
Functions-as-a-Service	Platform-as-a-Service	view engine
JAM Stack	push-based	WebSockets

13.8.2 Review Questions

1. What are the key advantages and disadvantages of using Node?
2. What is npm? What is its role in contemporary web development?
3. A nonblocking architecture can typically handle more simultaneous requests. Why is that?
4. What are modules in JavaScript? How does the Node CommonJS module system differ from the one introduced in ES6?
5. In the context of Node, what is Express?
6. What are Express routes?
7. In Express, what is middleware?
8. What is a CRUD API?
9. What are WebSockets? How do they differ from HTTP?
10. What role do view engines play in Node?
11. What are the benefits of serverless computing?
12. How does functions-as-a-service differ from platform-as-a-service?

13.8.3 Hands-On Practice

PROJECT 1:

DIFFICULTY LEVEL: Beginner

Overview
In this project, you will be creating a data retrieval API.

Instructions

1. You have been provided a folder named `project1`, that contains the data and other files needed for this project. Use `npm init` to setup the folder, and `npm install` to add express.
2. Name your server file `art.js`. Add a static file handler for resources in the `static` folder.
3. The data for the APIs is contained in a supplied json file. Create a provider module for this file.

Each chapter ends with three projects that allow the reader to practice the material covered in the chapter within a realistic context.

14.7 Chapter Summary 713

14. Why is it so important to use only one connection per page with PDO?
15. Describe the four types of NoSQL system.

14.7.3 Hands-On Practice

PROJECT 1: Share Your Travel Photos

DIFFICULTY LEVEL: Intermediate

Overview
Demonstrate your ability to retrieve information from a database and display it. This will require a variety of SQL queries. The results when finished will look similar to that shown in Figure 14.37.



The screenshot shows a web browser displaying a travel photo gallery. At the top, there's a search bar and a filter area. Below the filter area, a grid of travel photos is displayed. One photo is selected, and a detailed view of that photo is shown below the grid. The detailed view includes the photo, a title, a description, and social media sharing options.

FIGURE 14.37 Completed Project 1

Introduction to Web Development

1

CHAPTER OBJECTIVES

In this chapter you will learn . . .

- About web development in general
- The history of the Internet and World Wide Web
- Fundamental concepts that form the foundation of the Internet
- About the hardware and software that support the Internet
- The range of careers and companies in web development

This chapter introduces the World Wide Web (WWW). It begins with an answer to the broad question, what is web development. It then progresses from that large question to a brief history of the Internet. It also provides an overview of key Internet technologies and ideas that make web development possible. To truly understand these concepts in depth, one would normally take courses in computer science or information technology (IT) covering networking principles. If you find some of these topics too in-depth or advanced, you may decide to skip over some of the details here and return to them later.

1.1 A Complicated Ecosystem

You may remember from your primary school science class that nature can be characterized as an ecosystem, a complex system of interrelationships between living and nonliving elements of the environment. As visualized in Figure 1.1, web development can also be understood as an ecosystem, one that builds on existing technologies (URL, DNS, and Internet), and contributes new protocols and standards (HTTP, HTML, and JavaScript) that facilitate client-server interactions. As this ecosystem matures, new client and server technologies, frameworks, and platforms continue to be developed in support of the web (PHP, Node, React etc.). The rich web development ecosystem has created entirely new areas of interest for both research and businesses including search engines, social networks, ecommerce, content management systems, and more.

Just as you don't need to know everything about worms, trees, birds, amphibians, and dirt to be a biologist, you don't necessarily need to understand every concept in Figure 1.1 in complete depth in order to be successful as a web developer. Nonetheless, it is important to see how this complicated network of concepts and technologies defines the scope of modern web development, and how concepts from each chapter fit into the bigger picture.

In Figure 1.1, web development is visualized as a series of related platforms. The two teal platforms represent the topics typically understood to constitute web development.

There are two distinct development platforms in the diagram which represents the fact that there are two distinct forms of development: front end and back end. The term **front end** refers to those technologies that run in the browser: in this diagram, they are HTML, CSS, JavaScript, and a wide-range of front-end oriented frameworks such as React; much of this book is focused on these technologies. The term **back end** refers to those technologies that run on the server. The book focuses on two of the most popular back-end development technologies—PHP and Node—and covers a variety of other back-end-related topics such as APIs, databases, and a variety of server-based development tools.

The platform at the top of the diagram contains a variety of topics that are typically dependent upon first having knowledge of the development technologies. These “advanced” topics are typically an important part of “real” web development; however, not all developers require expertise in all of these topics.

At the bottom of the diagram are two white platforms that represent the infrastructural topics of web development. These include the servers and networking topics that constitute the infrastructure of the web. To fully learn about the infrastructure of the web is beyond the scope of this book; nonetheless, it is important for any contemporary web developer to have some understanding of the basics of this infrastructure.



FIGURE 1.1 The web development ecosystem

Finally, the light-blue platform just below the back-end platform represents a variety of foundational topics that are important for anyone who works within the programming or the infrastructural side of the web. This includes the key protocols and standards of the web, such as HTTP and DNS, as well as the vital topic of security.

The textbook also covers the topics of these different platforms but focuses especially on the front-end and back-end development topics, since most entry-level web development positions require proficiency with these topics.

It is the perspective of the book, however, that web development is more than just markup and programming. In recent years, knowledge of the infrastructure upon which the web is built has become increasingly important for practicing web developers. For this reason, this chapter (and the next) journeys into the basement of foundational protocols, hardware infrastructure, and key terminology.

The last third of the book corresponds to some of the topics covered in the top platform. If you are taking a single course in web development, you might not have time to cover these more “advanced” topics. Yet, as far as real-world web development, they are just as important as the more recognizable ones on the explicitly development-focused platforms. We would encourage all of our readers to ascend to the upper-platform topics during their journey to become a web developer with this book. But before we go there, it is now time to begin with the foundational knowledge and learn more about web development in general.

1.2 Definitions and History

The World Wide Web (WWW or simply the web) is certainly what most people think of when they see the word “Internet.” But the web is only a subset of the Internet, as illustrated in Figure 1.2. While this book is focused on the web, part of this chapter is also devoted to a broad understanding of that larger circle labeled the “Internet.”

1.2.1 A Short History of the Internet

The history of telecommunication and data transport is a long one. There is a strategic advantage in being able to send a message as quickly as possible (or at least, more quickly than your competition). The Internet is not alone in providing instantaneous digital communication. Earlier technologies such as the radio, the telegraph, and the telephone provided the same speed of communication, albeit in an analog form.

Telephone networks in particular provide a good starting place to learn about modern digital communications. In the telephone networks of the past, calls were routed through operators who physically connected the caller and the receiver by connecting a wire to a switchboard to complete a circuit. These operators were around in some areas for almost a century before being replaced with automatic mechanical switches that did the same job: physically connect caller and receiver.

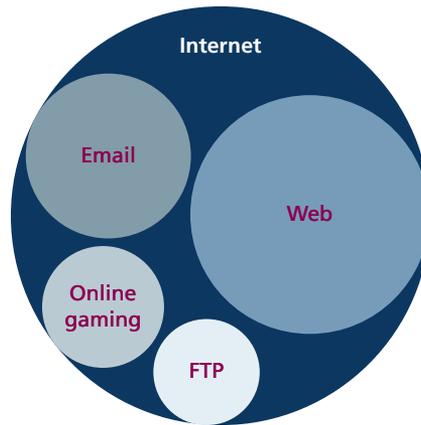


FIGURE 1.2 The web as a subset of the Internet

One of the weaknesses of having a physical connection is that you must establish a link and maintain a dedicated circuit for the duration of the call. This type of network connection is sometimes referred to as **circuit switching** and is shown in Figure 1.3.

The problem with circuit switching is that it can be difficult to have multiple conversations simultaneously (which a computer might want to do). It also requires more **bandwidth**, since even the silences are transmitted (that is, unused capacity in the network is not being used efficiently).

Bandwidth is a measurement of how much data can (maximally) be transmitted along a communication channel. Normally measured in bits per second (bps), this measurement differs according to the type of Internet access technology you are using. A dial-up 56-Kbps modem has far less bandwidth than a 10-Gbps fiber optic connection.

In the 1960s, as researchers explored digital communications and began to construct the first networks, the research network ARPANET was created. ARPANET did

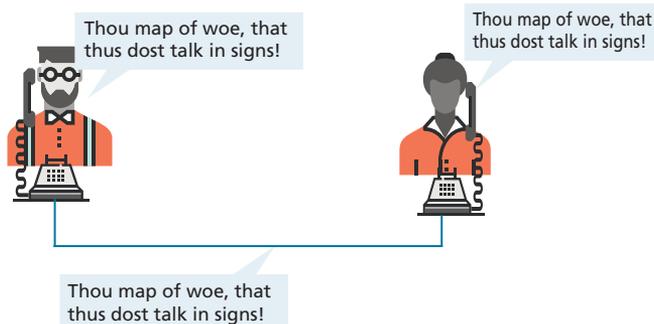


FIGURE 1.3 Telephone network as example of circuit switching

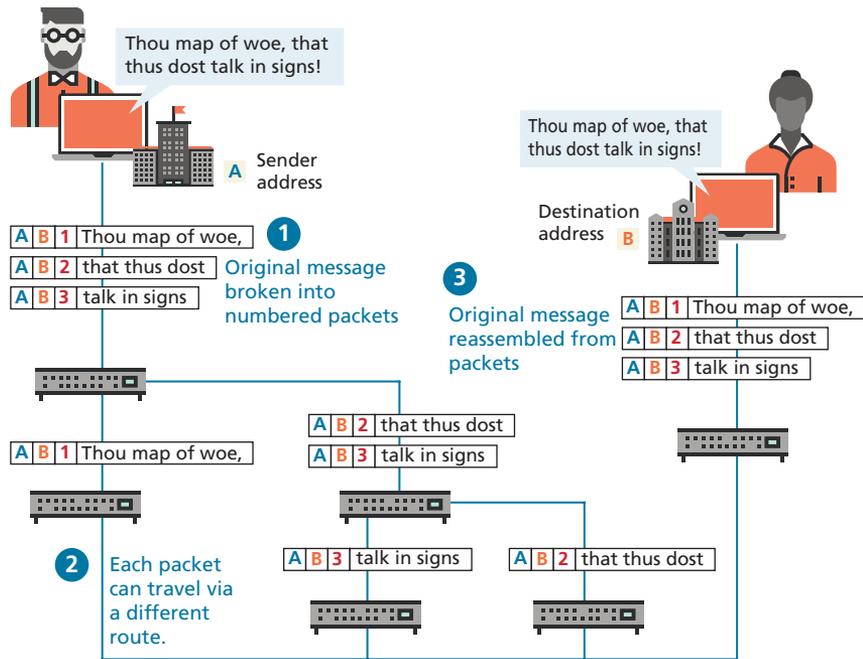


FIGURE 1.4 Internet network as example of packet switching

not use circuit switching but instead used an alternative communications method called **packet switching**. A packet-switched network does not require a continuous connection. Instead, it splits the messages into smaller chunks called **packets** and routes them to the appropriate place based on the destination address. The packets can take different routes to the destination, as shown in Figure 1.4. This may seem a more complicated and inefficient approach than circuit switching but is in fact more robust (it is not reliant on a single pathway that may fail) and a more efficient use of network resources (since a circuit can communicate data from multiple connections).

This early ARPANET network was funded and controlled by the United States government and was used exclusively for academic and scientific purposes. The early network started small, with just a handful of connected university campuses and research institutions and companies in 1969, and grew to a few hundred by the early 1980s.

At the same time, alternative networks were created like X.25 in 1974, which allowed (and encouraged) business use. USENET, built in 1979, had fewer restrictions still, and as a result grew quickly to 550 connected machines by 1981. Although there was growth in these various networks, the inability for them to communicate with each other was a real limitation. To promote the growth and unification of the disparate networks, a suite of **protocols** was invented to unify the networks. A protocol is the name given to a formal set of publicly available rules

that manage data exchange between two points. Communications protocols allow any two computers to talk to one another, so long as they implement the protocol.

By 1981, protocols for the Internet were published and ready for use.^{1,2} New networks built in the United States began to adopt the **TCP/IP (Transmission Control Protocol/Internet Protocol)** communication model (discussed in the next section), while older networks were transitioned over to it.

Any organization, private or public, could potentially connect to this new network so long as they adopted the TCP/IP protocol. On January 1, 1983, TCP/IP was adopted across all of ARPANET, marking the end of the research network that spawned the Internet.³ Over the next two decades, TCP/IP networking was adopted across the globe.

1.2.2 The Birth of the Web

The next decade saw an explosion in the number of users, but the Internet of the late 1980s and the very early 1990s did not resemble the Internet we know today. During these early years, email and text-based systems were the extent of the Internet experience.

This transition from the old terminal and text-only Internet of the 1980s to the Internet of today is due to the invention and massive growth of the web. This invention is usually attributed to the British Tim Berners-Lee (now Sir Tim Berners-Lee), who, along with the Belgian Robert Cailliau, published a proposal in 1990 for a hypertext system while both were working at CERN (European Organization for Nuclear Research) in Switzerland. Shortly thereafter Berners-Lee developed the main features of the web.⁴

This early web incorporated the following essential elements that are still the core features of the web today:

- A Uniform Resource Locator (URL) to uniquely identify a resource on the WWW.
- The Hypertext Transfer Protocol (HTTP) to describe how requests and responses operate.
- A software program (later called web server software) that can respond to HTTP requests.
- Hypertext Markup Language (HTML) to publish documents.
- A program (later called a browser) that can make HTTP requests to URLs and that can display the HTML it receives.

URLs and the HTTP are covered in this chapter. This chapter will also provide a little bit of insight into the nature of web server software; HTML will require several chapters to cover in this book. Chapter 17 will examine the inner workings of server software in more detail.

So while the essential outline of today's web was in place in the early 1990s, the web as we know it did not really begin until **Mosaic**, the first popular graphical

browser application, was developed at the National Center for Supercomputing Applications at the University of Illinois Urbana-Champaign and released in early 1993 by Eric Bina and Marc Andreessen (who was a computer science undergraduate student at the time). Andreessen later moved to California and cofounded Netscape Communications, which released **Netscape Navigator** in late 1994. Navigator quickly became the principal web browser, a position it held until the end of the 1990s, when Microsoft's Internet Explorer (first released in 1995) became the market leader, a position it would hold for over a decade.

Also in late 1994, Berners-Lee helped found the **World Wide Web Consortium (W3C)**, which would soon become the international standards organization that would oversee the growth of the web. This growth was very much facilitated by the decision of CERN to not patent the work and ideas done by its employee and instead leave the web protocols and code-base royalty free.



NOTE

The **Request for Comments (RFC)** archive lists all of the Internet and WWW protocols, concepts, and standards. It started out as an unofficial repository for ARPANET information and eventually became the de facto official record. Even today new standards are published there.

1.2.3 Web Applications in Comparison to Desktop Applications

The user experience for a website is unlike the user experience for traditional desktop software. The location of data storage, limitations with the user interface, and limited access to operating system features are just some of the distinctions. However, as web applications have become more and more sophisticated, the differences in the user experience between desktop applications and web applications are becoming more and more blurred.

There are a variety of advantages and disadvantages to web-based applications in comparison to desktop applications. Some of the advantages of web applications include the following:

- They can be accessed from any Internet-enabled computer.
- They can be used with different operating systems and browser applications.
- They are easier to roll out program updates since only software on the server needs to be updated as opposed to every computer in the organization using the software.
- They have a centralized storage on the server, which means fewer security concerns about local storage (which is important for sensitive information such as health care data).

Unfortunately, in the world of IT, for every advantage, there is often a corresponding disadvantage; this is also true of web applications. Some of these disadvantages include the following:

- Requirement to have an active Internet connection (the Internet is not always available everywhere at all times).
- Security concerns about sensitive private data being transmitted over the Internet.
- Concerns over the storage, licensing, and use of uploaded data.
- Problems with certain websites not having an identical appearance across all browsers.
- Restrictions on access to operating system resources can prevent additional software from being installed and hardware from being accessed (like Adobe Flash on iOS).
- In addition, clients or their IT staff may have additional plugins added to their browsers, which provide added control over their browsing experience, but which might interfere with JavaScript, cookies, or advertisements.

We will continually try to address these challenges throughout the book.

DIVE DEEPER

One of the more common terms you might encounter in web development is the term **“intranet”** (with an **“a”**), which refers to an internal network using Internet protocols that is local to an organization or business. Intranet resources are often private, meaning that only employees (or authorized external parties such as customers or suppliers) have access to those resources. Thus, **“Internet”** (with an **“e”**) is a broader term that encompasses both private (intranet) and public networked resources.

Intranets are typically protected from unauthorized external access via security features, such as firewalls or private IP ranges, as shown in Figure 1.5. Because intranets are private, search engines, such as Google, have limited or no access to content within them.

Due to this private nature, it is difficult to accurately gauge, for instance, how many web pages exist within intranets and what technologies are more common in them. Some especially expansive estimates guess that almost half of all web resources are hidden in private intranets.

Being aware of intranets is also important when one considers the job market and market usage of different web technologies. If one focuses just on the public Internet, it will appear that React, PHP, MySQL, and Node are the most commonly used web development stack. But when one adds in the private world of corporate intranets, other technologies such as ASP.NET, JSP, SharePoint, Oracle, SAP, and IBM WebSphere are just as important.

