

Contents

Preface

Part I The Java Language

Chapter 1 The History and Evolution of Java

Java's Lineage

The Birth of Modern Programming: C

C++: The Next Step

The Stage Is Set for Java

The Creation of Java

The C# Connection

How Java Impacted the Internet

Java Applets

Security

Portability

Java's Magic: The Bytecode

Moving Beyond Applets

A Faster Release Schedule

Servlets: Java on the Server Side

The Java Buzzwords

Simple

Object-Oriented

Robust

Multithreaded

Architecture-Neutral

Interpreted and High Performance

Distributed

Dynamic

The Evolution of Java

A Culture of Innovation

Chapter 2 An Overview of Java

Object-Oriented Programming

Two Paradigms

Abstraction

The Three OOP Principles

A First Simple Program

Entering the Program

Compiling the Program

A Closer Look at the First Sample Program

A Second Short Program

Two Control Statements

The if Statement

The for Loop

Using Blocks of Code

Lexical Issues

Whitespace

Identifiers

Literals

Comments

Separators

The Java Keywords

The Java Class Libraries

Chapter 3 Data Types, Variables, and Arrays

Java Is a Strongly Typed Language

The Primitive Types

Integers

byte

short

int

long

Floating-Point Types

float

double

Characters

Booleans

A Closer Look at Literals

Integer Literals

Floating-Point Literals

Boolean Literals

Character Literals

String Literals

Variables

Declaring a Variable

Dynamic Initialization

The Scope and Lifetime of Variables

Type Conversion and Casting

Java's Automatic Conversions

Casting Incompatible Types

Automatic Type Promotion in Expressions

The Type Promotion Rules

Arrays

One-Dimensional Arrays

Multidimensional Arrays

Alternative Array Declaration Syntax

Introducing Type Inference with Local Variables

Some var Restrictions

A Few Words About Strings

Chapter 4 Operators

Arithmetic Operators

The Basic Arithmetic Operators

The Modulus Operator

Arithmetic Compound Assignment Operators

Increment and Decrement

The Bitwise Operators

The Bitwise Logical Operators

The Left Shift

The Right Shift

The Unsigned Right Shift

Bitwise Operator Compound Assignments

Relational Operators

Boolean Logical Operators

Short-Circuit Logical Operators

The Assignment Operator

The ? Operator

Operator Precedence

Using Parentheses

Chapter 5 Control Statements

Java's Selection Statements

if

The Traditional switch

Iteration Statements

- while
- do-while
- for
- The For-Each Version of the for Loop
- Local Variable Type Inference in a for Loop
- Nested Loops
- Jump Statements
- Using break
- Using continue
- return

Chapter 6 Introducing Classes

- Class Fundamentals
 - The General Form of a Class
 - A Simple Class
- Declaring Objects
 - A Closer Look at new
- Assigning Object Reference Variables
- Introducing Methods
 - Adding a Method to the Box Class
 - Returning a Value
 - Adding a Method That Takes Parameters
- Constructors
 - Parameterized Constructors
- The this Keyword
 - Instance Variable Hiding
- Garbage Collection
- A Stack Class

Chapter 7 A Closer Look at Methods and Classes

- Overloading Methods
 - Overloading Constructors
- Using Objects as Parameters
- A Closer Look at Argument Passing
- Returning Objects
- Recursion
- Introducing Access Control
- Understanding static
- Introducing final
- Arrays Revisited
- Introducing Nested and Inner Classes
- Exploring the String Class
- Using Command-Line Arguments
- Varargs: Variable-Length Arguments
 - Overloading Vararg Methods
 - Varargs and Ambiguity
- Local Variable Type Inference with Reference Types

Chapter 8 Inheritance

- Inheritance Basics
 - Member Access and Inheritance
 - A More Practical Example
 - A Superclass Variable Can Reference a Subclass Object
- Using super
 - Using super to Call Superclass Constructors
 - A Second Use for super
- Creating a Multilevel Hierarchy
- When Constructors Are Executed
- Method Overriding
- Dynamic Method Dispatch
 - Why Overridden Methods?

- Applying Method Overriding
- Using Abstract Classes
- Using final with Inheritance
 - Using final to Prevent Overriding
 - Using final to Prevent Inheritance
- Local Variable Type Inference and Inheritance
- The Object Class

Chapter 9 Packages and Interfaces

- Packages
 - Defining a Package
 - Finding Packages and CLASSPATH
 - A Short Package Example
- Packages and Member Access
 - An Access Example
- Importing Packages
- Interfaces
 - Defining an Interface
 - Implementing Interfaces
 - Nested Interfaces
 - Applying Interfaces
 - Variables in Interfaces
 - Interfaces Can Be Extended
- Default Interface Methods
 - Default Method Fundamentals
 - A More Practical Example
- Multiple Inheritance Issues
- Use static Methods in an Interface
- Private Interface Methods
- Final Thoughts on Packages and Interfaces

Chapter 10 Exception Handling

- Exception-Handling Fundamentals
- Exception Types
- Uncaught Exceptions
- Using try and catch
 - Displaying a Description of an Exception
- Multiple catch Clauses
- Nested try Statements
- throw
- throws
- finally
- Java's Built-in Exceptions
- Creating Your Own Exception Subclasses
- Chained Exceptions
- Three Additional Exception Features
- Using Exceptions

Chapter 11 Multithreaded Programming

- The Java Thread Model
 - Thread Priorities
 - Synchronization
 - Messaging
 - The Thread Class and the Runnable Interface
- The Main Thread
- Creating a Thread
 - Implementing Runnable
 - Extending Thread
 - Choosing an Approach
- Creating Multiple Threads
- Using `isAlive()` and `join()`

- Thread Priorities
- Synchronization
 - Using Synchronized Methods
 - The synchronized Statement
- Interthread Communication
- Deadlock
- Suspending, Resuming, and Stopping Threads
- Obtaining a Thread's State
- Using a Factory Method to Create and Start a Thread
- Using Multithreading

Chapter 12 Enumerations, Autoboxing, and Annotations

- Enumerations
 - Enumeration Fundamentals
 - The values() and valueOf() Methods
 - Java Enumerations Are Class Types
 - Enumerations Inherit Enum
 - Another Enumeration Example
- Type Wrappers
 - Character
 - Boolean
 - The Numeric Type Wrappers
- Autoboxing
 - Autoboxing and Methods
 - Autoboxing/Unboxing Occurs in Expressions
 - Autoboxing/Unboxing Boolean and Character Values
 - Autoboxing/Unboxing Helps Prevent Errors
 - A Word of Warning
- Annotations
 - Annotation Basics
 - Specifying a Retention Policy
 - Obtaining Annotations at Run Time by Use of Reflection
 - The AnnotatedElement Interface
 - Using Default Values
 - Marker Annotations
 - Single-Member Annotations
 - The Built-In Annotations
- Type Annotations
- Repeating Annotations
- Some Restrictions

Chapter 13 I/O, Try-with-Resources, and Other Topics

- I/O Basics
 - Streams
 - Byte Streams and Character Streams
 - The Predefined Streams
- Reading Console Input
 - Reading Characters
 - Reading Strings
- Writing Console Output
 - The PrintWriter Class
- Reading and Writing Files
 - Automatically Closing a File
- The transient and volatile Modifiers
- Introducing instanceof
- strictfp
- Native Methods
- Using assert
 - Assertion Enabling and Disabling Options
- Static Import
- Invoking Overloaded Constructors Through this()

- Applying Method Overriding
- Using Abstract Classes
- Using final with Inheritance
 - Using final to Prevent Overriding
 - Using final to Prevent Inheritance
- Local Variable Type Inference and Inheritance
- The Object Class

Chapter 9 Packages and Interfaces

- Packages
 - Defining a Package
 - Finding Packages and CLASSPATH
 - A Short Package Example
- Packages and Member Access
 - An Access Example
- Importing Packages
- Interfaces
 - Defining an Interface
 - Implementing Interfaces
 - Nested Interfaces
 - Applying Interfaces
 - Variables in Interfaces
 - Interfaces Can Be Extended
- Default Interface Methods
 - Default Method Fundamentals
 - A More Practical Example
 - Multiple Inheritance Issues
- Use static Methods in an Interface
- Private Interface Methods
- Final Thoughts on Packages and Interfaces

Chapter 10 Exception Handling

- Exception-Handling Fundamentals
- Exception Types
- Uncaught Exceptions
- Using try and catch
 - Displaying a Description of an Exception
- Multiple catch Clauses
- Nested try Statements
- throw
- throws
- finally
- Java's Built-in Exceptions
- Creating Your Own Exception Subclasses
- Chained Exceptions
- Three Additional Exception Features
- Using Exceptions

Chapter 11 Multithreaded Programming

- The Java Thread Model
 - Thread Priorities
 - Synchronization
 - Messaging
 - The Thread Class and the Runnable Interface
- The Main Thread
- Creating a Thread
 - Implementing Runnable
 - Extending Thread
 - Choosing an Approach
- Creating Multiple Threads
- Using isAlive() and join()

- Thread Priorities
- Synchronization
 - Using Synchronized Methods
 - The synchronized Statement
- Interthread Communication
- Deadlock
- Suspending, Resuming, and Stopping Threads
- Obtaining a Thread's State
- Using a Factory Method to Create and Start a Thread
- Using Multithreading

Chapter 12 Enumerations, Autoboxing, and Annotations

- Enumerations
 - Enumeration Fundamentals
 - The values() and valueOf() Methods
 - Java Enumerations Are Class Types
 - Enumerations Inherit Enum
 - Another Enumeration Example
- Type Wrappers
 - Character
 - Boolean
 - The Numeric Type Wrappers
- Autoboxing
 - Autoboxing and Methods
 - Autoboxing/Unboxing Occurs in Expressions
 - Autoboxing/Unboxing Boolean and Character Values
 - Autoboxing/Unboxing Helps Prevent Errors
 - A Word of Warning
- Annotations
 - Annotation Basics
 - Specifying a Retention Policy
 - Obtaining Annotations at Run Time by Use of Reflection
 - The AnnotatedElement Interface
 - Using Default Values
 - Marker Annotations
 - Single-Member Annotations
 - The Built-In Annotations
- Type Annotations
- Repeating Annotations
- Some Restrictions

Chapter 13 I/O, Try-with-Resources, and Other Topics

- I/O Basics
 - Streams
 - Byte Streams and Character Streams
 - The Predefined Streams
- Reading Console Input
 - Reading Characters
 - Reading Strings
- Writing Console Output
 - The PrintWriter Class
- Reading and Writing Files
 - Automatically Closing a File
 - The transient and volatile Modifiers
- Introducing instanceof
- strictfp
- Native Methods
- Using assert
 - Assertion Enabling and Disabling Options
- Static Import
- Invoking Overloaded Constructors Through this()

A Word About Value-Based Classes

Chapter 14 Generics

What Are Generics?

A Simple Generics Example

- Generics Work Only with Reference Types

- Generic Types Differ Based on Their Type Arguments

- How Generics Improve Type Safety

A Generic Class with Two Type Parameters

The General Form of a Generic Class

Bounded Types

Using Wildcard Arguments

- Bounded Wildcards

Creating a Generic Method

- Generic Constructors

Generic Interfaces

Raw Types and Legacy Code

Generic Class Hierarchies

- Using a Generic Superclass

- A Generic Subclass

- Run-Time Type Comparisons Within a Generic Hierarchy

- Casting

- Overriding Methods in a Generic Class

Type Inference with Generics

Local Variable Type Inference and Generics

Erasure

- Bridge Methods

Ambiguity Errors

Some Generic Restrictions

- Type Parameters Can't Be Instantiated

- Restrictions on Static Members

- Generic Array Restrictions

- Generic Exception Restriction

Chapter 15 Lambda Expressions

Introducing Lambda Expressions

- Lambda Expression Fundamentals

- Functional Interfaces

- Some Lambda Expression Examples

Block Lambda Expressions

Generic Functional Interfaces

Passing Lambda Expressions as Arguments

Lambda Expressions and Exceptions

Lambda Expressions and Variable Capture

Method References

- Method References to static Methods

- Method References to Instance Methods

- Method References with Generics

Constructor References

Predefined Functional Interfaces

Chapter 16 Modules

Module Basics

- A Simple Module Example

- Compile and Run the First Module Example

- A Closer Look at requires and exports

java.base and the Platform Modules

Legacy Code and the Unnamed Module

Exporting to a Specific Module

Using requires transitive

Use Services

- Service and Service Provider Basics
- The Service-Based Keywords
- A Module-Based Service Example
- Module Graphs
- Three Specialized Module Features
 - Open Modules
 - The opens Statement
 - requires static
- Introducing jlink and Module JAR Files
 - Linking Files in an Exploded Directory
 - Linking Modular JAR Files
 - JMOD Files
- A Brief Word About Layers and Automatic Modules
- Final Thoughts on Modules

Chapter 17 Switch Expressions, Records, and Other Recently Added Features

- Enhancements to switch
 - Use a List of case Constants
 - Introducing the switch Expression and the yield Statement
 - Introducing the Arrow in a case Statement
 - A Closer Look at the Arrow case
 - Another switch Expression Example
- Text Blocks
 - Text Block Fundamentals
 - Understanding Leading Whitespace
 - Use Double Quotes in a Text Block
 - Escape Sequences in Text Blocks
- Records
 - Record Basics
 - Create Record Constructors
 - Another Record Constructor Example
 - Create Record Getter Methods
- Pattern Matching with instanceof
 - Pattern Variables in a Logical AND Expression
 - Pattern Matching in Other Statements
- Sealed Classes and Interfaces
 - Sealed Classes
 - Sealed Interfaces
- Future Directions

Part II The Java Library

Chapter 18 String Handling

- The String Constructors
- String Length
- Special String Operations
 - String Literals
 - String Concatenation
 - String Concatenation with Other Data Types
 - String Conversion and toString()
- Character Extraction
 - charAt()
 - getChars()
 - getBytes()
 - toCharArray()
- String Comparison
 - equals() and equalsIgnoreCase()
 - regionMatches()
 - startsWith() and endsWith()
 - equals() Versus ==
 - compareTo()

- Searching Strings
- Modifying a String
 - substring()
 - concat()
 - replace()
 - trim() and strip()
- Data Conversion Using valueOf()
- Changing the Case of Characters Within a String
- Joining Strings
- Additional String Methods
- StringBuffer
 - StringBuffer Constructors
 - length() and capacity()
 - ensureCapacity()
 - setLength()
 - charAt() and setCharAt()
 - getChars()
 - append()
 - insert()
 - reverse()
 - delete() and deleteCharAt()
 - replace()
 - substring()
 - Additional StringBuffer Methods
- StringBuilder

Chapter 19 Exploring java.lang

- Primitive Type Wrappers
 - Number
 - Double and Float
 - Understanding isInfinite() and isNaN()
 - Byte, Short, Integer, and Long
 - Character
 - Additions to Character for Unicode Code Point Support
 - Boolean
- Void
- Process
- Runtime
 - Executing Other Programs
- Runtime.Version
- ProcessBuilder
- System
 - Using currentTimeMillis() to Time Program Execution
 - Using arraycopy()
 - Environment Properties
- System.Logger and System.LoggerFinder
- Object
 - Using clone() and the Cloneable Interface
- Class
- ClassLoader
- Math
 - Trigonometric Functions
 - Exponential Functions
 - Rounding Functions
 - Miscellaneous Math Methods
- StrictMath
- Compiler
- Thread, ThreadGroup, and Runnable
 - The Runnable Interface
 - Thread
 - ThreadGroup

- ThreadLocal and InheritableThreadLocal
- Package
- Module
- ModuleLayer
- RuntimePermission
- Throwable
- SecurityManager
- StackTraceElement
- StackWalker and StackWalker.StackFrame
- Enum
- Record
- ClassValue
- The CharSequence Interface
- The Comparable Interface
- The Appendable Interface
- The Iterable Interface
- The Readable Interface
- The AutoCloseable Interface
- The Thread.UncaughtExceptionHandler Interface
- The java.lang Subpackages
 - java.lang.annotation
 - java.lang.constant
 - java.lang.instrument
 - java.lang.invoke
 - java.lang.management
 - java.lang.module
 - java.lang.ref
 - java.lang.reflect

Chapter 20 java.util Part 1: The Collections Framework

- Collections Overview
- The Collection Interfaces
 - The Collection Interface
 - The List Interface
 - The Set Interface
 - The SortedSet Interface
 - The NavigableSet Interface
 - The Queue Interface
 - The Deque Interface
- The Collection Classes
 - The ArrayList Class
 - The LinkedList Class
 - The HashSet Class
 - The LinkedHashSet Class
 - The TreeSet Class
 - The PriorityQueue Class
 - The ArrayDeque Class
 - The EnumSet Class
- Accessing a Collection via an Iterator
 - Using an Iterator
 - The For-Each Alternative to Iterators
- Spliterators
- Storing User-Defined Classes in Collections
- The RandomAccess Interface
- Working with Maps
 - The Map Interfaces
 - The Map Classes
- Comparators
 - Using a Comparator
- The Collection Algorithms
- Arrays

- The Legacy Classes and Interfaces
 - The Enumeration Interface
 - Vector
 - Stack
 - Dictionary
 - Hashtable
 - Properties
 - Using store() and load()

- Parting Thoughts on Collections

Chapter 21 java.util Part 2: More Utility Classes

- StringTokenizer
- BitSet
- Optional, OptionalDouble, OptionalInt, and OptionalLong
- Date
- Calendar
- GregorianCalendar
- TimeZone
- SimpleTimeZone
- Locale
- Random
- Timer and TimerTask
- Currency
- Formatter

- The Formatter Constructors
 - The Formatter Methods
 - Formatting Basics
 - Formatting Strings and Characters
 - Formatting Numbers
 - Formatting Time and Date
 - The %n and %% Specifiers
 - Specifying a Minimum Field Width
 - Specifying Precision
 - Using the Format Flags
 - Justifying Output
 - The Space, +, 0, and (Flags
 - The Comma Flag
 - The # Flag
 - The Uppercase Option
 - Using an Argument Index
 - Closing a Formatter
 - The Java printf() Connection

Scanner

- The Scanner Constructors
 - Scanning Basics
 - Some Scanner Examples
 - Setting Delimiters
 - Other Scanner Features

- The ResourceBundle, ListResourceBundle, and PropertyResourceBundle Classes

- Miscellaneous Utility Classes and Interfaces

- The java.util Subpackages

- java.util.concurrent, java.util.concurrent.atomic, and java.util.concurrent.locks
 - java.util.function
 - java.util.jar
 - java.util.logging
 - java.util.prefs
 - java.util.random
 - java.util.regex
 - java.util.spi
 - java.util.stream
 - java.util.zip

Chapter 22 Input/Output: Exploring java.io

The I/O Classes and Interfaces

File

Directories

Using FilenameFilter

The listFiles() Alternative

Creating Directories

The AutoCloseable, Closeable, and Flushable Interfaces

I/O Exceptions

Two Ways to Close a Stream

The Stream Classes

The Byte Streams

InputStream

OutputStream

FileInputStream

FileOutputStream

ByteArrayInputStream

ByteArrayOutputStream

Filtered Byte Streams

Buffered Byte Streams

SequenceInputStream

PrintStream

DataOutputStream and DataInputStream

RandomAccessFile

The Character Streams

Reader

Writer

FileReader

FileWriter

CharArrayReader

CharArrayWriter

BufferedReader

BufferedWriter

PushbackReader

PrintWriter

The Console Class

Serialization

Serializable

Externalizable

ObjectOutput

ObjectOutputStream

ObjectInput

ObjectInputStream

A Serialization Example

Stream Benefits

Chapter 23 Exploring NIO

The NIO Classes

NIO Fundamentals

Buffers

Channels

Charsets and Selectors

Enhancements Added by NIO.2

The Path Interface

The Files Class

The Paths Class

The File Attribute Interfaces

The Filesystem, FileSystems, and FileStore Classes

Using the NIO System

Use NIO for Channel-Based I/O

Use NIO for Stream-Based I/O

Chapter 24 Networking

Networking Basics

The java.net Networking Classes and Interfaces

InetAddress

Factory Methods

Instance Methods

InetSocketAddress and Inet6Address

TCP/IP Client Sockets

URL

URLConnection

HttpURLConnection

The URI Class

Cookies

TCP/IP Server Sockets

Datagrams

DatagramSocket

DatagramPacket

A Datagram Example

Introducing java.net.http

Three Key Elements

A Simple HTTP Client Example

Things to Explore in java.net.http

Chapter 25 Event Handling

Two Event Handling Mechanisms

The Delegation Event Model

Events

Event Sources

Event Listeners

Event Classes

The ActionEvent Class

The AdjustmentEvent Class

The ComponentEvent Class

The ContainerEvent Class

The FocusEvent Class

The InputEvent Class

The ItemEvent Class

The KeyEvent Class

The MouseEvent Class

The MouseWheelEvent Class

The TextEvent Class

The WindowEvent Class

Sources of Events

Event Listener Interfaces

The ActionListener Interface

The AdjustmentListener Interface

The ComponentListener Interface

The ContainerListener Interface

The FocusListener Interface

The ItemListener Interface

The KeyListener Interface

The MouseListener Interface

The MouseMotionListener Interface

The MouseWheelListener Interface

The TextListener Interface

The WindowFocusListener Interface

The WindowListener Interface

Using the Delegation Event Model

Some Key AWT GUI Concepts

- Handling Mouse Events
- Handling Keyboard Events
- Adapter Classes
- Inner Classes
- Anonymous Inner Classes

Chapter 26 Introducing the AWT: Working with Windows, Graphics, and Text

- AWT Classes
- Window Fundamentals
 - Component
 - Container
 - Panel
 - Window
 - Frame
 - Canvas

- Working with Frame Windows
 - Setting the Window's Dimensions
 - Hiding and Showing a Window
 - Setting a Window's Title
 - Closing a Frame Window
 - The `paint()` Method
 - Displaying a String
 - Setting the Foreground and Background Colors
 - Requesting Repainting
 - Creating a Frame-Based Application

- Introducing Graphics
 - Drawing Lines
 - Drawing Rectangles
 - Drawing Ellipses and Circles
 - Drawing Arcs
 - Drawing Polygons
 - Demonstrating the Drawing Methods
 - Sizing Graphics

- Working with Color
 - Color Methods
 - Setting the Current Graphics Color
 - A Color Demonstration Program

- Setting the Paint Mode

- Working with Fonts
 - Determining the Available Fonts
 - Creating and Selecting a Font
 - Obtaining Font Information
- Managing Text Output Using `FontMetrics`

Chapter 27 Using AWT Controls, Layout Managers, and Menus

- AWT Control Fundamentals
 - Adding and Removing Controls
 - Responding to Controls
 - The `HeadlessException`

- Labels

- Using Buttons

- Handling Buttons

- Applying Check Boxes

- Handling Check Boxes

- `CheckboxGroup`

- Choice Controls

- Handling Choice Lists

- Using Lists

- Handling Lists

- Managing Scroll Bars

- Handling Scroll Bars

- Using a TextField
 - Handling a TextField
- Using a TextArea
- Understanding Layout Managers
 - FlowLayout
 - BorderLayout
 - Using Insets
 - GridLayout
 - CardLayout
 - GridBagLayout
- Menu Bars and Menus
- Dialog Boxes
- A Word About Overriding paint()

Chapter 28 Images

- File Formats
- Image Fundamentals: Creating, Loading, and Displaying
 - Creating an Image Object
 - Loading an Image
 - Displaying an Image
- Double Buffering
- ImageProducer
 - MemoryImageSource
- ImageConsumer
 - PixelGrabber
- ImageFilter
 - CropImageFilter
 - RGBImageFilter
- Additional Imaging Classes

Chapter 29 The Concurrency Utilities

- The Concurrent API Packages
 - java.util.concurrent
 - java.util.concurrent.atomic
 - java.util.concurrent.locks
- Using Synchronization Objects
 - Semaphore
 - CountDownLatch
 - CyclicBarrier
 - Exchanger
 - Phaser
- Using an Executor
 - A Simple Executor Example
 - Using Callable and Future
- The TimeUnit Enumeration
- The Concurrent Collections
- Locks
- Atomic Operations
- Parallel Programming via the Fork/Join Framework
 - The Main Fork/Join Classes
 - The Divide-and-Conquer Strategy
 - A Simple First Fork/Join Example
 - Understanding the Impact of the Level of Parallelism
 - An Example that Uses RecursiveTask<V>
 - Executing a Task Asynchronously
 - Cancelling a Task
 - Determining a Task's Completion Status
 - Restarting a Task
 - Things to Explore
 - Some Fork/Join Tips
- The Concurrency Utilities Versus Java's Traditional Approach

Chapter 30 The Stream API

Stream Basics

Stream Interfaces

How to Obtain a Stream

A Simple Stream Example

Reduction Operations

Using Parallel Streams

Mapping

Collecting

Iterators and Streams

Use an Iterator with a Stream

Use Spliterator

More to Explore in the Stream API

Chapter 31 Regular Expressions and Other Packages

Regular Expression Processing

Pattern

Matcher

Regular Expression Syntax

Demonstrating Pattern Matching

Two Pattern-Matching Options

Exploring Regular Expressions

Reflection

Remote Method Invocation (RMI)

A Simple Client/Server Application Using RMI

Formatting Date and Time with java.text

DateFormat Class

SimpleDateFormat Class

The java.time Time and Date API

Time and Date Fundamentals

Formatting Date and Time

Parsing Date and Time Strings

Other Things to Explore in java.time

Part III Introducing GUI Programming with Swing

Chapter 32 Introducing Swing

The Origins of Swing

Swing Is Built on the AWT

Two Key Swing Features

Swing Components Are Lightweight

Swing Supports a Pluggable Look and Feel

The MVC Connection

Components and Containers

Components

Containers

The Top-Level Container Panes

The Swing Packages

A Simple Swing Application

Event Handling

Painting in Swing

Painting Fundamentals

Compute the Paintable Area

A Paint Example

Chapter 33 Exploring Swing

JLabel and ImageIcon

TextField

The Swing Buttons

JButton

JToggleButton

- Check Boxes
- Radio Buttons
- JTabbedPane
- JScrollPane
- JList
- JComboBox
- Trees
- JTable

Chapter 34 Introducing Swing Menus

- Menu Basics
 - An Overview of JMenuBar, JMenu, and JMenuItem
 - JMenuBar
 - JMenu
 - JMenuItem
 - Create a Main Menu
 - Add Mnemonics and Accelerators to Menu Items
 - Add Images and Tooltips to Menu Items
 - Use JRadioButtonMenuItem and JCheckBoxMenuItem
 - Create a Popup Menu
 - Create a Toolbar
 - Use Actions
 - Put the Entire MenuDemo Program Together
 - Continuing Your Exploration of Swing

Part IV Applying Java

Chapter 35 Java Beans

- What Is a Java Bean?
- Advantages of Beans
- Introspection
 - Design Patterns for Properties
 - Design Patterns for Events
 - Methods and Design Patterns
 - Using the BeanInfo Interface
- Bound and Constrained Properties
- Persistence
- Customizers
- The JavaBeans API
 - Introspector
 - PropertyDescriptor
 - EventSetDescriptor
 - MethodDescriptor
- A Bean Example

Chapter 36 Introducing Servlets

- Background
- The Life Cycle of a Servlet
- Servlet Development Options
- Using Tomcat
- A Simple Servlet
 - Create and Compile the Servlet Source Code
 - Start Tomcat
 - Start a Web Browser and Request the Servlet
- The Servlet API
- The jakarta.servlet Package
 - The Servlet Interface
 - The ServletConfig Interface
 - The ServletContext Interface
 - The ServletRequest Interface
 - The ServletResponse Interface
 - The GenericServlet Class

- The ServletInputStream Class
- The ServletOutputStream Class
- The Servlet Exception Classes
- Reading Servlet Parameters
- The jakarta.servlet.http Package
- The HttpServletResponse Interface
- The HttpSession Interface
- The Cookie Class
- The HttpServlet Class
- Handling HTTP Requests and Responses
- Handling HTTP GET Requests
- Handling HTTP POST Requests
- Using Cookies
- Session Tracking

Part V Appendixes

Appendix A Using Java's Documentation Comments

The javadoc Tags

- @author
- @code
- @deprecated
- @docRoot
- @exception
- @hidden
- @index
- @inheritDoc
- @link
- @linkplain
- @literal
- @param
- @provides
- @return
- @see
- @serial
- @serialData
- @serialField
- @since
- @summary
- @systemProperty
- @throws
- @uses
- @value
- @version

The General Form of a Documentation Comment

What javadoc Outputs

An Example that Uses Documentation Comments

Appendix B Introducing JShell

- JShell Basics
- List, Edit, and Rerun Code
- Add a Method
- Create a Class
- Use an Interface
- Evaluate Expressions and Use Built-in Variables
- Importing Packages
- Exceptions
- Some More JShell Commands
- Exploring JShell Further

Appendix C Compile and Run Simple Single-File Programs in One Step

Table of Contents

Preface.....	xii
1. Preliminaries.....	1
1.1 What Is This Book About?	1
What Kinds of Data?	1
1.2 Why Python for Data Analysis?	2
Python as Glue	2
Solving the “Two-Language” Problem	3
Why Not Python?	3
1.3 Essential Python Libraries	4
NumPy	4
pandas	4
matplotlib	5
IPython and Jupyter	6
SciPy	6
scikit-learn	7
statsmodels	8
1.4 Installation and Setup	8
Windows	9
Apple (OS X, macOS)	9
GNU/Linux	9
Installing or Updating Python Packages	10
Python 2 and Python 3	11
Integrated Development Environments (IDEs) and Text Editors	11
1.5 Community and Conferences	12
1.6 Navigating This Book	12
Code Examples	13
Data for Examples	13

Import Conventions	14
Jargon	14
2. Python Language Basics, IPython, and Jupyter Notebooks.....	15
2.1 The Python Interpreter	16
2.2 IPython Basics	17
Running the IPython Shell	17
Running the Jupyter Notebook	18
Tab Completion	21
Introspection	23
The %run Command	25
Executing Code from the Clipboard	26
Terminal Keyboard Shortcuts	27
About Magic Commands	28
Matplotlib Integration	29
2.3 Python Language Basics	30
Language Semantics	38
Scalar Types	46
Control Flow	
3. Built-in Data Structures, Functions, and Files.....	51
3.1 Data Structures and Sequences	51
Tuple	54
List	59
Built-in Sequence Functions	61
dict	65
set	67
List, Set, and Dict Comprehensions	69
3.2 Functions	70
Namespaces, Scope, and Local Functions	71
Returning Multiple Values	72
Functions Are Objects	73
Anonymous (Lambda) Functions	74
Currying: Partial Argument Application	75
Generators	77
Errors and Exception Handling	80
3.3 Files and the Operating System	83
Bytes and Unicode with Files	84
3.4 Conclusion	
4. NumPy Basics: Arrays and Vectorized Computation.....	85
4.1 The NumPy ndarray: A Multidimensional Array Object	87

Creating ndarrays	88
Data Types for ndarrays	90
Arithmetic with NumPy Arrays	93
Basic Indexing and Slicing	94
Boolean Indexing	99
Fancy Indexing	102
Transposing Arrays and Swapping Axes	103
4.2 Universal Functions: Fast Element-Wise Array Functions	105
4.3 Array-Oriented Programming with Arrays	108
Expressing Conditional Logic as Array Operations	109
Mathematical and Statistical Methods	111
Methods for Boolean Arrays	113
Sorting	113
Unique and Other Set Logic	114
4.4 File Input and Output with Arrays	115
4.5 Linear Algebra	116
4.6 Pseudorandom Number Generation	118
4.7 Example: Random Walks	119
Simulating Many Random Walks at Once	121
4.8 Conclusion	122
5. Getting Started with pandas.....	123
5.1 Introduction to pandas Data Structures	124
Series	124
DataFrame	128
Index Objects	134
5.2 Essential Functionality	136
Reindexing	136
Dropping Entries from an Axis	138
Indexing, Selection, and Filtering	140
Integer Indexes	145
Arithmetic and Data Alignment	146
Function Application and Mapping	151
Sorting and Ranking	153
Axis Indexes with Duplicate Labels	157
5.3 Summarizing and Computing Descriptive Statistics	158
Correlation and Covariance	160
Unique Values, Value Counts, and Membership	162
5.4 Conclusion	165
6. Data Loading, Storage, and File Formats.....	167
6.1 Reading and Writing Data in Text Format	167

Reading Text Files in Pieces	173
Writing Data to Text Format	175
Working with Delimited Formats	176
JSON Data	178
XML and HTML: Web Scraping	180
6.2 Binary Data Formats	183
Using HDFS Format	184
Reading Microsoft Excel Files	186
6.3 Interacting with Web APIs	187
6.4 Interacting with Databases	188
6.5 Conclusion	190
7. Data Cleaning and Preparation.	191
7.1 Handling Missing Data	191
Filtering Out Missing Data	193
Filling In Missing Data	195
7.2 Data Transformation	197
Removing Duplicates	198
Transforming Data Using a Function or Mapping	200
Replacing Values	201
Renaming Axis Indexes	203
Discretization and Binning	205
Detecting and Filtering Outliers	206
Permutation and Random Sampling	208
Computing Indicator/Dummy Variables	211
7.3 String Manipulation	211
String Object Methods	213
Regular Expressions	216
Vectorized String Functions in pandas	219
7.4 Conclusion	
8. Data Wrangling: Join, Combine, and Reshape.	221
8.1 Hierarchical Indexing	224
Reordering and Sorting Levels	225
Summary Statistics by Level	225
Indexing with a DataFrame's columns	227
8.2 Combining and Merging Datasets	227
Database-Style DataFrame Joins	232
Merging on Index	236
Concatenating Along an Axis	241
Combining Data with Overlap	242
8.3 Reshaping and Pivoting	

Reshaping with Hierarchical Indexing	243
Pivoting "Long" to "Wide" Format	246
Pivoting "Wide" to "Long" Format	249
8.4 Conclusion	251
9. Plotting and Visualization.....	253
9.1 A Brief matplotlib API Primer	253
Figures and Subplots	255
Colors, Markers, and Line Styles	259
Ticks, Labels, and Legends	261
Annotations and Drawing on a Subplot	265
Saving Plots to File	267
matplotlib Configuration	268
9.2 Plotting with pandas and seaborn	268
Line Plots	269
Bar Plots	272
Histograms and Density Plots	277
Scatter or Point Plots	280
Facet Grids and Categorical Data	283
9.3 Other Python Visualization Tools	285
9.4 Conclusion	286
10. Data Aggregation and Group Operations.....	287
10.1 GroupBy Mechanics	288
Iterating Over Groups	291
Selecting a Column or Subset of Columns	293
Grouping with Dicts and Series	294
Grouping with Functions	295
Grouping by Index Levels	295
10.2 Data Aggregation	296
Column-Wise and Multiple Function Application	298
Returning Aggregated Data Without Row Indexes	301
10.3 Apply: General split-apply-combine	302
Suppressing the Group Keys	304
Quantile and Bucket Analysis	305
Example: Filling Missing Values with Group-Specific Values	306
Example: Random Sampling and Permutation	308
Example: Group Weighted Average and Correlation	310
Example: Group-Wise Linear Regression	312
10.4 Pivot Tables and Cross-Tabulation	313
Cross-Tabulations: Crosstab	315
10.5 Conclusion	316

Reshaping with Hierarchical Indexing	243
Pivoting "Long" to "Wide" Format	246
Pivoting "Wide" to "Long" Format	249
8.4 Conclusion	251
9. Plotting and Visualization.....	253
9.1 A Brief matplotlib API Primer	253
Figures and Subplots	255
Colors, Markers, and Line Styles	259
Ticks, Labels, and Legends	261
Annotations and Drawing on a Subplot	265
Saving Plots to File	267
matplotlib Configuration	268
9.2 Plotting with pandas and seaborn	268
Line Plots	269
Bar Plots	272
Histograms and Density Plots	277
Scatter or Point Plots	280
Facet Grids and Categorical Data	283
9.3 Other Python Visualization Tools	285
9.4 Conclusion	286
10. Data Aggregation and Group Operations.....	287
10.1 GroupBy Mechanics	288
Iterating Over Groups	291
Selecting a Column or Subset of Columns	293
Grouping with Dicts and Series	294
Grouping with Functions	295
Grouping by Index Levels	295
10.2 Data Aggregation	296
Column-Wise and Multiple Function Application	298
Returning Aggregated Data Without Row Indexes	301
10.3 Apply: General split-apply-combine	302
Suppressing the Group Keys	304
Quantile and Bucket Analysis	305
Example: Filling Missing Values with Group-Specific Values	306
Example: Random Sampling and Permutation	308
Example: Group Weighted Average and Correlation	310
Example: Group-Wise Linear Regression	312
10.4 Pivot Tables and Cross-Tabulation	313
Cross-Tabulations: Crosstab	315
10.5 Conclusion	316

11. Time Series.....	311
11.1 Date and Time Data Types and Tools	311
Converting Between String and Datetime	311
11.2 Time Series Basics	321
Indexing, Selection, Subsetting	321
Time Series with Duplicate Indices	321
11.3 Date Ranges, Frequencies, and Shifting	324
Generating Date Ranges	327
Frequencies and Date Offsets	328
Shifting (Leading and Lagging) Data	330
11.4 Time Zone Handling	332
Time Zone Localization and Conversion	335
Operations with Time Zone-Aware Timestamp Objects	335
Operations Between Different Time Zones	338
11.5 Periods and Period Arithmetic	339
Period Frequency Conversion	340
Quarterly Period Frequencies	342
Converting Timestamps to Periods (and Back)	344
Creating a PeriodIndex from Arrays	345
11.6 Resampling and Frequency Conversion	348
Downsampling	349
Upsampling and Interpolation	352
Resampling with Periods	353
11.7 Moving Window Functions	354
Exponentially Weighted Functions	358
Binary Moving Window Functions	359
User-Defined Moving Window Functions	361
11.8 Conclusion	362
12. Advanced pandas.....	363
12.1 Categorical Data	363
Background and Motivation	363
Categorical Type in pandas	365
Computations with Categoricals	367
Categorical Methods	370
12.2 Advanced GroupBy Use	373
Group Transforms and “Unwrapped” GroupBys	373
Grouped Time Resampling	377
12.3 Techniques for Method Chaining	378
The pipe Method	380
12.4 Conclusion	381

13. Introduction to Modeling Libraries in Python.....	383
13.1 Interfacing Between pandas and Model Code	383
13.2 Creating Model Descriptions with Patsy	386
Data Transformations in Patsy Formulas	389
Categorical Data and Patsy	390
13.3 Introduction to statsmodels	393
Estimating Linear Models	393
Estimating Time Series Processes	396
13.4 Introduction to scikit-learn	397
13.5 Continuing Your Education	401
14. Data Analysis Examples.....	403
14.1 1.USA.gov Data from Bitly	403
Counting Time Zones in Pure Python	404
Counting Time Zones with pandas	406
14.2 MovieLens 1M Dataset	413
Measuring Rating Disagreement	418
14.3 US Baby Names 1880–2010	419
Analyzing Naming Trends	425
14.4 USDA Food Database	434
14.5 2012 Federal Election Commission Database	440
Donation Statistics by Occupation and Employer	442
Bucketing Donation Amounts	445
Donation Statistics by State	447
14.6 Conclusion	448
A. Advanced NumPy.....	449
A.1 ndarray Object Internals	449
NumPy dtype Hierarchy	450
A.2 Advanced Array Manipulation	451
Reshaping Arrays	452
C Versus Fortran Order	454
Concatenating and Splitting Arrays	454
Repeating Elements: tile and repeat	457
Fancy Indexing Equivalents: take and put	459
A.3 Broadcasting	460
Broadcasting Over Other Axes	462
Setting Array Values by Broadcasting	465
A.4 Advanced ufunc Usage	466
ufunc Instance Methods	466
Writing New ufuncs in Python	468
A.5 Structured and Record Arrays	469

Nested dtypes and Multidimensional Fields	469
Why Use Structured Arrays?	470
A.6 More About Sorting	471
Indirect Sorts: argsort and lexsort	472
Alternative Sort Algorithms	474
Partially Sorting Arrays	474
numpy.searchsorted: Finding Elements in a Sorted Array	475
A.7 Writing Fast NumPy Functions with Numba	476
Creating Custom numpy.ufunc Objects with Numba	478
A.8 Advanced Array Input and Output	478
Memory-Mapped Files	478
HDF5 and Other Array Storage Options	480
A.9 Performance Tips	480
The Importance of Contiguous Memory	480
B. More on the IPython System.....	483
B.1 Using the Command History	483
Searching and Reusing the Command History	483
Input and Output Variables	484
B.2 Interacting with the Operating System	485
Shell Commands and Aliases	486
Directory Bookmark System	487
B.3 Software Development Tools	487
Interactive Debugger	488
Timing Code: %time and %timeit	492
Basic Profiling: %prun and %run -p	494
Profiling a Function Line by Line	496
B.4 Tips for Productive Code Development Using IPython	498
Reloading Module Dependencies	498
Code Design Tips	499
B.5 Advanced IPython Features	500
Making Your Own Classes IPython-Friendly	500
Profiles and Configuration	501
B.6 Conclusion	503
Index.....	505

CONTENTS

INTRODUCTION

xxxi

CHAPTER 1: HELLO, ANDROID

1

Android Application Development

1

A Little Background

2

The Not-So-Distant Past

3

Living in the Future

3

The Android Ecosystem

3

Pre-installed Android Applications

4

Android SDK Features

5

What Does Android Run On?

6

Why Develop for Mobile?

6

Why Develop for Android?

7

Introducing the Development Framework

7

What Comes in the Box

8

Understanding the Android Software Stack

8

The Android Run Time

10

Android Application Architecture

11

Android Libraries

12

CHAPTER 2: GETTING STARTED

13

Getting Started Developing Android Apps

14

Developing for Android

15

What You Need to Begin

15

Creating Your First Android Application

20

Getting Started Writing Android Apps Using Kotlin

35

Using the Android Support Library Package

36

Developing for Mobile and Embedded Devices

39

Hardware-Imposed Design Considerations

39

Considering the User's Environment

43

Developing for Android

44

Android Development Tools

48

Android Studio

49

The Android Virtual Device Manager

51

The Android Emulator

51

Android Profiler	52
The Android Debug Bridge	54
APK Analyzer	54
The Lint Tool	55
Monkey, Monkey Runner, and Espresso UI Testing	55
Gradle	56
CHAPTER 3: APPLICATIONS AND ACTIVITIES AND FRAGMENTS, OH MY!	57
Applications, Activities, and Fragments	58
The Components of an Android Application	58
The Android Application Life Cycle, Priority, and Process States	59
Introducing the Android Application Class	61
A Closer Look at Android Activities	61
Creating Activities	62
Using the AppCompatActivity	63
The Activity Life Cycle	64
Responding to Memory Pressure	71
Introducing Fragments	73
Creating New Fragments	73
The Fragment Life Cycle	74
Introducing the Fragment Manager	79
Adding Fragments to Activities	79
Communicating Between Fragments and Activities	85
Fragments Without User Interfaces	86
Building an Earthquake Viewer Application	87
CHAPTER 4: DEFINING THE ANDROID MANIFEST AND GRADLE BUILD FILES, AND EXTERNALIZING RESOURCES	95
The Manifest, Build Files, and Resources	96
Introducing the Android Manifest	96
Configuring the Gradle Build	101
Gradle Settings File	101
Project Gradle Build File	102
Module Gradle Build Files	102
Externalizing Resources	107
Creating Resources	108
Using Resources	119
Creating Resources for Different Languages and Hardware	122
Runtime Configuration Changes	126

CHAPTER 5: BUILDING USER INTERFACES	129
Fundamental Android Design	130
Density-Independent Design	130
Android User Interface Fundamentals	131
Assigning User Interfaces to Activities	132
Introducing Layouts	132
Defining Layouts	134
Using Layouts to Create Device-Independent User Interfaces	136
Optimizing Layouts	139
The Android Widget Toolbox	143
Working with Lists and Grids	144
Recycler View and Layout Managers	145
Introducing Adapters	146
Returning to the Earthquake Viewer Application	149
Introducing Data Binding	150
Enabling Data Binding	151
Variables in Data Binding	152
Data Binding for the Earthquake Viewer Application	153
Creating New Views	155
Modifying Existing Views	155
Creating Compound Controls	159
Creating Simple Compound Controls as a Layout	161
Creating Custom Views	162
Using Custom Controls	176
CHAPTER 6: INTENTS AND BROADCAST RECEIVERS	177
Using Intents and Broadcast Receivers	178
Using Intents to Launch Activities	178
Explicitly Starting New Activities	179
Implicit Intents and Late Runtime Binding	179
Determining If an Intent Will Resolve	180
Returning Results from Activities	181
Using Platform-Native Actions to Launch Activities	184
Creating Intent Filters to Receive Implicit Intents	186
Defining an Intent Filter	186
Using Intent Filters for Plug-Ins and Extensibility	194
Introducing Linkify	198
Native Linkify Link Types	198
Creating Custom Link Strings	199

CONTENTS

Using the Match Filter	200
Using the Transform Filter	200
Using Intents to Broadcast Events	200
Broadcasting Events with Intents	201
Listening for Intent Broadcasts with Broadcast Receivers	202
Registering Broadcast Receivers in Code	203
Registering Broadcast Receivers in Your Application Manifest	204
Managing Manifest Receivers at Run Time	204
Monitoring Device State Changes Through Broadcast Intents	205
Introducing the Local Broadcast Manager	207
Introducing Pending Intents	208
CHAPTER 7: USING INTERNET RESOURCES	211
Connecting to the Internet	211
Connecting, Downloading, and Parsing Internet Resources	212
Why Build a Native Internet App?	212
Connecting to an Internet Resource	213
Performing Network Operations on Background Threads Using View Models, Live Data, and Asynchronous Tasks	214
Parsing XML Using the XML Pull Parser	219
Connecting the Earthquake Viewer to the Internet	220
Parsing JSON Using the JSON Parser	228
Using the Download Manager	233
Downloading Files	233
Customizing Download Manager Notifications	235
Specifying a Download Location	237
Canceling and Removing Downloads	238
Querying the Download Manager	238
Best Practices for Downloading Data Without Draining the Battery	241
An Introduction to Internet Services and Cloud Computing	242
CHAPTER 8: FILES, SAVING STATE, AND USER PREFERENCES	245
Saving Files, States, and Preferences	246
Saving and Restoring Activity and Fragment Instance State Using the Lifecycle Handlers	246
Retaining Instance State with Headless Fragments and View Models	248
View Models and Live Data	248
Headless Fragments	251
Creating and Saving Shared Preferences	252
Retrieving Shared Preferences	253

Introducing On Shared Preference Change Listeners	254
Configuring Auto Backup of Application Files and Shared Preferences	254
Building a Preference UI	256
Using the Preference Support Library	256
Defining a Preference Screen Layout in XML	257
Introducing the Preference Fragment	260
Creating a Settings Activity for the Earthquake Monitor	261
Including Static Files as Resources	267
Working with the Filesystem	267
File-Management Tools	267
Creating Files on Application-Specific Internal Storage	268
Creating Files on Application-Specific External Storage	268
Accessing Public Directories Using Scoped Directory Access	270
Sharing Files Using File Provider	274
Creating a File Provider	274
Sharing a File Using a File Provider	275
Receiving a File from a File Provider	275
Accessing Files from Other Applications Using the Storage Access Framework	275
Requesting Temporary Access to Files	276
Requesting Persistent Access to Files	277
Requesting Access to Directories	277
Creating New Files	278
Using URI-Based Permissions	278
CHAPTER 9: CREATING AND USING DATABASES	281
Introducing Structured Data Storage in Android	282
Storing Data Using the Room Persistence Library	282
Adding the Room Persistence Library	283
Defining a Room Database	284
Persisting Complex Objects Using Type Convertors	286
Defining Room Database Interactions Using Data Access Objects	288
Performing Room Database Interactions	291
Monitoring Query Result Changes with Live Data	292
Persisting Earthquakes to a Database with Room	294
Working with SQLite Databases	298
Input Validation and SQL Injection	299
Cursors and Content Values	299
Defining a Database Contract	300
Introducing the SQLiteOpenHelper	300

Opening Databases with the SQLite Open Helper	302
Opening and Creating Databases Without the SQLite Open Helper	303
Adding, Updating, and Deleting Rows	303
Querying a Database	305
Extracting Values from a Cursor	307
Introducing the Firebase Realtime Database	308
Adding Firebase to Your App	309
Defining a Firebase Database and Defining Access Rules	311
Adding, Modifying, Deleting, and Querying Data from a Firebase Realtime Database	313
CHAPTER 10: CONTENT PROVIDERS AND SEARCH	317
Introducing Content Providers	318
Why Should I Use Content Providers?	318
Creating Content Providers	319
Creating the Content Provider's Database	320
Registering Content Providers	321
Publishing Your Content Provider's URI Address	321
Implementing Content Provider Queries	322
Content Provider Transactions	325
Sharing Files Using a Content Provider	327
Adding Permission Requirements to Content Providers	328
Accessing Content Providers with Content Resolvers	330
Querying Content Providers	330
Cancelling Queries	333
Querying for Content Asynchronously with a Cursor Loader	333
Adding, Deleting, and Updating Content	336
Accessing Files Stored in Content Providers	338
Accessing Permission-Restricted Content Providers	339
Using Native Android Content Providers	341
Accessing the Call Log	341
Using the Media Store Content Provider	342
Using the Contacts Content Provider	344
Using the Calendar Content Provider	351
Adding Search to Your Application	354
Defining Your Search Metadata	354
Creating a Search Results Activity	355
Searching a Content Provider	357
Using the Search View Widget	360
Providing Search Suggestions Using a Content Provider	362
Searching the Earthquake Monitor Database	366

CHAPTER 11: WORKING IN THE BACKGROUND	377
Working in the Background	378
Using Background Threads	379
Using Asynchronous Tasks to Run Tasks Asynchronously	379
Manual Thread Creation Using Handler Threads	383
Scheduling Background Jobs	385
Creating a Job Service for the Job Scheduler	386
Scheduling Jobs with the Job Scheduler	388
Scheduling Jobs with the Firebase Job Dispatcher	391
Scheduling Work with the Work Manager	393
An Earthquake-Monitoring Job Service Example	396
Using Notifications to Notify Users	401
Introducing the Notification Manager	401
Working with Notification Channels	402
Creating Notifications	403
Setting a Notification's Priority	407
Adding Notification Actions	411
Adding Direct Reply Actions	412
Grouping Multiple Notifications	413
Adding Notifications to the Earthquake Monitor	414
Using Firebase Cloud Messaging	417
Triggering Notifications Remotely with Firebase Notifications	418
Receiving Data with Firebase Cloud Messaging	421
Using Alarms	422
Creating, Setting, and Canceling Alarms	423
Setting an Alarm Clock	424
Introducing Services	424
Using Bound Services	425
Creating a Started Service	427
CHAPTER 12: IMPLEMENTING THE ANDROID DESIGN PHILOSOPHY	433
Introducing the Android Design Philosophy	434
Designing for Every Screen	434
Resolution Independence	435
Supporting and Optimizing for Different Screen Sizes	436
Creating Scalable Graphics Assets	439
Introducing Material Design	445
Thinking in Terms of Paper and Ink	446
Using Color and Keylines as Guides	447
Continuity Through Motion	449

Material Design UI Elements	452
The App Bar	452
Applying Material Design to the Earthquake Monitor	455
Using Cards to Display Content	456
Floating Action Buttons	460
CHAPTER 13: IMPLEMENTING A MODERN ANDROID USER EXPERIENCE	463
The Modern Android UI	464
Creating Consistent, Modern User Interfaces Using AppCompatActivity	464
Creating and Applying Themes Using AppCompatActivity	465
Creating Theme Overlays for Specific Views	466
Adding a Menu and Actions to the App Bar	467
Defining a Menu Resource	467
Adding a Menu to an Activity	468
Adding a Menu to a Fragment	469
Updating Menu Items Dynamically	469
Handling Menu Selections	470
Adding Action Views and Action Providers	470
Going Beyond the Default App Bar	472
Replacing Your App Bar with a Toolbar	472
Advanced Scrolling Techniques for the Toolbar	473
Incorporating Menus Without the App Bar	476
Improving the Earthquake Monitor's App Bar	477
App Navigation Patterns	479
Navigating with Tabs	479
Implementing a Bottom Navigation Bar	482
Using a Navigation Drawer	485
Combining Navigation Patterns	491
Adding Tabs to the Earthquake Monitor	492
Choosing the Right Level of Interruption	496
Initiating a Dialog	497
Let's Make a Toast	498
Inline Interruptions with Snackbars	499
CHAPTER 14: ADVANCED CUSTOMIZATION OF YOUR USER INTERFACE	501
Expanding the User Experience	502
Supporting Accessibility	502

Supporting Navigation Without a Touch Screen	502
Providing a Textual Description of Each View	503
Introducing Android Text-to-Speech	503
Using Speech Recognition	505
Using Speech Recognition for Voice Input	506
Using Speech Recognition for Search	507
Controlling Device Vibration	508
Going Full Screen	508
Working with Property Animations	510
Enhancing Your Views	513
Advanced Canvas Drawing	514
Creating Interactive Controls	530
Composite Drawable Resources	536
Transformative Drawables	536
Layer Drawables	537
State List Drawables	537
Level List Drawables	538
Copy, Paste, and the Clipboard	539
Copying Data to the Clipboard	539
Pasting Clipboard Data	539

CHAPTER 15: LOCATION, CONTEXTUAL AWARENESS, AND MAPPING 541

Adding Location, Maps, and Contextual Awareness to Your Applications	542
Introducing Google Play Services	542
Adding Google Play Services to Your Application	543
Determining the Availability of Google Play Services	545
Finding Device Location Using Google Location Services	546
Using the Emulator to Test Location-Based Functionality	548
Finding the Last Known Location	549
"Where Am I" Example	551
Requesting Location Change Updates	555
Changing Device Location Settings	560
Updating the Location in the "Where Am I" Example	563
Best Practices When Using Location	566
Setting and Managing Geofences	567
Using the Legacy Platform Location-Based Services	571
Selecting a Location Provider	572
Finding the Last Known Location	574

Requesting Location Change Updates	575
Best Practice for Using the Legacy Location-Based Services	577
Using the Geocoder	580
Reverse Geocoding	581
Forward Geocoding	582
Geocoding Where Am I	583
Creating Map-Based Activities	585
Getting Your Maps API Key	586
Creating a Map-Based Activity	586
Configuring Google Maps	589
Changing the Camera Position with Camera Updates	590
Mapping Where Am I	592
Displaying the Current Location with the My Location Layer	596
Displaying Interactive Map Markers	596
Adding Shapes to Google Maps	599
Adding Image Overlays to Google Maps	602
Adding Markers and Shapes to Where Am I	602
Mapping the Earthquake Example	605
Adding Contextual Awareness	609
Connecting to the Google Play Services API Client and Obtaining API Keys	610
Using Awareness Snapshots	612
Setting and Monitoring Awareness Fences	613
Awareness Best Practices	617
CHAPTER 16: HARDWARE SENSORS	619
Introducing Android Sensors	620
Using the Sensor Manager	620
Understanding the Android Sensors	621
Discovering and Identifying Sensors	623
Determining Sensor Capabilities	625
Wakeup and Non-Wakeup Sensors	627
Monitoring Sensor Results	627
Interpreting Sensor Values	632
Testing Sensors with the Android Virtual Device and Emulator	635
Best Practices for Working with Sensors	637
Monitoring a Device's Movement and Orientation	637
Determining the Natural Orientation of a Device	638
Introducing Accelerometers	639
Detecting Acceleration Changes	640
Creating a Gravitational Force Meter	642
Determining a Device's Orientation	645
Creating a Compass and Artificial Horizon	650

Using the Environmental Sensors	654
Using the Barometer Sensor	654
Creating a Weather Station	655
Using Body Sensors	659
User Activity Recognition	662
CHAPTER 17: AUDIO, VIDEO, AND USING THE CAMERA	665
Playing Audio and Video, and Using the Camera	666
Playing Audio and Video	666
Introducing the Media Player	667
Using Media Player for Video Playback	669
Using ExoPlayer for Video Playback	672
Requesting and Managing Audio Focus	674
Pausing Playback When the Output Changes	676
Responding to the Volume Controls	677
Working with a Media Session	678
Using the Media Router and Cast Application Framework	682
Background Audio Playback	686
Building an Audio Playback Service	686
Using a Media Browser to Connect Your Activity to a Media Browser Service	688
Life Cycle of a Media Browser Service	690
Playing Audio as a Foreground Service	691
Creating Media Style Notifications	693
Using the Media Recorder to Record Audio	695
Using the Camera for Taking Pictures	697
Using Intents to Take Pictures	697
Controlling the Camera Directly	699
Reading and Writing JPEG EXIF Image Details	706
Recording Video	706
Using Intents to Record Video	707
Using the Media Recorder to Record Video	707
Adding Media to the Media Store	710
Inserting Media Using the Media Scanner	710
Inserting Media Manually	711
CHAPTER 18: COMMUNICATING WITH BLUETOOTH, NFC, AND WI-FI PEER-TO-PEER	713
Networking and Peer-to-Peer Communication	713
Transferring Data Using Bluetooth	714
Managing the Local Bluetooth Device Adapter	714
Being Discoverable and Remote Device Discovery	716

Bluetooth Communications	720
Bluetooth Profiles	725
Bluetooth Low Energy	726
Transferring Data Using Wi-Fi Peer-to-Peer	728
Initializing the Wi-Fi Peer-to-Peer Framework	729
Discovering Peers	731
Connecting with Peers	732
Transferring Data Between Peers	733
Using Near Field Communication	735
Reading NFC Tags	735
Using the Foreground Dispatch System	736
Using Android Beam	738
Creating Android Beam Messages	739
Assigning the Android Beam Payload	740
Receiving Android Beam Messages	742
CHAPTER 19: INVADING THE HOME SCREEN	743
Customizing the Home Screen	743
Introducing Home Screen Widgets	744
Defining the Widget Layout	745
Defining Your Widget Size and Other Metadata	746
Implementing Your Widget	748
Updating the Widget UI Using the App Widget Manager and Remote Views	749
Forcing Refreshes of Your Widget Data and UI	753
Creating and Using a Widget Configuration Activity	756
Creating an Earthquake Widget	757
Introducing Collection View Widgets	763
Creating Collection View Widget Layouts	764
Updating Collection View Items with a Remote Views Factory	765
Updating Collection View Items with a Remote Views Service	767
Populating Collection View Widgets Using a Remote Views Service	768
Adding Interactivity to the Items Within a Collection View Widget	769
Refreshing Your Collection View Widgets	770
Creating an Earthquake Collection View Widget	770
Creating Live Wallpaper	777
Creating a Live Wallpaper Definition Resource	778
Creating a Wallpaper Service Engine	778
Creating a Wallpaper Service	780

Creating App Shortcuts	781
Static Shortcuts	783
Dynamic Shortcuts	784
Tracking App Shortcut Use	785

CHAPTER 20: ADVANCED ANDROID DEVELOPMENT	787
---	------------

Advanced Android	788
Paranoid Android	788
Linux Kernel Security	788
Re-introducing Permissions	789
Storing Keys in the Android Keystore	792
Using the Fingerprint Sensor	792
Dealing with Different Hardware and Software Availability	793
Specifying Required Hardware	794
Confirming Hardware Availability	795
Building Backward-Compatible Applications	795
Optimizing UI Performance with Strict Mode	797
Telephony and SMS	798
Telephony	799
Sending and Receiving SMS Messages	806

CHAPTER 21: RELEASING, DISTRIBUTING, AND MONITORING APPLICATIONS	825
---	------------

Preparing for Release	826
Preparing Release Support Material	826
Preparing Your Code for a Release Build	827
Updating Application Metadata in Your Application Manifest	828
Reviewing Application Installation Restrictions	828
Application Versioning	830
Signing Production Builds of Your Application	830
Creating a Keystore and Signing Key with Android Studio	832
Obtaining API Keys Based on Your Private Release Key	833
Building and Signing a Production Release	834
Distributing Your Application on the Google Play Store	835
Introducing the Google Play Store	835
Getting Started with the Google Play Store	836
Creating an Application on the Google Play Store	837
Publishing Your Application	845
Monitoring Your Application in Production	848

Creating App Shortcuts	781
Static Shortcuts	783
Dynamic Shortcuts	784
Tracking App Shortcut Use	785
CHAPTER 20: ADVANCED ANDROID DEVELOPMENT	787
Advanced Android	788
Paranoid Android	788
Linux Kernel Security	788
Re-introducing Permissions	789
Storing Keys in the Android Keystore	792
Using the Fingerprint Sensor	792
Dealing with Different Hardware and Software Availability	793
Specifying Required Hardware	794
Confirming Hardware Availability	795
Building Backward-Compatible Applications	795
Optimizing UI Performance with Strict Mode	797
Telephony and SMS	798
Telephony	799
Sending and Receiving SMS Messages	806
CHAPTER 21: RELEASING, DISTRIBUTING, AND MONITORING APPLICATIONS	825
Preparing for Release	826
Preparing Release Support Material	826
Preparing Your Code for a Release Build	827
Updating Application Metadata in Your Application Manifest	828
Reviewing Application Installation Restrictions	828
Application Versioning	830
Signing Production Builds of Your Application	830
Creating a Keystore and Signing Key with Android Studio	832
Obtaining API Keys Based on Your Private Release Key	833
Building and Signing a Production Release	834
Distributing Your Application on the Google Play Store	835
Introducing the Google Play Store	835
Getting Started with the Google Play Store	836
Creating an Application on the Google Play Store	837
Publishing Your Application	845
Monitoring Your Application in Production	848

CONTENTS

An Introduction to Monetizing Applications	853
Application Marketing, Promotion, and Distribution Strategies	854
Application Launch Strategies	854
Internationalization	855
Using Firebase to Monitor Your Application	856
Adding Firebase to Your Application	856
Using Firebase Analytics	857
Firebase Performance Monitoring	860
 INDEX	 863

Contents

About the Author

Preface

1 Information Systems and People

Learning Objectives

Introduction

Information Systems in Action

Managing Operations

Supporting Customer Interactions

Making Decisions

Collaborating on Teams

Gaining Competitive Advantage

Improving Individual Productivity

The Nature of Information

Data, Information, and Knowledge

What Makes Information Valuable?

The Components of an Information System

People

Technology

Processes

Data

Information Systems, the Discipline

Information Systems Throughout the Organization

Information Systems in Business

Information Systems in Nonprofits and Government

Inside the IT Department

Collaborating on Information Systems

Improving Your Own Productivity

Promises, Perils, and Ethical Issues

THE ETHICAL FACTOR: *Ethical Issues Surrounding Information Systems*

INTERACTIVE SIMULATION: THE WORLD OF MAMMALS A Role-Playing

Simulation on Choosing a New CIO for an Animal Preserve

Chapter 1 Summary

Key Terms and Concepts

Chapter Review Questions

Projects and Discussion Questions

Application Exercises

Excel: Staff Planning Spreadsheet

Access: Information Systems in Business

Case Studies

1. Trading at the Speed of Light: Nasdaq's Information Challenges

2. Breaking News: Twitter's Growing Role in Emergencies and Disaster Communications

E-Projects

1. Analyzing the May 6 "Flash Crash" with Excel Charts

2. Gathering, Visualizing, and Evaluating Reports from Twitter and Other Sources During a Disaster

Endnotes

vii

xix

2 Information Systems and Strategy

Learning Objectives

1 Introduction

1 Porter's Five Competitive Forces

1 Threat of New Entrants

2 Power of Buyers

2 Power of Suppliers

4 Threat of Substitutes

4 Rivalry among Existing Competitors

5 Factors That Affect How the Five Forces Operate

6 Disruptive Technology and Innovations

6 Government Policies and Actions

7 Complementary Services and Products in the

Ecosystem

8 Environmental Events and "Wildcards"

9 The Value Chain and Strategic Thinking

9 Extending the Value Chain: from Suppliers to the

Firm to Customers

9 Benchmarking Components of the Value Chain

10 IT Benchmarks

12 Competitive Strategies in Business

13 The Role of Information Systems in Strategy

15 Information Systems: Run, Grow, and Transform the

Business

16 Information Strategies and Nonprofit Organizations

17 Fund-Raising

17 Volunteering

19 Information Strategies and Government

19 INCREASING ACCESS AND ENHANCING SERVICES TO

THE PUBLIC 49 • FUNDING RESEARCH FOR TECHNOLOGICAL

INNOVATION 50

21 Does IT Matter?

Spending on Running, Growing, and Transforming

Leveling UP!: A Strategic Analysis

THE ETHICAL FACTOR: *Ethical Responsibility in an Extended*

Value Chain

INTERACTIVE SIMULATION: LEVELING UP! A Role-Playing Simulation

on Business Strategy for a New Smartphone App

Chapter 2 Summary

Key Terms and Concepts

Chapter Review Questions

Projects and Discussion Questions

Application Exercises

Excel: IT Benchmarks

Access: Telethon Call Reports

Case Studies

1. Can GameStop Survive with Its Brick-and-Mortar Stores?

2. The Battle over Net Neutrality

30

30

31

32

33

34

34

35

36

36

38

39

39

40

40

42

42

44

45

46

48

48

48

49

49

49

49

49

49

49

49

50

51

51

42

52

52

53

53

54

55

55

56

57

56

57

56

57

xi

E-Projects	
1. Identifying Company Strategy with Online Financial Chart Tools	58
2. Analyzing Media Download Times with Excel	58
Endnotes	58

3 Information and Communications Technologies: The Enterprise Architecture

Learning Objectives	
Introduction	
The Hardware	
Input and Output	
HUMAN INPUT 61 • SCANNERS AND SENSORS 63 • OUTPUT DEVICES 64	
Processing	
Storage	
PRIMARY STORAGE 66 • SECONDARY STORAGE 66	
The Software	
Types of Software	
How Is Software Created?	
PROGRAMMING LANGUAGES AND DEVELOPMENT ENVIRONMENTS 69 • SOFTWARE DEVELOPMENT AND DEPLOYMENT STRATEGIES 70 • OPEN SOURCE SOFTWARE 70	
Networks and Telecommunications	
Transmission Media and Protocols	
WIRED MEDIA 71 • WIRELESS MEDIA 72	
Networking Basics	
PACKET SWITCHING 73 • CLIENT-SERVER AND PEER-TO-PEER NETWORKS 74	
Network Protocols	
ETHERNET 75 • TCP/IP AND THE INTERNET'S HOURGLASS ARCHITECTURE 76 • WIRELESS PROTOCOLS 76	
Strategy and Competition in Telecommunications	
THE WIRELESS SPECTRUM AS OCEANFRONT PROPERTY 77 • THE LAST MILE 77 • CORD CUTTING 77	
The Enterprise Architecture	
Trends in Enterprise Architectures	
FROM MAINFRAMES TO MICROCOMPUTERS 78 • CLIENT SERVER ARCHITECTURES 78 • THIN CLIENTS 79 • VIRTUALIZATION 79 • INTEGRATION OF VOICE AND DATA 80 • CLOUD COMPUTING 80	
Guiding the Enterprise Architecture	
THE ETHICAL FACTOR: Ethical Implications of Big Data	
INTERACTIVE SIMULATION: RIVERSIDE LODGE A Role-Playing Simulation on Enterprise Architecture for a River Resort	
Chapter 3 Summary	84
Key Terms and Concepts	85
Chapter Review Questions	85
Projects and Discussion Questions	86
Application Exercises	
Excel: Analyzing Growth in Computer Storage Capacities	87
Access: Managing ICT Assets with a Database	87
Case Studies	
1. Dropbox and the Personal Cloud	87
2. The Race to 5G	88

E-Projects

1. Voluntary Distributed Computing	89
2. Analyzing Costs for Software as a Service (SaaS)	90
Endnotes	90

4 Databases and Data Warehouses

Learning Objectives	
Introduction	
The Nature of Information Resources	
Structured, Unstructured, and Semistructured Information	
Metadata	
THE QUALITY OF INFORMATION 94	
Managing Information: from Filing Cabinets to the Database	
Tables, Records, and Fields	
The Rise and Fall of File Processing Systems	
DATA REDUNDANCY AND INCONSISTENCY 97 • LACK OF DATA INTEGRATION 98 • INCONSISTENT DATA DEFINITIONS 98 • DATA DEPENDENCE 99	
Databases and Database Management Systems	
DATABASE ARCHITECTURE 99	
• THE RELATIONAL DATABASE 100	
Developing and Managing a Relational Database	
Planning the Data Model	
ENTITIES AND ATTRIBUTES 101 • PRIMARY KEYS AND UNIQUENESS 101 • NORMALIZING THE DATA MODEL 102 • RELATIONSHIPS AND FOREIGN KEYS 103 • HANDLING COMPLEX RELATIONSHIPS 104	
Accessing the Database and Retrieving Information	
SQL: STRUCTURED QUERY LANGUAGE 106 • OTHER ACCESS AND RETRIEVAL TOOLS 107 • NATURAL LANGUAGE INTERFACES 107	
Managing and Maintaining the Database	
PERFORMANCE TUNING AND SCALABILITY 108 • INTEGRITY, SECURITY, AND RECOVERY 109 • DOCUMENTATION 109	
Data Warehouses and Big Data	
Integrating Information with a Data Warehouse	
SOURCES OF DATA FOR THE DATA WAREHOUSE 110 • BUILDING THE DATA WAREHOUSE 111	
The Challenge of Big Data	
WHAT IS BIG DATA? 112 • BIG DATA TECHNOLOGIES 113	
Distributed Databases and Blockchain	
Distributed Database Architectures	
Blockchain	
The Challenges of Information Management:	
The Human Element	
Ownership Issues	
Shadow Systems	
Master Data Management	
Databases without Boundaries	
Balancing Stakeholders' Information Needs	
THE ETHICAL FACTOR: Ethical Issues in Database Design: The Case of Race and Ethnicity	
INTERACTIVE SIMULATION: VOLUNTEER NOW! A Role-Playing Simulation on Designing the Database for a Volunteer-Matching Service	

Chapter 4 Summary	117
Key Terms and Concepts	118
Chapter Review Questions	119
Projects and Discussion Questions	119
Application Exercises	
Excel: Managing Catering Supplies	120
Access: GO-Designs	121
Case Studies	
1. UK Police Track Suspicious Vehicles in Real Time with Cameras and the License Plate Database	122
2. Walmart Deploys Blockchain for Food Safety	122
E-Projects	
1. Identifying Suspects with a License Plate Database: Constructing Queries with Access	124
2. Building a Database for Customer Records	124
Endnotes	125

5 Information Systems for the Enterprise

Learning Objectives	127
Introduction	127
Finance Management	128
Components of Financial Information Systems	128
INTEGRATING THE COMPONENTS 128 • FINANCIAL WORKFLOWS 129	
Financial Reporting, Compliance, and Transparency	130
EXCEPTION REPORTING 131 • COMPLIANCE REPORTING 131 • XBRL 131 • IMPROVING TRANSPARENCY 131	
Human Capital Management	132
Components of Human Capital Management Systems	132
HUMAN RESOURCES MANAGEMENT 132 • WORKFORCE MANAGEMENT 132 • TALENT MANAGEMENT 132 • SOCIAL NETWORKING AND HCM 132	
HCM Metrics	133
Managing the Supply Chain	134
Supply Chain Fundamentals	134
THE PLANNING STEP 134 • CHOOSING SOURCES 135 • MAKE/DELIVER/RETURN 135	
Measuring Performance in Supply Chains	136
SUPPLY CHAIN VISIBILITY 136 • SUPPLY CHAIN METRICS 136 • REDUCING SUPPLY CHAIN COSTS 137 • SUPPLY CHAIN DISRUPTIONS 137	
Information Systems and Technology for Supply Chain Management	138
SUPPLY CHAIN COLLABORATION: ELECTRONIC DATA INTERCHANGE AND BLOCKCHAIN 138 • SUPPLY CHAIN AND THE INTERNET OF THINGS 139	
Customer Relationship Management	141
CRM Goals and Metrics	142
IMPROVING CUSTOMER RETENTION 142 • IMPROVING PROFITABILITY 142 • GROWING REVENUE 142 • LISTENING TO CUSTOMERS 143	
CRM Strategies and Technologies	143
MARKETING 144 • SALES FORCE AUTOMATION 145 • CUSTOMER SERVICE AND SUPPORT 145 • MOBILE CRM 146	

Enterprise Resource Planning (ERP): Bringing It All Together	147
ERP Components	147
STUDENT'S VIEW OF THE ERP 147 • THE FACULTY'S VIEW OF THE ERP 148	
ERP Integration Strategies	149
MAKING CONNECTIONS WITH MIDDLEWARE 150 • PROS AND CONS OF DIFFERENT INTEGRATION STRATEGIES 150	
Implementation Issues	150
ERP AND SOFTWARE AS A SERVICE (SaaS) 151 • ERP PROS AND CONS 151	
THE ETHICAL FACTOR: Ethics and Talent Management	152
INTERACTIVE SIMULATION: CUSTOM CAKES: A Role-Playing Simulation on Enterprise Information Systems and the Supply Chain	152
Chapter 5 Summary	152
Key Terms and Concepts	153
Chapter Review Questions	153
Projects and Discussion Questions	154
Application Exercises	
Excel: Performance Bicycle Parts	154
Access: VSI Consultants	155
Case Studies	
1. Salesforce.com: Taking CRM to the Cloud	156
2. Meeting Demands of Global Growth, Netflix Migrates to Integrated ERP	157
E-Projects	
1. CRM for Human Services Agencies	158
2. Evaluating Employment and Recruitment Websites	159
Endnotes	159

6 Developing a Digital Presence: Websites, Social Media, and Mobile Apps

Learning Objectives	161
Introduction	161
Developing a Digital Strategy	162
Choosing a Goal	162
INFORM OR ENTERTAIN THE AUDIENCE 162 • INFLUENCE THE AUDIENCE 163 • SELL PRODUCTS AND SERVICES 163 • FACILITATE OFFLINE RELATIONSHIPS 163	
Social Media Goals	164
Building the Website	164
The Website's Name and Virtual Address	165
COMPONENTS OF A URL 165 • MANAGING DOMAIN NAMES AND VIRTUAL REAL ESTATE 166 • DISPUTES OVER DOMAIN NAMES 166	
Website Design	167
WEBSITE INFORMATION ARCHITECTURE AND NAVIGATION 167 • USABILITY AND USER INTERFACE DESIGN 168 • WEB ACCESSIBILITY FOR PEOPLE WITH DISABILITIES 168	
Software Development Strategies for the Web	171
HTML AND HTML 5 172 • CREATING INTERACTIVE, MEDIA-RICH WEBSITES 173 • CONTENT MANAGEMENT SYSTEMS 174	
E-Commerce	175
The Online Transaction and E-Commerce Software	175

10 Ethics, Privacy, and Security

Learning Objectives

Introduction

Ethics

Ethical Frameworks

Ethics and the Law

Ethical Issues and Information and Communications Technologies

Information Ethics

Intellectual Property and Digital Rights Management

ENFORCING IP LAWS 293 • PIRACY 293 • PROTECTING IP WITH TECHNOLOGY 294

Plagiarism

Privacy

Trading Privacy for Convenience and Freebies

Anonymity

Surveillance

"The Right to Be Forgotten"

Information Security

Risk Management

Identifying Threats

MALWARE AND BOTNETS 301 • DISTRIBUTED DENIAL OF SERVICE 302 • PHISHING 302 • RANSOMWARE 304 • INFORMATION LEAKAGE 304

Assessing Vulnerability

Administrative Security Controls

Technical Security Controls

AUTHENTICATION STRATEGIES 307 • ENCRYPTION 308 • INTRUSION PREVENTION AND DETECTION SYSTEMS 308 • FIREWALLS 309 • BLOCKING SPAM 309

Information Security and Cloud Computing

The Human Element in Information Ethics, Security, and Privacy

Cognitive Issues and Productivity

AVOIDING WEAK PASSWORDS 311 • REDUCING COMPLEXITY 311

Social Engineering and Information Security

Security Awareness and Ethical Decision Making

THE ETHICAL FACTOR: *Ethical Dilemmas in a Distributed Denial of Service Attack*

INTERACTIVE SIMULATION: VAMPIRE LEGENDS A Role-Playing

Simulation on Ethics, Privacy, and Security in the

Multiplayer Online Game Business

Chapter 10 Chapter Summary 314

Key Terms and Concepts 315

Chapter Review Questions 315

Projects and Discussion Questions 316

Application Exercises

Excel: Citywide Community College 317

Access: Citywide Community College 317

Case Studies

1. Equifax: A Massive Data Breach at a Consumer Reporting Agency 318

2. Community Policing on the Internet: Spamhaus Targets Worldwide Spammers 319

289 E-Projects

1. Tracking the Trackers: Investigating How Third-Party Cookies Steer the Ads You See 320

2. Who Are the Spammers? 321

Endnotes 321

11 Systems Development and Procurement

Learning Objectives

Introduction

Systems Development Life Cycle

Planning

ASSESSING BUSINESS NEED 324 • FEASIBILITY STUDY 325

Analysis

PROCESS DIAGRAMS AND BUSINESS PROCESS IMPROVEMENT 325 • REQUIREMENTS DEFINITION DOCUMENT 326 • BUILD OR BUY? 327

Design Phase

ARCHITECTURAL DESIGN 327 • SERVICE-ORIENTED ARCHITECTURE 328 • APPLICATION PROGRAMMING INTERFACES (API) 328 • DATA MODELS AND DATABASE DESIGN 329

Development Phases

Testing Phase

Implementation

Maintenance

BUG FIXES AND CHANGE REQUESTS 333 • WHEN INFORMATION SYSTEMS GROW OLD 334

Software Development Strategies

Waterfall Software Development

Iterative Methods

Agile Methods

SCRUM 337 • EXTREME PROGRAMMING (XP) 337

311 Comparing Software Development Approaches

Type of Project

Organizational Culture

Is Waterfall Dead?

Global Software Development

Software Procurement: The "Buy" Strategy

Pros and Cons of Build and Buy

The Procurement Process

RFI AND RFP 340 • EVALUATING THE OPTIONS 341

Adaptation and Customization

The Human Element in Systems

Development and Procurement

Working in Teams

Working with Consultants

ADVANTAGES AND DISADVANTAGES 343 • CONTRACT MANAGEMENT 344

The Role of Senior Management

THE ETHICAL FACTOR: *Developing Systems That Promote Ethical Decision Making and Social Responsibility*

INTERACTIVE SIMULATION: GREEN WHEELING A Role-Playing

Simulation on Systems Development and Procurement

Chapter 11 Chapter Summary	345	
Key Terms and Concepts	346	
Chapter Review Questions	347	
Projects and Discussion Questions	347	
Application Exercises		
Excel: Jay's Bikes	348	
Access: Managing a Recipe Collection	348	
Case Studies		
1. Baby Steps toward Scrum: How BabyCenter.com Made the Cultural Transition to Agile Software Development	349	
2. Extreme Programming at the US Strategic Command	350	
E-Projects		
1. Watching Babycenter.com Change over Time with the Internet Archive	351	
2. Analyzing Software Defect Rates Using Excel	351	
Endnotes	352	
12 Information Systems Project Management and Strategic Planning	353	
Learning Objectives	353	
Introduction	353	
What Is a Project?	354	
Projects versus Processes	354	
The Triple Constraint: Time, Cost, and Scope	355	
Project Management	355	
The Five Project Management Processes	356	
INITIATING 356 • PLANNING 357 • EXECUTING 358 • MONITORING AND CONTROLLING 359 • CLOSING 359		
The Role of the Project Manager	359	
Project Management Software	360	
Managing Time	360	
Managing People and Resources	361	
Managing Costs	361	
Why Projects Succeed and Why They Fail	362	
Why Do Projects Fail?	362	
Success Factors for Project Management	363	
Strategic Planning for Information Systems	364	
Vision, Principles, and Policies	364	
FUNDING MODELS FOR IT 364 • ACCEPTABLE-USE AND SECURITY POLICIES 365 • RECORD RETENTION POLICIES 366 • ENTERPRISE ARCHITECTURE 367		
Project Portfolio Management	367	
DECIDING WHICH PROJECTS TO PURSUE 367 • MANAGING THE PORTFOLIO 368		
Disaster Recovery and Business Continuity Planning	369	
Technology and Industry Trends	370	
Planning for the Future: the Human Element	371	
Cognitive Biases and Strategic Planning	371	
The Black Swan	373	
THE ETHICAL FACTOR: Code of Ethics for Project Managers	360	
INTERACTIVE SIMULATION: EXTREME VIRTUAL REALITY: A Role-Playing Simulation on Managing a Project to Open a New Business	374	
Chapter 12 Chapter Summary	375	
Key Terms and Concepts	376	
Chapter Review Questions	376	
Projects and Discussion Questions	376	
Application Exercises		
Excel: Creating a Gantt Chart with Excel	377	
Access: Apprentice Project Managers	378	
Case Studies		
1. Predicting the Future: Gartner's Research Informs Strategic Planning	379	
2. JetBlue and WestJet: A Tale of Two Software Implementations	381	
E-Projects		
1. Examining an IT Strategic Plan	382	
2. Analyzing Airline Performance with Excel Pivot Tables	382	
Endnotes	382	
Comprehensive Case Studies		
1. Facebook's Privacy Challenges	384	
2. Enabling the Sharing Economy: The Case of Uber Technologies	388	
3. Apple: Can the Company Pull off Another Disruptive Innovation?	391	
4. Managing the Federal Government's IT Project Portfolio	394	
Case Studies	384	
Glossary	397	
Index	405	

Brief Contents

- 1 Environmental Considerations 1
- 2 Invertebrate Classification and Relationships 5
- 3 The Protozoans 33
- 4 The Poriferans and Placozoans 75
- 5 Introduction to the Hydrostatic Skeleton 93
- 6 The Cnidarians 97
- 7 The Ctenophores 131
- 8 The Platyhelminths 143
- 9 The Mesozoans:
Possible Flatworm Relatives 173
- 10 The Rotifers and Acanthocephalans 177
- 11 The Nemertines 195
- 12 The Molluscs 207
- 13 The Annelids and Sipunculans 285
- 14 The Arthropods 329
- 15 Two Phyla of Likely Arthropod Relatives:
Tardigrades and Onychophorans 407
- 16 The Nematodes 417
- 17 Four Phyla of Likely Nematode Relatives:
Nematomorpha, Priapulida, Kinorhyncha,
and Loricifera 437
- 18 Five Phyla (Plus One Species) of Uncertain
Affiliation: Myxozoa, Gnathostomulida,
Gastrotricha, *Xenoturbella bocki*,
Chaetognatha, and Cyclophora 445
- 19 The Lophophorates (Phoronids,
Brachiopods, Bryozoans) and
Entoprocts 461
- 20 The Echinoderms 485
- 21 The Hemichordates 515
- 22 The Nonvertebrate Chordates 523
- 23 Invertebrate Reproduction
and Development—An Overview 539

Expanded Contents

<i>List of Research Focus Boxes</i>	<i>iv</i>
<i>Preface/Introduction</i>	<i>xi</i>
<i>Guide to the Major Animal Groups</i>	<i>xvi</i>
<i>The Geologic Time Scale</i>	<i>xvii</i>

1

Environmental Considerations 1

2

Invertebrate Classification and Relationships 5

Introduction	5
Classification by Cell Number, Embryology, and Body Symmetry	6
Classification by Developmental Pattern	7
Classification by Evolutionary Relationship	14
Deducing Evolutionary Relationships	17
Why Determine Evolutionary Trees?	21
How Evolutionary Relationships Are Determined	21
Uncertainty about Evolutionary Relationships	27
Time Machines: Help from the Fossil Record	27
Classification by Habitat and Lifestyle	28

3

The Protozoans 33

Introduction	33
General Characteristics	35

Protozoan Locomotory Systems	37
Structure and Function of Cilia	38
Structure and Function of Flagella	39
Structure and Function of Pseudopodia	39
Protozoan Reproduction	40
Protozoan Feeding	42
General Summary	42
The Alveolates	42
Phylum Ciliophora	42
Patterns of Ciliation	43
Other Morphological Features	43
Reproductive Characteristics	45
Ciliate Lifestyles	48
Phylum Dinozoa (= Dinoflagellata)	50
Phylum Apicomplexa ($\approx$ Sporozoa)	54
Phylum Microsporidea	57
Phylum Myxozoa (= Myxospora)	57
Amoeboid Protozoans	58
The Gymnamoebae (members of the Amoebozoa)	58
The Arcellanid and Other Test-bearing Amoebae (members of the Amoebozoa)	59
Phylum Granuloreticulosa (members of the Cercozoa)	59
Phylum Radiozoa (members of the Cercozoa)	61
Phylum Heliozoa (not members, but likely relatives of the Cercozoa)	61
Flagellated Protozoans	62
The Phytoflagellated Protozoans	63
The Zooflagellated Protozoans— Free-Living Forms	63
The Zooflagellated Protozoans— Parasitic Forms	63
Some Transitional Forms and Misfits	66

4

The Poriferans
and Placozoans 75

- Phylum Porifera 75
 - Introduction 75
 - General Characteristics 77
 - Poriferan Diversity 82
 - Other Features of Poriferan Biology:
 - Reproduction and Development 86
- Phylum Placozoa 87
 - Introduction 87
 - General Characteristics 87

5

Introduction to the
Hydrostatic Skeleton 93

6

The Cnidarians 97

- Introduction and General Characteristics 97
- Class Scyphozoa 100
- Class Cubozoa 105
- Class Hydrozoa 105
 - Order Hydroida 105
 - Order Siphonophora 110
 - The Hydrocorals 112
- Class Anthozoa 113
 - Subclass Hexacorallia (= Zoantharia) 116
 - Subclass Octocorallia (= Alcyonaria) 119

7

The Ctenophores 131

- Introduction and General Characteristics 131
- Ctenophore Diversity 137
 - Class Tentaculata 137
 - Class Nuda 140
- Other Features of Ctenophore Biology:
 - Reproduction 140

8

The Platyhelminths 143

- Introduction and General Characteristics 143
- Class Turbellaria 145
- Class Cestoda 149
- Class Monogenea 153
- Class Trematoda 153
 - The Digeneans 154
 - The Aspidogastrea (= Aspidobothreans) 163

9

The Mesozoans:
Possible Flatworm Relatives 173

- The Mesozoans 173
 - Class Orthonectida 174
 - Class Rhombozoa 175

10

The Rotifers
and Acanthocephalans 177

- Introduction 177
- Phylum Rotifera 178
- Introduction and General Characteristics 178
 - Class Seisonidea 182
 - Class Bdelloidea 183
 - Class Monogononta 183
- Other Features of Rotifer Biology 188
 - Digestive System 188
 - Nervous and Sensory Systems 189
 - Excretion and Water Balance 189
- Phylum Acanthocephala 189

11

The Nemertines 195

- Introduction and General Characteristics 195
- Other Features of Nemertine Biology 202
 - Classification 202
 - Protection from Predators 202
 - Reproduction and Development 202

12

The Molluscs 207

- Introduction and General Characteristics 207
- Class Polyplacophora 210
- Class Aplacophora 214
- Class Monoplacophora 214
- Class Gastropoda 216
 - The Prosobranchs 221
 - The Opisthobranchia 227
 - The Pulmonata 229
- Class Bivalvia (= Pelecypoda) 230
 - Subclass Protobranchia 233
 - Lamellibranchs 235
 - Subclass Anomalodesmata 243
- Class Scaphopoda 246
- Class Cephalopoda 247
- Other Features of Molluscan Biology 257
 - Reproduction and Development 257
 - Circulation, Blood Pigments,
and Gas Exchange 260
 - Nervous System 261
 - Digestive System 261
 - Excretory System 261

13

The Annelids
and Sipunculans 285

- Introduction 285
- Phylum Annelida 285
 - General Annelid Characteristics 285
- Class Polychaeta 287
 - Polychaete Reproduction 293
- Family Siboglinidae
(formerly the Pogonophora) 295
 - General Characteristics 295
 - Siboglinid Reproduction
and Development 300
- Class Clitellata 302
 - Subclass Oligochaeta 302
 - Oligochaete Reproduction 304
 - Subclass Hirudinea 306
 - Leech Reproduction 308

Class Echinura 308

Other Features of Annelid Biology 311

Digestive System 311

Nervous System and Sense Organs 311

Circulatory System 314

Phylum Sipuncula 314

14

The Arthropods 329

- Introduction and General Characteristics 329
 - The Exoskeleton 330
 - The Hemocoel 330
 - Molting 331
 - Nerves and Muscles 332
 - The Circulatory System 333
 - Arthropod Visual Systems 333
 - Classification and Evolutionary
Relationships 337
- Subphylum Trilobitomorpha 338
 - Class Trilobita 338
- Subphylum Chelicerata 339
 - Class Merostomata 339
 - Class Arachnida 340
 - Class Pycnogonida (= Pantopoda) 344
- Subphylum Mandibulata 345
 - Class Myriapoda 345
 - Orders Chilopoda and Diplopoda 346
 - Class Insecta (= Hexapoda) 347
 - Class Crustacea 358
 - Subclass Malacostraca 359
 - Subclass Branchiopoda 363
 - Subclass Ostracoda 365
 - Subclass Copepoda 365
 - Subclass Pentastomida 371
 - Subclass Cirripedia 373
- Other Features
 - of Arthropod Biology 373
 - Reproduction and Development 373
 - Digestion 380
 - Excretion 382
 - Blood Pigments 383

15

Two Phyla of Likely Arthropod Relatives: Tardigrades and Onychophorans 407

Introduction and General Characteristics 407

Phylum Tardigrada 408

Phylum Onychophora 410

16

The Nematodes 417

Introduction and General Characteristics 417

Body Coverings and Body Cavities 418

Musculature, Internal Pressure, and Locomotion 420

Organ Systems and Behavior 421

Reproduction and Development 423

Parasitic Nematodes 424

Beneficial Nematodes 429

17

Four Phyla of Likely Nematode Relatives: Nematomorpha, Priapulida, Kinorhyncha, and Loricifera 437

Introduction 437

Phylum Nematomorpha 438

Phylum Priapulida 438

Phylum Kinorhyncha (= Echinoderida) 440

Phylum Loricifera 440

18

Five Phyla (Plus One Species) of Uncertain Affiliation: Myxozoa, Gnathostomulida, Gastrotricha, *Xenoturbella bocki*, Chaetognatha, and Cyclophora 445

Introduction 445

Phylum Myxozoa (= Myxospora) 445

Phylum Gnathostomulida 446

Phylum Gastrotricha 447

Phylum Uncertain 449

Xenoturbella bocki 449

Phylum Chaetognatha 449

General Characteristics and Feeding 449

Chaetognath Reproduction 452

Chaetognath Lifestyles and Behavior 452

Chaetognath Relationships 453

Phylum Cyclophora 455

19

The Lophophorates (Phoronids, Brachiopods, Bryozoans) and Entoprocts 461

Introduction and General Characteristics 461

Phylum Phoronida 463

Phylum Brachiopoda 464

Phylum Bryozoa

(= Ectoprocta; = Polyzoa) 468

Class Phylactolaemata 471

Class Gymnolaemata 473

Class Stenolaemata 476

Other Features of Lophophorate Biology 476

Reproduction 476

Digestion 477

Nervous System 477

Phylum Entoprocta (= Kamptozoa) 478

20

The Echinoderms 485

Introduction and General Characteristics 485

Class Crinoidea 488

Class Stellerioidea 491

Subclass Ophiuroidea 491

Subclass Asteroidea 493

The Concentricycloids 496

Class Echinoidea 497

Class Holothuroidea 502

Other Features of Echinoderm Biology 507

Reproduction and Development 507

Nervous System 507

21

The Hemichordates 515

Introduction and General Characteristics 515

Class Enteropneusta 516

Class Pterobranchia 518

22

The Nonvertebrate Chordates 523

Introduction and General Characteristics 523

Subphylum Urochordata (= Tunicata) 524

Class Ascidiacea 524

Class Larvacea (= Appendicularia) 527

Class Thaliacea 528

Other Features of Urochordate Biology 531

Reproduction 531

Excretory and Nervous Systems 532

Subphylum Cephalochordata (= Acrania) 532

23

Invertebrate Reproduction and Development— An Overview 539

Introduction 539

Asexual Reproduction 540

Sexual Reproduction 542

Patterns of Sexuality 542

Gamete Diversity 543

Getting the Gametes Together 545

Larval Forms 551

Dispersal as a Component of the Life-History Pattern 561

Glossary of Frequently Used Terms 571

Index 575

Contents

List of Contributors	xi
Preface	xiii

1 Bioenergetics

Dominique P. Bureau, Sadasivam J. Kaushik,
and C. Young Cho

1.1	Introduction	2
1.2	History of Nutritional Energetics	3
1.3	Energy Exchange in Biological Systems	5
1.4	Energy Utilization and Requirements	7
1.5	Digestible Energy of Feedstuffs	14
1.6	Effect of Biological and Environmental Factors	16
1.7	Urinary and Branchial Energy and Metabolizable Energy	18
1.8	Factors Affecting Metabolic Waste Output	21
1.9	Heat Production	24
1.10	Minimal Metabolism	29
1.11	Heat Increment of Feeding	35
1.12	Digestion and Absorption Processes (HdE)	37
1.13	Recovered Energy and Growth	43
1.14	Reproduction	47
1.15	Integrating and Using Information from Bioenergetics	48
1.16	Limitations and Perspectives of Bioenergetics	53
	References	54

2 The Vitamins

John E. Halver

2.1	Historical Introduction	62
2.2	The Water-Soluble Vitamins	66
2.3	The Fat-Soluble Vitamins	113
2.4	Other Factors	128
2.5	Anemias and Hemapoiesis	130
	References	132

3 Amino Acids and Proteins

Robert P. Wilson

3.1	Introduction	144
3.2	Protein Requirements	145
3.3	Qualitative Amino Acid Requirements	151
3.4	Quantitative Amino Acid Requirements	152
3.5	Other Methods of Estimating Amino Acid Needs	170
	References	175

4 The Lipids

John R. Sargent, Douglas R. Tocher,
and J. Gordon Bell

4.1	Introduction	182
4.2	Structures and Biosynthesis	184
4.3	Functions	194
4.4	Fatty Acids and Dietary Energy	201
4.5	Optimal Levels and Ratios of Dietary <i>n</i> -3 and <i>n</i> -6 Polyunsaturated Fatty Acids	206
4.6	Dietary Phosphoglycerides: Inositol and Choline	227
4.7	Fatty Acid Peroxidation	232
4.8	Sources of Lipids for Farmed Fish Feeds	239
4.9	Prospects	244
	References	246

5 The Minerals

Santosh P. Lall

5.1	Introduction	260
5.2	Essential Minerals for Finfish	271
5.3	Concluding Remarks	300
	References	301

6 Intermediary Metabolism

Konrad Dabrowski and Helga Guderley

6.1	Introduction: Metabolic Circuitry and Control Mechanisms	310
6.2	Carbohydrate Metabolism	313
6.3	Protein and Amino Acid Metabolism	333
6.4	Conclusions	358
	References	360

7 Nutritional Physiology

Michael B. Rust

7.1	Introduction	
7.2	Gross Juvenile and Adult Anatomy	368
7.3	Sensory Organs	369
7.4	Food Capture Structures and Organs	378
7.5	Digestive Organs	389
7.6	Liver	393
7.7	Anatomy and Diet	413
7.8	Digestive Processes	415
7.9	Postabsorptive Transport and Processing	417
7.10	Control and Regulation of Digestion	427
7.11	Nutritional Physiology in Larval Fish	428
	References	432
		446

8 Nutritional Pathology

Ronald J. Roberts

8.1	Introduction	
8.2	Principles of Nutritional Pathology	454
8.3	The Deficiency and Imbalance Diseases	455
8.4	Micronutrients	459
8.5	Mineral Deficiencies and Imbalances	464
8.6	Dietary Mineral Toxicity	480
8.7	Mycotoxins	484
8.8	Toxic Algae	489
8.9	Cottonseeds	492
8.10	<i>Senecio</i> Alkaloids	492
8.11	<i>Leucaena</i> Toxins	492
8.12	Anthropogenic Chemicals	494
8.13	Binders	494
8.14	Photosensitizers	494
8.15	Sekoke Disease	495
8.16	Spleen- and Liver-Induced Cataracts	497
8.17	Single-Cell Protein Lesions	498
8.18	Antibiotic and Chemotherapeutic Toxicity	500
	References	500
		500

9 Diet Formulation and Manufacture

Ronald W. Hardy and Frederick T. Barrows

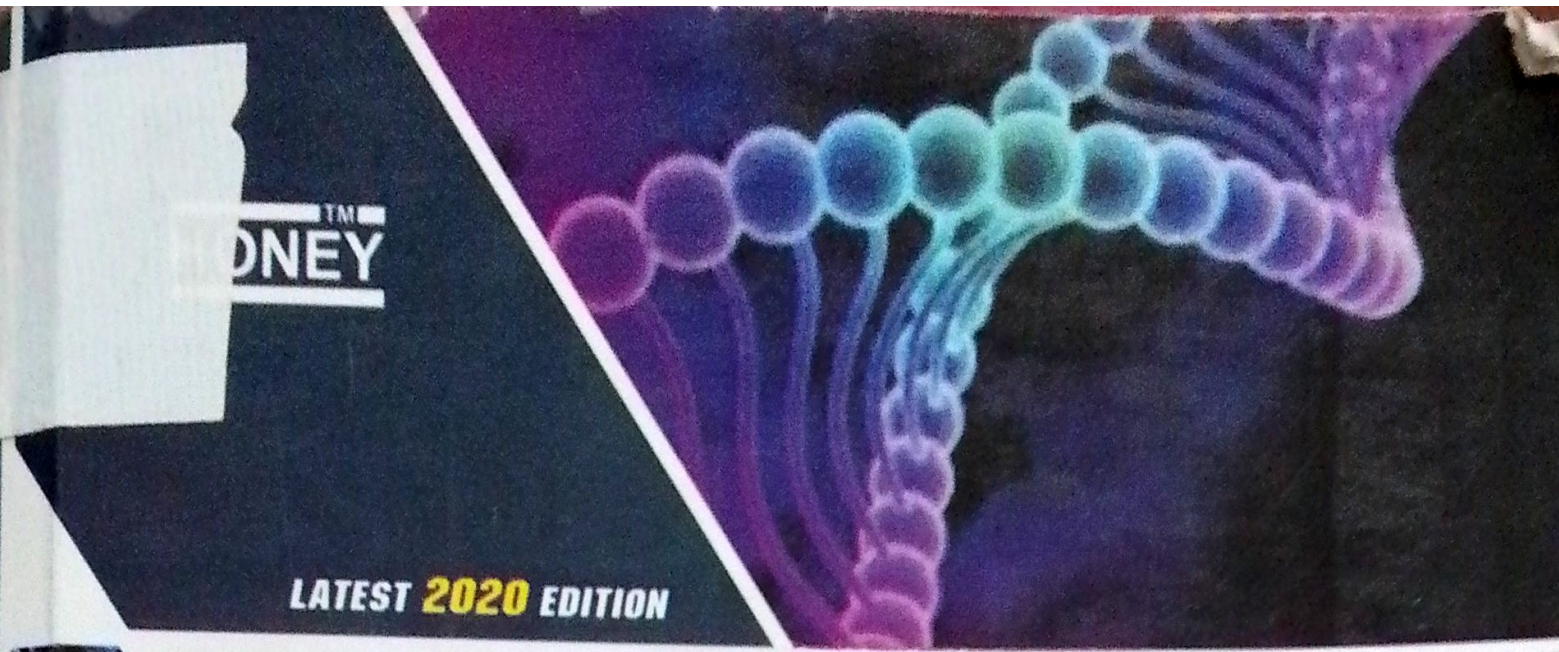
9.1	Introduction	
9.2	Aims and Strategy of Fish Feed Production	506
		514

9.3	Feed Ingredients	515
9.4	Diet Formulation	538
9.5	Diet Manufacture and Storage	558
9.6	Ingredient and Diet Evaluation	578
9.7	Glossary	594
	References	596
10	Adventitious Toxins	
	Jerry D. Hendricks	
10.1	Introduction	602
10.2	Naturally Occurring Toxins in Formulated Fish Rations	603
10.3	Nonnatural Components and Additives in Formulated Rations	630
10.4	Summary	641
	References	641
11	Special Feeds	
	George M. Pigott and Barbee W. Tucker	
11.1	Introduction	652
11.2	Formulation of Special Feeds	652
11.3	Feed Manufacturing	661
11.4	Summary	667
	References	668
12	Nutrition and Fish Health	
	Delbert M. Gatlin III	
12.1	Introduction	672
12.2	Factors Affecting Fish Health	673
12.3	Dietary Components Influencing Fish Health	675
12.4	Feeding Practices Affecting Fish Health	694
12.5	Concluding Remarks and Research Needs	698
	References	699
13	Diet and Fish Husbandry	
	Richard T. Lovell	
13.1	Introduction	704
13.2	Channel Catfish	708
13.3	Salmonids	720
13.4	Tilapias	732
13.5	Penaeid Shrimp	741
	References	753

14 Nutrient Flow and Retention

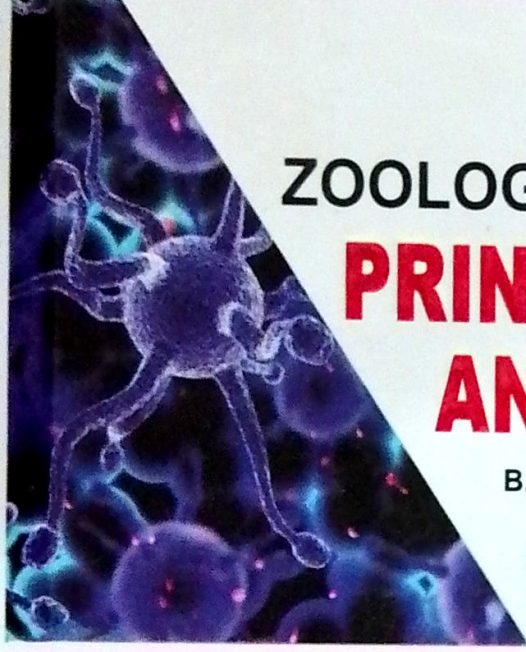
John E. Halver and Ronald W. Hardy

14.1	Introduction	756
14.2	Carbohydrate Metabolism	757
14.3	Glycolysis	757
14.4	Carbohydrate Synthesis	759
14.5	Pentose Phosphate Pathway	759
14.6	Glycogenolysis	759
14.7	Diet and Carbohydrate Metabolism	760
14.8	Lipid Metabolism	760
14.9	Odd-Chain-Length Fatty Acid Oxidation	762
14.10	Electron Transfer Cascade	763
14.11	Amino Acid Metabolism	763
14.12	Effect of Diet on Intermediary Metabolism	765
14.13	Measuring Protein Accretion and Degradation	766
14.14	Intake and Metabolism	767
14.15	Sexual Maturity and Metabolism	767
14.16	Prospects for Improvement of Protein Retention Efficiency	768
	References	769
Appendix		771
Index		807



HONEYTM

LATEST 2020 EDITION



ZOOLOGY PAPER-A

**PRINCIPLES OF
ANIMAL LIFE**

B.Sc. (2 Year) & B.S. (4 Years)

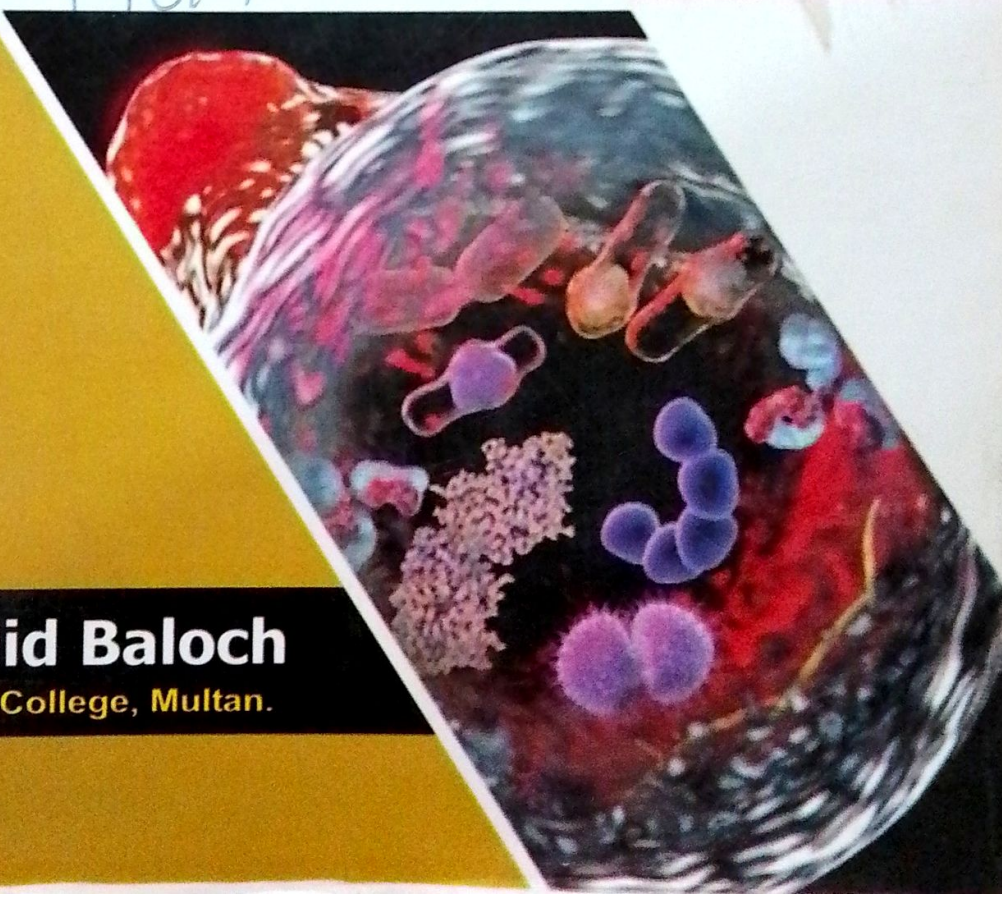
(126)
14614

ADS (B.Sc.) 2 Year

B.S. (4 Years): Semester I & II

B.Sc. (IIIrd year):

Paper - A (P.U.)



Prof. M. Khalid Baloch

Government Emerson College, Multan.

CONTENTS

Sr. No	Chapter	Page No
1	Place of Zoology in Sciences	7
2	The Chemical Basis of Animal life	24
3	Cells, Tissues, Organs and Organs system	63
4	Energy and Enzyme: Life's Driving and Controlling Forces	101
5	How animals Harvest energy Stored in Nutrients	117
6	Cell Division	135
7	Inheritance Pattern	152
8	Chromosome and Gene Linkage	173
9	Molecular Genetics: Ultimate Cellular Control	199
10	Ecology I: Individuals and Populations	228
11	Ecology II: Communities and Ecosystems	240
12	Animal Behavior	273
13	Evolution: A Historical Perspective	289
14	Evolution and Gene Frequencies	304
•	Previous Papers (B.Sc)	323

Honey Zoology Subjective (A,B,C)
Honey Practical Zoology (A,B,C)
Honey Subjective Biology (1st and 2nd Year)
Honey Objective BIOLOGY (1st & 2nd Year)
Honey Model Papers BIOLOGY (1st & 2nd Year)
Decent Experimental Biology (1st & 2nd Year)
Honey Solved Board's Paper (Biology)
Honey Biology Practical Guide (1st & 2nd Year)
Honey Biology Practical Guide (9th & 10th)
Honey Biology Subjective & Objective (9th & 10th)
Honey Practical Botany (A,B,C,D)

بھی مارکیٹ میں دستیاب ہیں

ENCYCLOPEDIA OF FISHES

CONSULTANT EDITORS

Dr John R. Paxton

Australian Museum, Sydney, Australia

&

Dr William N. Eschmeyer

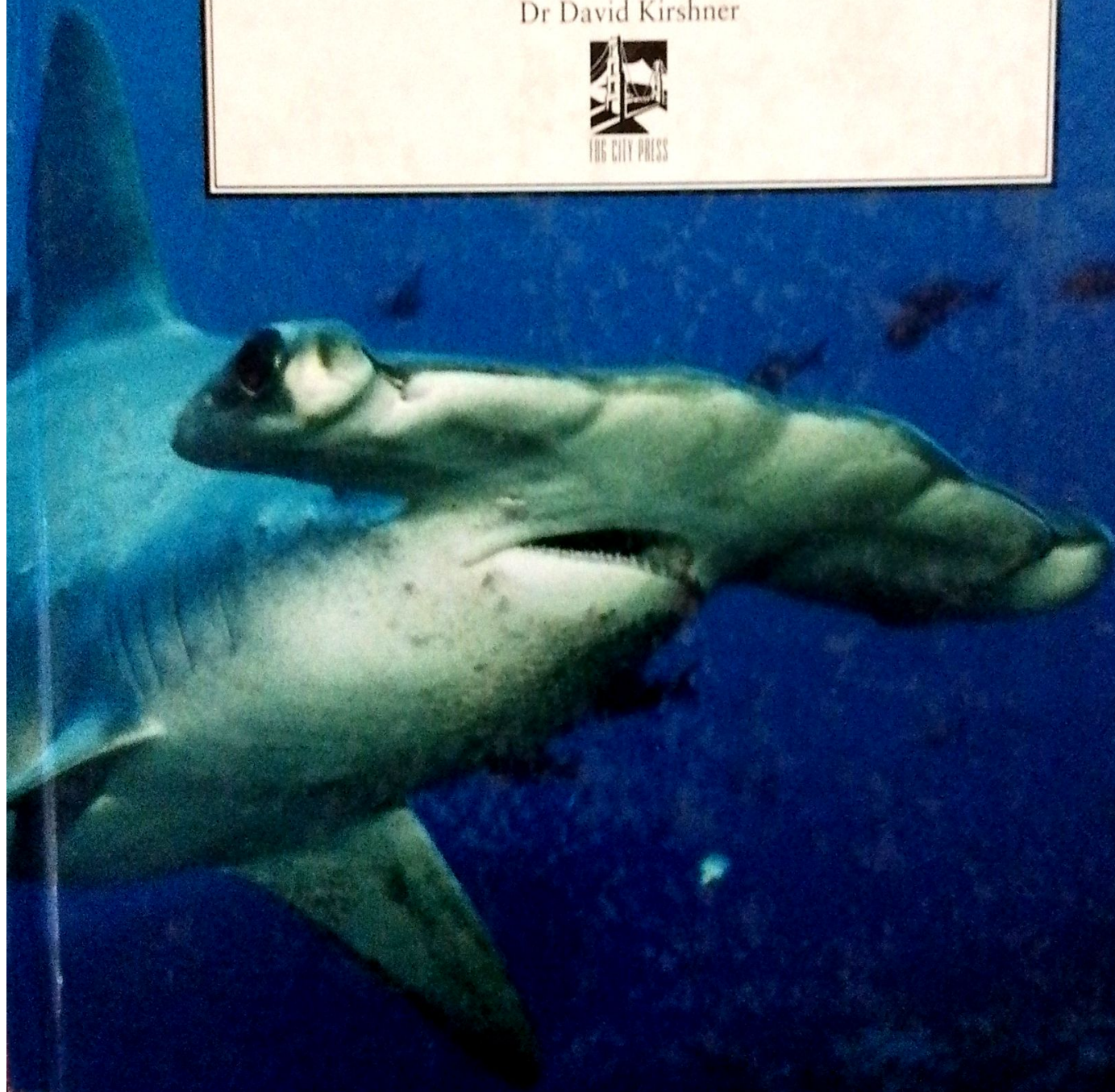
California Academy of Sciences, San Francisco, USA

ILLUSTRATIONS BY

Dr David Kirshner



THE CITY PRESS



CONTENTS

FOREWORD
Frank H. Talbot

10

PART ONE

THE WORLD OF FISHES

INTRODUCING FISHES 14
Karel F. Liem

CLASSIFYING FISHES 20
Stanley H. Weitzman

FISHES THROUGH THE AGES 27
Lance Grande

HABITATS & ADAPTATIONS 32
John R. Paxton

FISH BEHAVIOR 42
Julia K. Parrish

ENDANGERED SPECIES 48
Patricia C. Almada-Villela



PART TWO

KINDS OF FISHES

JAWLESS FISHES 56
Ian C. Potter

SHARKS, RAYS & CHIMAERAS 60
John Stevens & Peter R. Last

LUNGFISHES & COELACANTH 70
Michael N. Bruton

BICHIRS & THEIR ALLIES 75
Edward O. Wiley

BONYTONGUES & THEIR ALLIES 80
Original text by P. Humphry Greenwood;
revised by Mark V. H. Wilson

EELS & THEIR ALLIES 85
John E. McCosker

SARDINES & THEIR ALLIES 91
Gareth Nelson

CARPS & THEIR ALLIES 96
Keith E. Banister

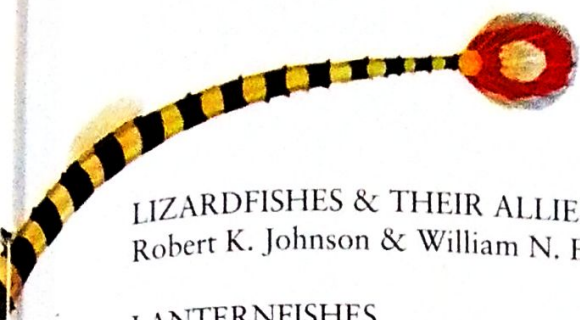
CHARACINS & THEIR ALLIES 101
Stanley H. Weitzman & Richard P. Vari

CATFISHES & KNIFEFISHES 106
Carl J. Ferraris, Jr

SALMONS & THEIR ALLIES 113
Robert M. McDowall

DRAGONFISHES & THEIR ALLIES 119
William L. Fink





LIZARDFISHES & THEIR ALLIES
Robert K. Johnson & William N. Eschmeyer

123

LANTERNFISHES
P. Alexander Hulley

127

TROUTPERCHES & THEIR ALLIES
Daniel M. Cohen

129

CODFISHES & THEIR ALLIES
Daniel M. Cohen

130

CUSKEELS & THEIR ALLIES
Jørgen G. Nielsen

133

TOADFISHES
J. Barry Hutchins

135

ANGLERFISHES
Original text by E. Bertelsen;
revised by Theodore W. Pietsch

137

CLINGFISHES & THEIR ALLIES
Original text by John C. Briggs;
revised by J. Barry Hutchins

142

FLYINGFISHES & THEIR ALLIES
Bruce B. Collette & Nikolay V. Parin

144

KILLIFISHES & RICEFISHES
Lynne R. Parenti

148

SILVERSIDES & THEIR ALLIES
Gerald R. Allen

153

OARFISHES & THEIR ALLIES
John E. Olney

157

SQUIRRELFISHES & THEIR ALLIES
John R. Paxton

160

DORIES & THEIR ALLIES
Christine Karrer & Hans-Christian John

163

PIPEFISHES & THEIR ALLIES
James Wilder Orr & Theodore W. Pietsch

168

SWAMPEELS & THEIR ALLIES
Karel F. Liem

173

SCORPIONFISHES & THEIR ALLIES
William N. Eschmeyer

175

PERCHES & THEIR ALLIES
G. David Johnson & Anthony C. Gill

181

GROUPERS, SEABASSES & THEIR ALLIES
John E. Randall

195

CICHLIDS
Original text by P. Humphry Greenwood;
revised by Melanie L. J. Stiassny

200

DAMSELFISHES
Gerald R. Allen

205

WRASSES & PARROTFISHES
J. Howard Choat & David R. Bellwood

209

BLENNIES
Victor G. Springer

214

GOBIES
Douglass F. Hoese

218

FLATFISHES
François Chapleau & Kunio Amaoka

223

TRIGGERFISHES & THEIR ALLIES
Keiichi Matsuura & James C. Tyler

227

FURTHER READING

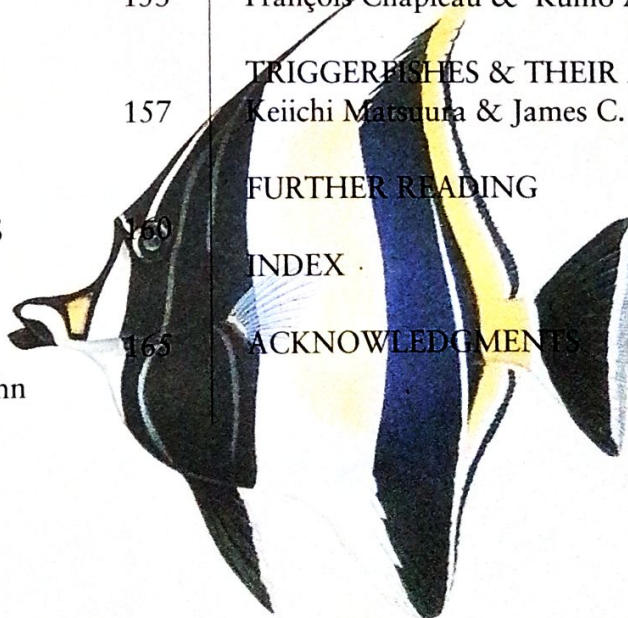
232

INDEX

234

ACKNOWLEDGMENTS

240



Exploring Animal Behavior



Readings from American Scientist

SECOND EDITION

Edited by Paul W. Sherman and John Alcock

CONTENTS

Preface iv

PART I *Doing Science* 1

Integrity in Science Lewis M. Branscomb 3

Conduct, Misconduct and the Structure of Science James Woodward and David Goodstein 7

Infanticide as a Primate Reproductive Strategy Sarah Blaffer Hrdy 19

Primate Social Behavior in a Changing World Richard Curtin and Phyllis Dolhinow 29

The Science of Scientific Writing George D. Gopen and Judith A. Swan 37

PART II *The Mechanisms of Behavior* 47

Why Male Ground Squirrels Disperse Kay E. Holekamp and Paul W. Sherman 50

Animal Thinking Donald R. Griffin 58

Reward Deficiency Syndrome Kenneth Blum, John G. Cull, Eric R. Braverman, and David E. Comings 67

Mozart's Starling Meredith J. West and Andrew P. King 81

Testosterone and Aggression in Birds John C. Wingfield, Gregory F. Ball, Alfred M. Dufty, Jr.,
Robert E. Hegner, and Marilyn Ramenofsky 90

Shaping Brain Sexuality Andrew H. Bass 97

Aerial Defense Tactics of Flying Insects Mike May 109

Moth Hearing and the Feeding Strategies of Bats M. Brock Fenton and James H. Fullard 122

PART III *The Evolutionary History of Behavior* 133

Evolution and the Triumph of Homology, or Why History Matters Stephen Jay Gould 136

The Evolution of Communal Nest-Weaving in Ants Bert Hölldobler and Edward O. Wilson 146

Untangling the Evolution of the Web William A. Shear 156

Why Do Bowerbirds Build Bowers? Gerald Borgia 167

Hunter-Gatherers of the New World Kim Hill and A. Magdalena Hurtado 173

PART IV *The Adaptive Value of Reproductive Behavior* 181

The Evolution of Sexual Differences in Insects Randy Thornhill and Darryl T. Gwynne 184

Animal Genitalia and Female Choice William G. Eberhard 192

Prairie-Vole Partnerships Lowell L. Getz and C. Sue Carter 200

Mating Behavior and Hermaphroditism in Coral Reef Fishes Robert R. Warner 207

The Strategies of Human Mating David M. Buss 216

Avian Siblicide Douglas W. Mock, Hugh Drummond, and Christopher H. Stinson 228

PART V *The Adaptive Value of Social Behavior* 240

Why Ravens Share Bernd Heinrich and John Marzluff 243

Communal Breeding in Burying Beetles Michelle Pellissier Scott 251

Making Decisions in the Family: An Evolutionary Perspective Stephen T. Emlen, Peter H. Wrege, and
Natalie J. Demong 258

Naked Mole-Rats Rodney L. Honeycutt 268

The Honey Bee Colony as a Superorganism Thomas D. Seeley 279

The Essence of Royalty: Honey Bee Queen Pheromone Mark L. Winston and Keith N. Slessor 287

Index 299

Genetics

A Conceptual Approach

FIFTH EDITION



Benjamin A. Pierce

Contents in Brief

1. Introduction to Genetics	1
2. Chromosomes and Cellular Reproduction	17
3. Basic Principles of Heredity	45
4. Sex Determination and Sex-Linked Characteristics	77
5. Extensions and Modifications of Basic Principles	103
6. Pedigree Analysis, Applications, and Genetic Testing	139
7. Linkage, Recombination, and Eukaryotic Gene Mapping	165
8. Chromosome Variation	209
9. Bacterial and Viral Genetic Systems	241
10. DNA: The Chemical Nature of the Gene	277
11. Chromosome Structure and Organelle DNA	299
12. DNA Replication and Recombination	325
13. Transcription	357
14. RNA Molecules and RNA Processing	383
15. The Genetic Code and Translation	411
16. Control of Gene Expression in Bacteria	443
17. Control of Gene Expression in Eukaryotes	473
18. Gene Mutations and DNA Repair	493
19. Molecular Genetic Analysis and Biotechnology	535
20. Genomics and Proteomics	579
21. Epigenetics	613
22. Developmental Genetics and Immunogenetics	633
23. Cancer Genetics	661
24. Quantitative Genetics	683
25. Population Genetics	715
26. Evolutionary Genetics	743
Reference Guide to Model Genetic Organisms	A1

Contents

Letter from the Author xv
Preface xvi

Chapter 1 Introduction to Genetics 1

Albinism in the Hopis 1

1.1 Genetics Is Important to Us Individually, to Society, and to the Study of Biology 2

The Role of Genetics in Biology 4

Genetic Diversity and Evolution 4

Divisions of Genetics 5

Model Genetic Organisms 5

1.2 Humans Have Been Using Genetics for Thousands of Years 7

The Early Use and Understanding of Heredity 7

The Rise of the Science of Genetics 9

The Future of Genetics 10

1.3 A Few Fundamental Concepts Are Important for the Start of Our Journey into Genetics 11

Chapter 2 Chromosomes and Cellular Reproduction 17

The Blind Men's Riddle 17

2.1 Prokaryotic and Eukaryotic Cells Differ in a Number of Genetic Characteristics 18

2.2 Cell Reproduction Requires the Copying of the Genetic Material, Separation of the Copies, and Cell Division 20

Prokaryotic Cell Reproduction 20

Eukaryotic Cell Reproduction 20

The Cell Cycle and Mitosis 23

Genetic Consequences of the Cell Cycle 26

CONNECTING CONCEPTS Counting Chromosomes and DNA Molecules 27

2.3 Sexual Reproduction Produces Genetic Variation Through the Process of Meiosis 27

Meiosis 28

Sources of Genetic Variation in Meiosis 31

CONNECTING CONCEPTS Mitosis and Meiosis Compared 33

The Separation of Sister Chromatids and Homologous Chromosomes 33

Meiosis in the Life Cycles of Animals and Plants 35

Chapter 3 Basic Principles of Heredity 45

The Genetics of Red Hair 45

3.1 Gregor Mendel Discovered the Basic Principles of Heredity 46

Mendel's Success 47

Genetic Terminology 48

3.2 Monohybrid Crosses Reveal the Principle of Segregation and the Concept of Dominance 49

What Monohybrid Crosses Reveal 50

CONNECTING CONCEPTS Relating Genetic Crosses to Meiosis 52

The Molecular Nature of Alleles 53

Predicting the Outcomes of Genetic Crosses 53

The Testcross 57

Genetic Symbols 58

CONNECTING CONCEPTS Ratios in Simple Crosses 58

3.3 Dihybrid Crosses Reveal the Principle of Independent Assortment 59

Dihybrid Crosses 59

The Principle of Independent Assortment 59

Relating the Principle of Independent Assortment to Meiosis 60

Applying Probability and the Branch Diagram to Dihybrid Crosses 61

The Dihybrid Testcross 62

3.4 Observed Ratios of Progeny May Deviate from Expected Ratios by Chance 64

The Goodness-of-Fit Chi-Square Test 64

Chapter 4 Sex Determination and Sex-Linked Characteristics 77

The Strange Case of Platypus Sex 77

4.1 Sex Is Determined by a Number of Different Mechanisms 78

Chromosomal Sex-Determining Systems 79

Genic Sex Determination 81

Environmental Sex Determination 81

Sex Determination in *Drosophila melanogaster* 82

Sex Determination in Humans 83

4.2 Sex-Linked Characteristics Are Determined by Genes on the Sex Chromosomes 85

X-Linked White Eyes in *Drosophila* 85

Nondisjunction and the Chromosome Theory of Inheritance 86

X-Linked Color Blindness in Humans 88

Symbols for X-Linked Genes 89

Z-Linked Characteristics 89

Y-Linked Characteristics 90

CONNECTING CONCEPTS Recognizing Sex-Linked Inheritance 92

4.3 Dosage Compensation Equalizes the Amount of Protein Produced by X-Linked and Autosomal Genes in Some Animals 92

Lyon Hypothesis 93

Mechanism of Random X Inactivation 94

Chapter 5 Extensions and Modifications of Basic Principles 103

The Odd Genetics of Left-Handed Snails 103

5.1 Additional Factors at a Single Locus Can Affect the Results of Genetic Crosses 104

Types of Dominance 104

Penetrance and Expressivity 107

Lethal Alleles 107

Multiple Alleles 108

5.2 Gene Interaction Takes Place When Genes at Multiple Loci Determine a Single Phenotype 110

Gene Interaction That Produces Novel Phenotypes 110

Gene Interaction with Epistasis 111

CONNECTING CONCEPTS Interpreting Ratios Produced by Gene Interaction 115

Complementation: Determining Whether Mutations Are at the Same Locus or at Different Loci 117

The Complex Genetics of Coat Color in Dogs 117

5.3 Sex Influences the Inheritance and Expression of Genes in a Variety of Ways 119

Sex-Influenced and Sex-Limited Characteristics 119

Cytoplasmic Inheritance 121

Genetic Maternal Effect 123

Genomic Imprinting 124

5.4 Anticipation Is the Stronger or Earlier Expression of Traits in Succeeding Generations 126

5.5 The Expression of a Genotype May Be Affected by Environmental Effects 126

Environmental Effects on the Phenotype 127

The Inheritance of Continuous Characteristics 127

Chapter 6 Pedigree Analysis, Applications, and Genetic Testing 139

The Mystery of Missing Fingerprints 139

6.1 The Study of Genetics in Humans Is Constrained by Special Features of Human Biology and Culture 140

6.2 Geneticists Often Use Pedigrees to Study the Inheritance of Characteristics in Humans 141

Symbols Used in Pedigrees 141

Analysis of Pedigrees 141

Autosomal Recessive Traits 142

Autosomal Dominant Traits 143

X-Linked Recessive Traits 143

X-Linked Dominant Traits 145

Y-Linked Traits 146

6.3 Studying Twins and Adoptions Can Help Assess the Importance of Genes and Environment 147

Types of Twins 147

Concordance in Twins 148

A Twin Study of Asthma 149

Adoption Studies 150

6.4 Genetic Counseling and Genetic Testing Provide Information to Those Concerned about Genetic Diseases and Traits 150

Genetic Counseling 151

Genetic Testing 152

Interpreting Genetic Tests 156

Direct-to-Consumer Genetic Testing 156

Genetic Discrimination and Privacy 156

Chapter 7 Linkage, Recombination, and Eukaryotic Gene Mapping 165

Linked Genes and Bald Heads 165

- 7.1 Linked Genes Do Not Assort Independently 166**
- 7.2 Linked Genes Segregate Together and Crossing Over Produces Recombination Between Them 167**
 - Notation for Crosses with Linkage 168
 - Complete Linkage Compared with Independent Assortment 168
 - Crossing Over with Linked Genes 170
 - Calculating Recombination Frequency 171
 - Coupling and Repulsion 172

CONNECTING CONCEPTS Relating Independent Assortment, Linkage, and Crossing Over 173

- Evidence for the Physical Basis of Recombination 174
- Predicting the Outcomes of Crosses with Linked Genes 175
- Testing for Independent Assortment 176
- Gene Mapping with Recombination Frequencies 178
- Constructing a Genetic Map with the Use of Two-Point Testcrosses 179

7.3 A Three-Point Testcross Can Be Used to Map Three Linked Genes 180

- Constructing a Genetic Map with the Three-Point Testcross 181

CONNECTING CONCEPTS Stepping Through the Three-Point Cross 186

- Effect of Multiple Crossovers 188
- Mapping Human Genes 189
- Mapping with Molecular Markers 190
- Genes Can Be Located with Genomewide Association Studies 191

7.4 Physical-Mapping Methods Are Used to Determine the Physical Positions of Genes on Particular Chromosomes 192

- Somatic-Cell Hybridization 192
- Deletions Mapping 194
- Physical Chromosome Mapping Through Molecular Analysis 195

7.5 Recombination Rates Exhibit Extensive Variation 195

Chapter 8 Chromosome Variation 209

Building a Better Banana 209

- 8.1 Chromosome Mutations Include Rearrangements, Aneuploids, and Polyploids 210**
 - Chromosome Morphology 210
 - Types of Chromosome Mutations 211
- 8.2 Chromosome Rearrangements Alter Chromosome Structure 212**
 - Duplications 212
 - Deletions 214
 - Inversions 216
 - Translocations 219
 - Fragile Sites 221
 - Copy-Number Variations 222
- 8.3 Aneuploidy Is an Increase or Decrease in the Number of Individual Chromosomes 222**
 - Types of Aneuploidy 222
 - Effects of Aneuploidy 223
 - Aneuploidy in Humans 224
 - Uniparental Disomy 227
 - Mosaicism 228
- 8.4 Polyploidy Is the Presence of More than Two Sets of Chromosomes 228**
 - Autopolyploidy 228
 - Allopolyploidy 229
 - The Significance of Polyploidy 232

Chapter 9 Bacterial and Viral Genetic Systems 241

Life in a Bacterial World 241

- 9.1 Genetic Analysis of Bacteria Requires Special Methods 242**
 - Bacterial Diversity 242
 - Techniques for the Study of Bacteria 243
 - The Bacterial Genome 244
 - Plasmids 245
- 9.2 Bacteria Exchange Genes Through Conjugation, Transformation, and Transduction 247**
 - Conjugation 247
 - Natural Gene Transfer and Antibiotic Resistance 254
 - Transformation in Bacteria 254
 - Bacterial Genome Sequences 256
 - Horizontal Gene Transfer 256

- 9.3 Viruses Are Simple Replicating Systems Amenable to Genetic Analysis** 257
 Techniques for the Study of Bacteriophages 257
 Transduction: Using Phages to Map Bacterial Genes 258

CONNECTING CONCEPTS Three Methods for Mapping Bacterial Genes 261

- Gene Mapping in Phages 261
 Fine-Structure Analysis of Bacteriophage Genes 263
 RNA Viruses 265
 Human Immunodeficiency Virus and AIDS 267
 Influenza 268

Chapter 10 DNA: The Chemical Nature of the Gene 277

Arctic Treks and Ancient DNA 277

- 10.1 Genetic Material Possesses Several Key Characteristics** 278
- 10.2 All Genetic Information Is Encoded in the Structure of DNA or RNA** 278
 Early Studies of DNA 278
 DNA As the Source of Genetic Information 280
 Watson and Crick's Discovery of the Three-Dimensional Structure of DNA 283
 RNA As Genetic Material 285
- 10.3 DNA Consists of Two Complementary and Antiparallel Nucleotide Strands That Form a Double Helix** 286
 The Primary Structure of DNA 286
 Secondary Structures of DNA 288

CONNECTING CONCEPTS Genetic Implications of DNA Structure 290

- 10.4 Special Structures Can Form in DNA and RNA** 291

Chapter 11 Chromosome Structure and Organelle DNA 299

Telomeres and Childhood Adversity 299

- 11.1 Large Amounts of DNA Are Packed into a Cell** 300
 Supercoiling 300
 The Bacterial Chromosome 301
 Eukaryotic Chromosomes 302
 Changes in Chromatin Structure 304

- 11.2 Eukaryotic Chromosomes Possess Centromeres and Telomeres** 306
 Centromere Structure 306
 Telomere Structure 307

- 11.3 Eukaryotic DNA Contains Several Classes of Sequence Variation** 308
 The Denaturation and Renaturation of DNA 308
 Types of DNA Sequences in Eukaryotes 308

- 11.4 Organelle DNA Has Unique Characteristics** 309
 Mitochondrion and Chloroplast Structure 309
 The Endosymbiotic Theory 310
 Uniparental Inheritance of Organelle-Encoded Traits 311
 The Mitochondrial Genome 314
 The Evolution of Mitochondrial DNA 316
 Damage to Mitochondrial DNA Is Associated with Aging 316
 The Chloroplast Genome 317
 Through Evolutionary Time, Genetic Information Has Moved Between Nuclear, Mitochondrial, and Chloroplast Genomes 318

Chapter 12 DNA Replication and Recombination 325

Topoisomerase, Replication, and Cancer 325

- 12.1 Genetic Information Must Be Accurately Copied Every Time a Cell Divides** 326
- 12.2 All DNA Replication Takes Place in a Semiconservative Manner** 326
 Meselson and Stahl's Experiment 327
 Modes of Replication 329
 Requirements of Replication 332
 Direction of Replication 332

CONNECTING CONCEPTS The Direction of Synthesis in Different Models of Replication 334

- 12.3 Bacterial Replication Requires a Large Number of Enzymes and Proteins** 334
 Initiation 334
 Unwinding 334
 Elongation 336
 Termination 339
 The Fidelity of DNA Replication 339

CONNECTING CONCEPTS The Basic Rules of Replication 340

12.4 Eukaryotic DNA Replication Is Similar to Bacterial Replication but Differs in Several Aspects 340

- Eukaryotic Origins 340
- The Licensing of DNA Replication 341
- Unwinding 341
- Eukaryotic DNA Polymerases 341
- Nucleosome Assembly 342
- The Location of Replication Within the Nucleus 343
- DNA Synthesis and the Cell Cycle 343
- Replication at the Ends of Chromosomes 344
- Replication in Archaea 346

12.5 Recombination Takes Place Through the Breakage, Alignment, and Repair of DNA Strands 346

- Models of Recombination 347
- Enzymes Required for Recombination 348
- Gene Conversion 349

Chapter 13 Transcription 357

Death Cap Poisoning 357

13.1 RNA, Consisting of a Single Strand of Ribonucleotides, Participates in a Variety of Cellular Functions 358

- An Early RNA World 358
- The Structure of RNA 358
- Classes of RNA 359

13.2 Transcription Is the Synthesis of an RNA Molecule from a DNA Template 360

- The Template 361
- The Substrate for Transcription 363
- The Transcription Apparatus 363

13.3 Bacterial Transcription Consists of Initiation, Elongation, and Termination 365

- Initiation 365
- Elongation 367
- Termination 368

CONNECTING CONCEPTS The Basic Rules of Transcription 369

13.4 Eukaryotic Transcription Is Similar to Bacterial Transcription but Has Some Important Differences 370

- Transcription and Nucleosome Structure 370
- Promoters 370

- Initiation 371
- Elongation 373
- Termination 373

13.5 Transcription in Archaea Is More Similar to Transcription in Eukaryotes Than to Transcription in Eubacteria 374

Chapter 14 RNA Molecules and RNA Processing 383

A Royal Disease 383

14.1 Many Genes Have Complex Structures 384

- Gene Organization 384
- Introns 385
- The Concept of the Gene Revisited 387

14.2 Messenger RNAs, Which Encode the Amino Acid Sequences of Proteins, Are Modified after Transcription in Eukaryotes 387

- The Structure of Messenger RNA 387
- Pre-mRNA Processing 388
- The Addition of the 5' Cap 388
- The Addition of the Poly(A) Tail 389
- RNA Splicing 390
- Alternative Processing Pathways 393
- RNA Editing 395

CONNECTING CONCEPTS Eukaryotic Gene Structure and Pre-mRNA Processing 396

14.3 Transfer RNAs, Which Attach to Amino Acids, Are Modified after Transcription in Bacterial and Eukaryotic Cells 397

- The Structure of Transfer RNA 398
- Transfer RNA Gene Structure and Processing 399

14.4 Ribosomal RNA, a Component of the Ribosome, Is Also Processed after Transcription 400

- The Structure of the Ribosome 400
- Ribosomal RNA Gene Structure and Processing 401

14.5 Small RNA Molecules Participate in a Variety of Functions 402

- RNA Interference 402
- Small Interfering and Micro RNAs 403
- Piwi-Interacting RNAs 404
- CRISPR RNA 404

14.6 Long Noncoding RNAs Regulate Gene Expression 405

Chapter 15 The Genetic Code and Translation 411

Hutterites, Ribosomes, and Bowen–Conradi Syndrome 411

- 15.1 Many Genes Encode Proteins 412
 - The One Gene, One Enzyme Hypothesis 412
 - The Structure and Function of Proteins 415
- 15.2 The Genetic Code Determines How the Nucleotide Sequence Specifies the Amino Acid Sequence of a Protein 417
 - Breaking the Genetic Code 418
 - The Degeneracy of the Code 420
 - The Reading Frame and Initiation Codons 421
 - Termination Codons 422
 - The Universality of the Code 422

CONNECTING CONCEPTS Characteristics of the Genetic Code 422

- 15.3 Amino Acids Are Assembled into a Protein Through Translation 422
 - The Binding of Amino Acids to Transfer RNAs 423
 - The Initiation of Translation 424
 - Elongation 426
 - Termination 427

CONNECTING CONCEPTS A Comparison of Bacterial and Eukaryotic Translation 430

- 15.4 Additional Properties of RNA and Ribosomes Affect Protein Synthesis 430
 - The Three-Dimensional Structure of the Ribosome 430
 - Polyribosomes 431
 - Messenger RNA Surveillance 431
 - Folding and Posttranslational Modifications of Proteins 433
 - Translation and Antibiotics 433

Chapter 16 Control of Gene Expression in Bacteria 443

Operons and the Noisy Cell 443

- 16.1 The Regulation of Gene Expression Is Critical for All Organisms 444
 - Genes and Regulatory Elements 445
 - Levels of Gene Regulation 445
 - DNA-Binding Proteins 446
- 16.2 Operons Control Transcription in Bacterial Cells 447
 - Operon Structure 447

- Negative and Positive Control: Inducible and Repressible Operons 448
- The *lac* Operon of *E. coli* 450
- lac* Mutations 453
- Positive Control and Catabolite Repression 457
- The *trp* Operon of *E. coli* 458
- Bacterial Enhancers 460

- 16.3 Some Operons Regulate Transcription Through Attenuation, the Premature Termination of Transcription 460
 - Attenuation in the *trp* Operon of *E. coli* 460
 - Why Does Attenuation Take Place in the *trp* Operon? 464

- 16.4 RNA Molecules Control the Expression of Some Bacterial Genes 464
 - Antisense RNA 464
 - Riboswitches 464
 - RNA-Mediated Repression Through Ribozymes 466

Chapter 17 Control of Gene Expression in Eukaryotes 473

Genetic Differences That Make Us Human 473

- 17.1 Eukaryotic Cells and Bacteria Have Many Features of Gene Regulation in Common, but They Differ in Several Important Ways 474
- 17.2 Changes in Chromatin Structure Affect the Expression of Genes 474
 - DNase I Hypersensitivity 474
 - Chromatin Remodeling 475
 - Histone Modification 475
 - DNA Methylation 478
- 17.3 The Initiation of Transcription Is Regulated by Transcription Factors and Transcriptional Regulator Proteins 479
 - Transcriptional Activators and Coactivators 479
 - Transcriptional Repressors 481
 - Enhancers and Insulators 481
 - Regulation of Transcriptional Stalling and Elongation 482
 - Coordinated Gene Regulation 482
- 17.4 Some Genes Are Regulated by RNA Processing and Degradation 483
 - Gene Regulation Through RNA Splicing 483
 - The Degradation of RNA 484
- 17.5 RNA Interference Is an Important Mechanism of Gene Regulation 485
 - Small Interfering RNAs and MicroRNAs 485

Mechanisms of Gene Regulation by RNA
Interference 486
The Control of Development by RNA
Interference 487

17.6 Some Genes Are Regulated by Processes That Affect Translation or by Modifications of Proteins 487

CONNECTING CONCEPTS A Comparison of Bacterial and Eukaryotic Gene Control 488

Chapter 18 Gene Mutations and DNA Repair 493

A Fly Without a Heart 493

18.1 Mutations Are Inherited Alterations in the DNA Sequence 494

The Importance of Mutations 494
Categories of Mutations 494
Types of Gene Mutations 495
Phenotypic Effects of Mutations 497
Suppressor Mutations 498
Mutation Rates 502

18.2 Mutations Are Potentially Caused by a Number of Different Factors 503

Spontaneous Replication Errors 503
Spontaneous Chemical Changes 504
Chemically Induced Mutations 506
Radiation 508

18.3 Mutations Are the Focus of Intense Study by Geneticists 509

Detecting Mutations with the Ames Test 509
Radiation Exposure in Humans 510

18.4 Transposable Elements Cause Mutations 511

General Characteristics of Transposable Elements 511
Transposition 512
The Mutagenic Effects of Transposition 513
Transposable Elements in Bacteria 514
Transposable Elements in Eukaryotes 515

CONNECTING CONCEPTS Types of Transposable Elements 519

Transposable Elements Have Played an Important Role in Genome Evolution 520

18.5 A Number of Pathways Repair Changes in DNA 520

Mismatch Repair 520
Direct Repair 522
Base-Excision Repair 522
Nucleotide-Excision Repair 523

CONNECTING CONCEPTS The Basic Pathway of DNA Repair 524

Repair of Double-Strand Breaks 524
Translesion DNA Polymerases 524
Genetic Diseases and Faulty DNA Repair 525

Chapter 19 Molecular Genetic Analysis and Biotechnology 535

Helping the Blind to See 535

19.1 Techniques of Molecular Genetics Have Revolutionized Biology 536

The Molecular Genetics Revolution 536
Working at the Molecular Level 536

19.2 Molecular Techniques Are Used to Isolate, Recombine, and Amplify Genes 537

Cutting and Joining DNA Fragments 537
Viewing DNA Fragments 539
Locating DNA Fragments with Southern Blotting and Probes 540
Cloning Genes 541
Application: The Genetic Engineering of Plants with Pesticides 545
Amplifying DNA Fragments with the Polymerase Chain Reaction 546

19.3 Molecular Techniques Can Be Used to Find Genes of Interest 549

Gene Libraries 549
In Situ Hybridization 552
Positional Cloning 552
Application: Isolating the Gene for Cystic Fibrosis 553

19.4 DNA Sequences Can Be Determined and Analyzed 555

Restriction Fragment Length Polymorphisms 555
DNA Sequencing 556
Next-Generation Sequencing Technologies 559
DNA Fingerprinting 561
Application: Identifying People Who Died in the Collapse of the World Trade Center 562

19.5 Molecular Techniques Are Increasingly Used to Analyze Gene Function 563

Forward and Reverse Genetics 563
Creating Random Mutations 564
Site-Directed Mutagenesis 564
Transgenic Animals 565
Knockout Mice 566
Silencing Genes with RNAi 567
Application: Using RNAi to Treat Human Disease 568

- 19.6 Biotechnology Harnesses the Power of Molecular Genetics 569
 - Pharmaceutical Products 569
 - Specialized Bacteria 569
 - Agricultural Products 569
 - Genetic Testing 570
 - Gene Therapy 571

Chapter 20 Genomics and Proteomics 579

Decoding the Waggle Dance: The Genome of the Honeybee 579

- 20.1 Structural Genomics Determines the DNA Sequences of Entire Genomes 580
 - Genetic Maps 580
 - Physical Maps 581
 - Sequencing an Entire Genome 582
 - The Human Genome Project 583
 - Single-Nucleotide Polymorphisms 587
 - Copy-Number Variations 588
 - Sequence-Tagged Sites and Expressed-Sequence Tags 589
 - Bioinformatics 589
 - Metagenomics 590
 - Synthetic Biology 591

- 20.2 Functional Genomics Determines the Function of Genes by Using Genomic-Based Approaches 591
 - Predicting Function from Sequence 591
 - Gene Expression and Microarrays 592
 - Gene Expression and Reporter Sequences 595
 - Genome-Wide Mutagenesis 595

- 20.3 Comparative Genomics Studies How Genomes Evolve 596
 - Prokaryotic Genomes 596
 - Eukaryotic Genomes 598
 - Comparative *Drosophila* Genomics 601
 - The Human Genome 601

- 20.4 Proteomics Analyzes the Complete Set of Proteins Found in a Cell 603
 - Determination of Cellular Proteins 603
 - Affinity Capture 604
 - Protein Microarrays 604
 - Structural Proteomics 605

Chapter 21 Epigenetics 613

How Your Grandfather's Diet Could Affect Your Health 613

- 21.1 What Is Epigenetics? 614

- 21.2 Several Molecular Processes Lead to Epigenetic Changes 615
 - DNA Methylation 615
 - Histone Modifications 617
 - Epigenetic Effects by RNA Molecules 618

- 21.3 Epigenetic Processes Produce a Diverse Set of Effects 619
 - Paramutation 619
 - Behavioral Epigenetics 621
 - Epigenetic Effects of Environmental Chemicals 623
 - Transgenerational Epigenetic Effects on Metabolism 623
 - Epigenetic Effects in Monozygotic Twins 623
 - X Inactivation 623
 - Epigenetic Changes Associated with Cell Differentiation 625
 - Genomic Imprinting 626

- 21.4 The Epigenome 627

Chapter 22 Developmental Genetics and Immunogenetics 633

The Origin of Spineless Sticklebacks 633

- 22.1 Development Takes Place Through Cell Determination 634
 - Cloning Experiments on Plants 635
 - Cloning Experiments on Animals 635
- 22.2 Pattern Formation in *Drosophila* Serves As a Model for the Genetic Control of Development 636
 - The Development of the Fruit Fly 636
 - Egg-Polarity Genes 637
 - Segmentation Genes 640
 - Homeotic Genes in *Drosophila* 640
 - Homeobox Genes in Other Organisms 642

CONNECTING CONCEPTS The Control Of Development 643

- Epigenetic Changes in Development 643

- 22.3 Genes Control the Development of Flowers in Plants 644
 - Flower Anatomy 644
 - Genetic Control of Flower Development 644

CONNECTING CONCEPTS Comparison of Development in *Drosophila* and Flowers 646

- 22.4 Programmed Cell Death Is an Integral Part of Development 646
- 22.5 The Study of Development Reveals Patterns and Processes of Evolution 647

22.6 The Development of Immunity Is Through Genetic Rearrangement 649

- The Organization of the Immune System 650
- Immunoglobulin Structure 651
- The Generation of Antibody Diversity 652
- T-Cell-Receptor Diversity 653
- Major Histocompatibility Complex Genes 654
- Genes and Organ Transplants 654

Chapter 23 Cancer Genetics 661

Palladin and the Spread of Cancer 661

23.1 Cancer Is a Group of Diseases Characterized by Cell Proliferation 662

- Tumor Formation 662
- Cancer As a Genetic Disease 663
- The Role of Environmental Factors in Cancer 665

23.2 Mutations in a Number of Different Types of Genes Contribute to Cancer 666

- Oncogenes and Tumor-Suppressor Genes 666
- Mutations in Genes That Control the Cycle of Cell Division 668
- DNA-Repair Genes 672
- Genes That Regulate Telomerase 672
- Genes That Promote Vascularization and the Spread of Tumors 672
- MicroRNAs and Cancer 673
- Cancer Genome Projects 674

23.3 Epigenetic Changes Are Often Associated with Cancer 674

23.4 Colorectal Cancer Arises Through the Sequential Mutation of a Number of Genes 675

23.5 Changes in Chromosome Number and Structure Are Often Associated with Cancer 676

23.6 Viruses Are Associated with Some Cancers 678

Chapter 24 Quantitative Genetics 683

Corn Oil and Quantitative Genetics 683

24.1 Quantitative Characteristics Vary Continuously and Many Are Influenced by Alleles at Multiple Loci 684

- The Relation Between Genotype and Phenotype 684
- Types of Quantitative Characteristics 686
- Polygenic Inheritance 686

Kernel Color in Wheat 687

Determining Gene Number for a Polygenic Characteristic 688

24.2 Statistical Methods Are Required for Analyzing Quantitative Characteristics 689

- Distributions 689
- Samples and Populations 690
- The Mean 690
- The Variance and Standard Deviation 691
- Correlation 692
- Regression 693
- Applying Statistics to the Study of a Polygenic Characteristic 695

24.3 Heritability Is Used to Estimate the Proportion of Variation in a Trait That Is Genetic 696

- Phenotypic Variance 696
- Types of Heritability 698
- Calculating Heritability 698
- The Limitations of Heritability 700
- Locating Genes That Affect Quantitative Characteristics 702

24.4 Genetically Variable Traits Change in Response to Selection 704

- Predicting the Response to Selection 705
- Limits to Selection Response 706
- Correlated Responses 707

Chapter 25 Population Genetics 715

Genetic Rescue of Bighorn Sheep 715

25.1 Genotypic and Allelic Frequencies Are Used to Describe the Gene Pool of a Population 716

- Calculating Genotypic Frequencies 717
- Calculating Allelic Frequencies 717

25.2 The Hardy-Weinberg Law Describes the Effect of Reproduction on Genotypic and Allelic Frequencies 719

- Genotypic Frequencies at Hardy-Weinberg Equilibrium 719
- Closer Examination of the Hardy-Weinberg Law 720
- Implications of the Hardy-Weinberg Law 720
- Extensions of the Hardy-Weinberg Law 721
- Testing for Hardy-Weinberg Proportions 721
- Estimating Allelic Frequencies with the Hardy-Weinberg Law 722

25.3 Nonrandom Mating Affects the Genotypic Frequencies of a Population 723

- 25.4 Several Evolutionary Forces Potentially Cause Changes in Allelic Frequencies 726**
 Mutation 726
 Migration 727
 Genetic Drift 728
 Natural Selection 731

CONNECTING CONCEPTS The General Effects of Forces That Change Allelic Frequencies 736

Chapter 26 Evolutionary Genetics 743

- Taster Genes in Spitting Apes 743**
- 26.1 Evolution Occurs Through Genetic Change Within Populations 744**
- 26.2 Many Natural Populations Contain High Levels of Genetic Variation 745**
 Molecular Variation 745
 Protein Variation 746
 DNA Sequence Variation 747
- 26.3 New Species Arise Through the Evolution of Reproductive Isolation 749**
 The Biological Species Concept 749
 Reproductive Isolating Mechanisms 750
 Modes of Speciation 751
 Genetic Differentiation Associated with Speciation 755

- 26.4 The Evolutionary History of a Group of Organisms Can Be Reconstructed by Studying Changes in Homologous Characteristics 756**
 The Alignment of Homologous Sequences 757
 The Construction of Phylogenetic Trees 758

- 26.5 Patterns of Evolution Are Revealed by Molecular Changes 758**
 Rates of Molecular Evolution 759
 The Molecular Clock 760
 Evolution Through Changes in Gene Regulation 761
 Genome Evolution 762

Reference Guide to Model Genetic Organisms A1

- The Fruit Fly *Drosophila melanogaster* A2
 The Bacterium *Escherichia coli* A4
 The Nematode Worm *Caenorhabditis elegans* A6
 The Plant *Arabidopsis thaliana* A8
 The Mouse *Mus musculus* A10
 The Yeast *Saccharomyces cerevisiae* A12

Glossary B1

Answers to Selected Questions and Problems C1

Index D1

Fifth Edition

Fundamentals of
ECOLOGY

14593



EUGENE P. ODUM

GARY W. BARRETT

Foreword xiii

Preface xv

Acknowledgments xvii

1 The Scope of Ecology 1

1. Ecology: History and Relevance to Humankind 2
2. Levels-of-Organization Hierarchy 4
3. The Emergent Property Principle 7
4. Transcending Functions and Control Processes 9
5. Ecological Interfacing 10
6. About Models 10
7. Disciplinary Reductionism to Transdisciplinary Holism 15

2 The Ecosystem 17

1. Concept of the Ecosystem and Ecosystem Management 18
2. Trophic Structure of the Ecosystem 21
3. Gradients and Ecotones 24
4. Examples of Ecosystems 26
5. Ecosystem Diversity 37
6. Study of Ecosystems 42
7. Biological Control of the Geochemical Environment: The Gaia Hypothesis 43
8. Global Production and Decomposition 46
9. Microcosms, Mesocosms, and Macrocosms 60
10. Ecosystem Cybernetics 67
11. Technoecosystems 71
12. Concept of the Ecological Footprint 74
13. Classification of Ecosystems 75

3 Energy in Ecological Systems 77

1. Fundamental Concepts Related to Energy: The Laws of Thermodynamics 78
2. Solar Radiation and the Energy Environment 82
3. Concept of Productivity 86
4. Energy Partitioning in Food Chains and Food Webs 108
5. Energy Quality: eMergy 121
6. Metabolism and Size of Individuals: The 3/4 Power Principle 124
7. Complexity Theory, Energetics of Scale, and the Law of Diminishing Returns 126
8. Concepts of Carrying Capacity and Sustainability 127
9. Net Energy Concept 132
10. An Energy-Based Classification of Ecosystems 132
11. Energy Futures 135
12. Energy and Money 137

4 Biogeochemical Cycles 140

1. Basic Types of Biogeochemical Cycles 141
2. Cycling of Nitrogen 143
3. Cycling of Phosphorus 149
4. Cycling of Sulfur 151
5. Cycling of Carbon 153
6. The Hydrologic Cycle 156
7. Turnover and Residence Times 162
8. Watershed Biogeochemistry 163
9. Cycling of Nonessential Elements 168
10. Nutrient Cycling in the Tropics 170
11. Recycling Pathways: The Cycling Index 172
12. Global Climate Change 175

5 Limiting and Regulatory Factors 177

1. Concept of Limiting Factors: The Liebig Law of the Minimum 178
2. Factor Compensation and Ecotypes 183
3. Conditions of Existence as Regulatory Factors 185
4. Soil: Organizing Component for Terrestrial Ecosystems 187
5. Fire Ecology 194
6. Review of Other Physical Limiting Factors 199
7. Biological Magnification of Toxic Substances 215
8. Anthropogenic Stress as a Limiting Factor for Industrial Societies 219

6 Population Ecology 224

1. Properties of the Population 225
2. Basic Concepts of Rate 236
3. Intrinsic Rate of Natural Increase 238
4. Concept of Carrying Capacity 241

5. Population Fluctuations and Cyclic Oscillations 246
6. Density-Independent and Density-Dependent Mechanisms of Population Regulation 255
7. Patterns of Dispersion 258
8. The Allee Principle of Aggregation and Refuging 260
9. Home Range and Territoriality 263
10. Metapopulation Dynamics 267
11. Energy Partitioning and Optimization: *r*- and *K*-Selection 268
12. Population Genetics 275
13. Life History Traits and Tactics 280

7 Community Ecology 282

1. Types of Interaction Between Two Species 283
2. Coevolution 286
3. Evolution of Cooperation: Group Selection 288
4. Interspecific Competition and Coexistence 289
5. Positive/Negative Interactions: Predation, Herbivory, Parasitism, and Allelopathy 296
6. Positive Interactions: Commensalism, Cooperation, and Mutualism 304
7. Concepts of Habitat, Ecological Niche, and Guild 311
8. Biodiversity 316
9. Paleoecology: Community Structure in Past Ages 327
10. From Populations and Communities to Ecosystems and Landscapes 329

8 Ecosystem Development 336

1. Strategy of Ecosystem Development 337
2. Concept of the Climax 356
3. Evolution of the Biosphere 360
4. Microevolution Compared with Macroevolution, Artificial Selection, and Genetic Engineering 364
5. Relevance of Ecosystem Development to Human Ecology 368

9 Landscape Ecology 374

1. Landscape Ecology: Definition and Relation to Levels-of-Organization Concept 375
2. Landscape Elements 377
3. Biodiversity at the Community and Landscape Levels 386
4. Island Biogeography 389
5. Neutral Theory 392
6. Temporal and Spatial Scale 396
7. Landscape Geometry 399
8. Concept of Landscape Sustainability 404
9. Domesticated Landscapes 404

10 Regional Ecology: Major Ecosystem Types and Biomes 412

1. Marine Ecosystems 414
2. Freshwater Ecosystems 424
3. Terrestrial Biomes 432
4. Human-Designed and Managed Systems 457

11 Global Ecology 459

1. The Transition from Youth to Maturity: Toward Sustainable Civilizations 460
2. Ecological-Societal Gaps 465
3. Global Sustainability 467
4. Scenarios 472
5. Long-Term Transitions 477

12 Statistical Thinking for Students of Ecology 479

Guest Author R. Cary Tuckfield

1. Ecosystems and Scale 480
2. Theory, Knowledge, and Research Design 482
3. The Ecological Study Unit 484
4. Inference Methods and Reliability 486
5. Experimental versus Observational Method in Ecology 489
6. Statistical Thinking in Ecology 490
7. The Nature of Evidence 492
8. Evidence and Hypothesis Testing 494
9. Formulating the Right Problem 496
10. Publish or "Parish"? 496
11. The Evidence-Oriented Alternative 498
12. The Two Ways of Discovery 505
13. The Weight of Evidence Paradigm 507

Glossary 509

References 533

Credits 581

Index 583

***INVERTEBRATE
FOSSILS***

RAYMOND C. MOORE

CECIL G. LALICKER

ALFREDO G. FISCHER

Contents

<i>Preface</i>	1
1. THE NATURE OF FOSSILS (MOORE, FISCHER, LALICKER)	16
Requisites of fossilization	1
Types of preservation	1
Unaltered soft parts—Unaltered hard parts	
Altered hard parts—Traces of animals—	
Distortion and obliteration of fossils	
Diversity of fossils	6
Value of fossils	7
Stratigraphic indicators—Records of past	
forms of life—Significance in historical	
geology	
Kinds of animals and names for them	9
Concepts of species and genera—Scientific	
names of species and genera—Subdivisions	
of species—Subgenera—Categories of higher	
rank than genus—Principal divisions of	
animals	
Adaptation to environment	16
Factors in marine environments—Kinds of	
marine environments—Land environments—	
Facies fossils	
Development of individual animals	22
Kinds of individuals and their associations—	
Beginning of the individual—Factors in-	
fluencing development—Nature of growth—	
Life history	
Evolution of animals	28
Evidence of evolution—Evolutionary changes	
in animal assemblages—Branching of species	
—Extinction of animals—Patterns of evolu-	
tion—Rates of evolution	
Fossil-bearing rock divisions	35
References	38
2. FORAMINIFERA AND RADIOLARIA (LALICKER)	39
Foraminifera	39
Living animal—Life history—Test—Ecology—	
Classification—Geological distribution	
Larger Foraminifera	60
Fusulinids—Camerinids—Orbitoidids—Dis-	
cocylinids—Miliolinids—Ecology	
Radiolaria	72
Skeletal structures—Physiological features	
—Classification—Geological distribution	
and importance	
Flagellates	75
Silicoflagellates—Coccoliths—Dinoflagel-	
lates	
Tintinnids	76
References	76
3. SPONGES AND SPONGELIKE FOSSILS (MOORE)	79
General characters	79
Reproduction	80
Fossil record	81
Structural features	81
Soft parts—Skeleton	
Classification	87
Calcareous sponges	89
Siliceous sponges	91
Spongelike organisms	93
Pleospoges—Receptaculitids—Nidulites	
References	97
4. COELENTERATES (MOORE)	99
Characters of representative modern coel-	
enterates	99
Hydra, a simple hydrozoan—Obelia, a co-	
lonial hydrozoan—Metridium, an anthozoan	
Classification	103
Hydrozoans	105
Hydroids—Milleporids and stylasterids—	
Sphaeractiniids—Stromatoporids and labe-	
chiids	
Scyphozoans	309

Alcyonarians	110	genaria and Pachyphyllum—Main groups and their geological occurrence—Evolutionary trends	
Tabulate corals	112	Heterocorals	
<i>Scleroporals</i> — <i>Thallicorals</i>		Scleractinian corals	
Zoantharians	115	Morphological features—Main groups and evolutionary trends of scleractinians—Origin and geological history	
Rugose corals	118	References	
Structures illustrated by <i>Streptelasma</i> and <i>Lambeophyllum</i> —Structures illustrated by <i>Heritichia</i> —Structures illustrated by <i>Synaptophyllum</i> —Structures illustrated by <i>Hexagonaria</i>			
5. BRYOZOANS (MOORE)			
Anatomical features	156	Skeletal features of main bryozoan groups	
Collection and study of bryozoans	158	<i>Trepastome</i> bryozoans— <i>Cryptostome</i> bryozoans— <i>Ctenostome</i> bryozoans— <i>Cyclostome</i> bryozoans— <i>Cheilostome</i> bryozoans	
Preparation of thin sections—Interpretation of thin sections		Geological distribution and importance	
Classification	159	References	
6. BRACHIOPODS (MOORE)			
Anatomical features	199	Classification	
Soft parts—Hard parts		Definition of main divisions—Significance of shell structure—Summary of classification	
Reproduction and larval growth	204	Inarticulate brachiopods	
Inarticulate shells	205	<i>Atremates</i> — <i>Neotremates</i>	
Morphological features		Articulate brachiopods	
Articulate shells	207	<i>Palaeotremates</i> — <i>Orthis</i> — <i>Terebratulids</i> — <i>Pentamerids</i> — <i>Triplerids</i> — <i>Rhynchonellids</i> — <i>Strophomenids</i> — <i>Spiriferids</i>	
Morphological features		Geological distribution	
Shell growth	213	References	
Types of enlargement—Evolution of interareas			
Shell form	216		
Homeomorphy	217		
7. MOLLUSKS (MOORE)			
Classification	269	Minor classes	
Anatomical features	270	<i>Chitons</i> — <i>Scaphopods</i>	
Soft parts—Hard parts		References	
8. GASTROPODS (MOORE)			
Soft parts	277	<i>Archaeogastropods</i> — <i>Mesogastropods</i> — <i>Neogastropods</i>	
Head—Viscera—Foot and mantle		Opisthobranchs	
Hard parts	279	<i>Pleurocoels</i> — <i>Pteropods</i>	
Noncoiled shells—Coiled shells		Pulmonates	
Classification	287	<i>Basommatophorans</i> — <i>Stylommatophorans</i>	
Evolutionary trends	290	Indirect paleontological evidence of gastropods	
Geological distribution	296	References	
Amphigastropods	297		
Prosobranchs	301		
9. CEPHALOPODS (FISCHER)			
Living cephalopods	336	Nautiloid cephalopods	
<i>Loligo</i> , a squid— <i>Nautilus</i> — <i>Octopus</i>		Kinds of nautiloids— <i>Volborthella</i> — <i>Ellesmeroceroids</i> — <i>Michelinoceroids</i> — <i>Ascoceroids</i> — <i>Oncoceroids</i> — <i>Endoceroids</i> — <i>Actinoceroids</i> — <i>Discosoroids</i> — <i>Nautilids</i> —Geological history of nautiloids	
Geologic importance	341		
Classification	341		
Functions and development of shell	343		

Ammonoid cephalopods	361	<i>belemnoids—Function of the belemnoid shell</i>	
<i>Goniatites—Variations of ammonoid shells</i>		<i>—Geological history and evolutionary trends</i>	393
<i>—Geological history of ammonoids—Evo-</i>		Sepioids	394
<i>lutionary trends—Life habits</i>		Teuthoids	395
Belemnoids	388	Octopods	395
<i>Megatritids—Other belemnoids—Origin of</i>		References	398
10. PELECYPODS (MOORE)		Dysodonts	423
Anatomical features	400	<i>Pectinacea—Mytilacea—Pinnacea—Ostre-</i>	
<i>Soft parts—Shell</i>		<i>acea—Limacea—Dreissenacea</i>	434
Modes of life	406	Heterodonts	440
Reproduction and ontogeny	407	<i>Cypricardiacea—Lucinacea—Cyrenacea</i>	
Classification	409	Pachyodonts	440
Palaeoconchs	412	<i>Chamaea—Ruditacea</i>	
Taxodonts	414	Desmodonts	442
<i>Nuculacea—Arcacea</i>		<i>Anatinaea—Myacea—Adesmaea—Mac-</i>	
Schizodonts	418	<i>tracea—Solenacea—Purpuracea</i>	
<i>Trigoniacea—Cardiniacea</i>		Evolutionary trends	447
Isodonts	422	Geological distribution and importance	450
<i>Spondylacea—Anomiaea</i>		References	450
11. ANNELIDS AND OTHER WORMS (LALICKER, MOORE)			
Morphological features of annelids	452	Conulariids	458
<i>External features—Digestive, circulatory,</i>		<i>Morphological features—Kinds of conu-</i>	
<i>and respiratory systems—Excretory and</i>		<i>lariids—Ecologic association—Zoological</i>	
<i>nervous systems—Reproductive organs</i>		<i>affinities</i>	
Geologic work of worms	453	References	462
Classification	454		
12. ARTHROPODS (MOORE)			
Skeletal features	464	Mode of life	469
<i>Segmentation of body—Organization of body</i>		Classification	470
<i>segments—Appendages</i>		Geological distribution	471
Growth stages	467	Pararthropods	472
Physiological structures	468	References	474
<i>Digestive, circulatory, and respiratory sys-</i>			
<i>tems—Nervous system and sense organs</i>			
13. TRILOBITES (MOORE)			
Structure of main skeletal divisions	478	<i>Protoparians—Proparians—Opisthoparians</i>	
<i>Cephalon—Thorax—Pygidium</i>		<i>—Hypoparians—Eodiscids—Agnostids</i>	
Internal anatomy	484	Evolutionary trends of trilobites	497
Growth stages	484	<i>Primitive characters—Facial sutures—Gla-</i>	
<i>Larval development—Attainment of adult</i>		<i>bella—Eyes—Thorax—Pygidium—Spi-</i>	
<i>characters</i>		<i>nosity—General conclusions</i>	
Classification	486	Geological distribution	515
Character of main trilobite groups	488	Minor trilobitiforms	519
		References	519
14. OSTRACODES AND OTHER CRUSTACEANS (LALICKER, MOORE)			
Characters of crustaceans	521	<i>Hard parts—Orientation of shell—Growth</i>	
<i>Morphological features—Growth stages—</i>		<i>stages—Appendages—Physiological features</i>	
<i>Physiological features—Crustaceans as food</i>		<i>—Reproduction—Mode of life—Classifica-</i>	
Ostracodes	526	<i>tion—Geological distribution and importance</i>	

Other crustaceans	541	References	550
<i>Branchiopods—Cirripeds—Malacostracans</i>			
15. CHELICERATES, MYRIAPODS, AND INSECTS (MOORE)			552
Chelicerates	552	<i>Diplopods—Chilopods</i>	
<i>Distinguishing features—Merostomes (Xiphosurans, Eurypterids)—Arachnids—Pycnogonids</i>		Insects	567
Myriapods	566	<i>Primitive wingless insects—Winged insects</i>	
		References	572
16. ECHINODERMS (MOORE)			574
Kinds of echinoderms	577	Relationships	580
Modes of life	578	Geological distribution	581
Larval development	578	References	581
17. PRIMITIVE ATTACHED ECHINODERMS (MOORE)			582
Eocrinoids	583	Blastoids	594
Paracrinoids	583	<i>Structural features of Pentremites—Geological record and evolutionary trends of blastoids</i>	
Carpoids	585	References	601
Edrioasteroids	586		
Cystoids	587		
<i>Cystoids bearing pore rhombs—Cystoids bearing paired pores—Evolution of cystoids</i>			
18. CRINOIDS (MOORE)			604
Modern crinoids	604	Flexible crinoids	626
<i>Soft parts—Hard parts—Orientation</i>		Camerate crinoids	628
Classification	613	<i>General evolutionary trends—Diplobathrid camerates—Monobathrid camerates</i>	
Structures of fossil crinoids	614	Articulate crinoids	635
<i>Calyx—Dorsal cup—Ray system—Column</i>		<i>Stem-bearing forms—Free-swimming forms</i>	
Inadunate crinoids	621	References	650
<i>Disparid inadunates—Hybocrinid inadunates—Cladid inadunates</i>			
19. HOLOTHUROID (FISCHER)			653
Morphology	653	Geological distribution	657
<i>Soft parts—Skeleton</i>		Relationships	658
Life habits	656	References	658
Classification	657		
20. STARFISHES (FISCHER)			659
Classification of starfishes	659	Ophiuroids	665
Somasteroids	659	<i>Structure—Mode of life—Geological distribution and evolution</i>	
Asteroids	661	References	674
<i>Structure of a sea star—Mode of life—Geological distribution and evolution</i>			
21. ECHINOIDS (FISCHER)			675
Regular echinoids	675	Irregular echinoids	684
<i>Morphology—Orientation—Classification of regular echinoids—Structural variations of regular echinoids—Lepidocentroids—Melo-nechinoids—Cidaroids—Stirodonta—Aulodonta—Camarodonts</i>		<i>Main divisions of irregular echinoids—Holoctypoids—Cassiduloids—Spatangoids—Clypeastroids</i>	
		Ecology and mode of life	703

CONTENTS

xiii

Geological history and importance. . . 709
*Relationships and origin—Development of
 orders—Geological importance*
 Primitive cleutherozoans of uncertain

affinities 712
Bothriocidaroids—Ophiocystids
 References 713

22. GRAPTOLITES AND PTEROBRANCHS (FISCHER) 715

Relation of graptolites and pterobranchs 716
Rhabdopleura, a representative ptero-
 branch. 716
 Classification of protochordates 717

Graptolites 718
*Preservation and preparation—Dendroid
 graptolites—Tuboids, camaroids, and stolo-
 noids—Graptoloids*
 References 732

23. CONODONTS (LALICKER) 733

Sedimentary environment. 733
 Classification 733

Orientation. 738
 References 738

Index. 739

VEER BALA KRISHNAN

VERTEBRATE ZOOLOGY

KEDAR NATH RAM NATH
MEERUT

CONTENTS

PROTOCHORDATES

Chapter 1.	Chordate Characters	1—7
Chapter 2.	Hemichordata	8—10
Chapter 3.	Balanoglossus	11—23
Chapter 4.	Urochordata	24—33
Chapter 5.	Herdmania	34—59
Chapter 6.	Cephalochordata	60—81
Chapter 7.	Comparative Questions	82—88
Chapter 8.	Short Notes	89—94

LOWER CHORDATES

Chapter 1.	Cyclostomats	95—100
Chapter 2.	Pisces	101—121
Chapter 3.	Pisces (Miscellaneous)	122—130
Chapter 4.	Class Amphibia	131—145
Chapter 5.	Comparative Questions (Lower Chordates)	147—158
Chapter 6.	Short Notes	158—172

HIGHER CHORDATES

Chapter 1.	Class Reptilia	173—186
Chapter 2.	<u>Snakes</u>	187—206
Chapter 3.	<u>Class Aves</u>	207—214
Chapter 4.	<u>Pigeon</u>	215—262
Chapter 5.	Mammalia	263—287
Chapter 6.	Comparative Questions (Higher Chordates)	288—312
Chapter 7.	Short Notes	313 324

HISTOLOGY

Chapter 1.	Histology	325—35
------------	-----------	--------

Embryology of Chick and Man

Chapter 1. Embryology of Chick

PHYSIOLOGY

- Chapter 1. Food and Digestion**
- Chapter 2. Metabolism**
- Chapter 3. Respiration**
- Chapter 4. Circulation**
- Chapter 5. Excretion**
- Chapter 6. Osmo-Regulation**
- Chapter 7. Muscular Activity**
- Chapter 8. Nervous System**
- Chapter 9. Endocrine System**
- Chapter 10. Short Notes**

EVIDENCES OF ORGANIC EVOLUTION

- Chapter 1. Geographical Distribution of Animal or Zoogeography**
- Chapter 2.**



THE INVERTEBRATE ZOOLOGY

HAMID KHAN BHATTI
TAJAMMUL HUSSAIN HASHIMI



THE CARAVAN BOOK HOUSE LAHORE
KUTCHERY ROAD, LAHORE

Contents

	Page
Preface	v
List of contents	vii
Introduction	xii
1. SUBKINGDOM AND PHYLUM PROTOZOA	1
✓ General Account of Protozoa.	2
Subphylum Sarcomastigophora.	7
Superclass Sarcodina	9
Class Rhizopoda	9
Type— <i>Amoeba proteus</i> .	7
Classification and general survey	9
Superclass Opalinata	19
Type— <i>Opalina</i> .	19
Superclass Mastigophora	19
Class Phytomastigophora	19
Type— <i>Euglena viridis</i>	19
Class Zoomastigophora	21
Type— <i>Trypanosoma gambiense</i>	21
Classification and General Survey	22
Subphylum Sporozoa	29
Class Telesporea	29
Type—1. <i>Monocystis magna</i>	29
Type 2. <i>Eimeria perforans</i>	31
Classification and General Survey	32
Subphylum Cnidospora	34
Type— <i>Myxobolus</i>	34
Subphylum Ciliophora	36
Class Ciliata	36
Type— <i>Paramecium caudatum</i> ✓	36
Classification and General Survey	40
Relationship of Protozoa with other organisms	44
Behaviour of Protozoa	45
Introduction to Subkingdom Metazoa	46
2. SUBKINGDOM PARAZOA	48
PHYLUM PORIFERA ✓	48
Class Calcarea	48
✓ Type— <i>Sycon gelatinosum</i> ✓	48
General Account—	51
Classification and General Survey	57
3. SUBKINGDOM METAZOA	60
PHYLUM COELENTERATA (CNIDARIA) ✓	60
Class Hydrozoa	60
Type 1.— <i>Hydra vulgaris</i>	60
Type 2.— <i>Obelia geniculata</i> ✓	66

Classification and General Survey of Class Hydrozoa..	...	...
Class Scyphozoa	...	...
Type— <i>Aurelia aurita</i>	...	...
Classification and General Survey	...	...
Class Actinozoa	...	...
Type— <i>Taelia crassicornis</i>	...	...
Classification and General Survey	...	...
4. PHYLUM CTENOPHORA	...	...
Type— <i>Hormiphora plumosa</i>	...	...
General Account and Classification	...	...
Affinities	...	...
5. PHYLUM PLATYHELMINTHES ✓	...	...
Class Turbellaria	...	...
Type— <i>Planaria (Dugesia)</i>	...	...
Classification	...	...
General Account	...	...
Affinities	...	...
Class Trematoda	...	...
Type— <i>Fasciola hepatica</i> ✓	...	...
Classification	...	...
General Account	...	...
Affinities	...	...
Class Cestoidea	...	...
Type— <i>Taenia solium</i>	...	...
Classification	...	...
General Account	...	...
Affinities	...	...
Mode of life in Platyhelminthes	...	...
6. PHYLUM ASCHELMINTHES ✓	...	...
Nemathelminthes	...	...
Class 1. Nematoda	...	...
Type— <i>Ascaris lumbricoides</i> ✓	...	...
Classification	...	...
General Account	...	...
Affinities	...	...
Class 2. Nematomorpha	...	...
Classification	...	...
Affinities	...	...
Class 3. Rotifera	...	...
Type— <i>Brachionus rubens</i>	...	...
Classification and General Accounts	...	...
Class 4. Gastrotricha	...	...
Type— <i>Chaetonotus maximus</i>	...	...
Classification and Affinities	...	...
Class 5. Kinorhyncha	...	...
Type— <i>Echinoderes</i>	...	...
Affinities	...	...
7. MINOR PHYLA	...	...
MINOR ACOELOMATE PHYLA	...	...
1. PHYLUM NEMERTEA (RHYNCHOCEPHALA)	...	...
Classification	...	...
General Account	...	...

A
HANDBOOK
OF®



Zoology

FOR: BSc.

PAPER - B

JAVED IQBAL MUGHAL

Majeed Sons



**URDU BAZAR, LAHORE
FAISALABAD**

uzma

PREFACE

The Handbook of **Chordate Zoology** is written for graduate students of zoology to cover **Paper - B**. There are 26 chapters in this book which are divided into three parts. In part One types are discussed; in part **Two different systems** are discussed on comparative bases and in part **Three classification** is taken up. No doubt the subject under discussion is very vast and open, but I have tried my level best to limit myself strictly within the spectrum of syllabus.

The Handbook of chordate zoology is designed to provide all the relevant information needed for the preparation of B.Sc. Paper B.

As this is my first effort there may be certain omissions and some mistakes. Perfection is difficult to achieve but it should aim at. It is therefore requested that the errors detected should be brought to the notice of author or publisher. Positive suggestion and constructive criticism of colleagues and students will encourage me to improve the book.

I am sincerely thankful to my friends for their valuable suggestions. I am extremely thankful to my teacher to whom I owe greatly for their excellent guidance.

I am also thankful to Mr. Yousaf Mukhtar Ahmad who helped me in the publication of this book.

Prof. Javed Iqbal Mughal

Zoology Department

Government College Lahore.

VERTEBRATE BIOLOGY

THIRD EDITION

**JOSEPH G. ENGEMANN
ROBERT W. HEGNER**

Contents

Introduction	xvii
General References	xix
1. Basic Principles of Invertebrate Zoology	1
References	26
2. Protozoa	27
Superclass Mastigophora	29
EUGLENA / OTHER MASTIGOPHORA	52
Superclass Sarcodina	78
AMOEBA PROTEUS / OTHER SARCODINA	92
Sporozoa (Superclasses Apicomplexa-Microspora)	
MONOCYSTIS / PLASMODIUM VIVAX / OTHER SPOROZOA	
Superclass Ciliata	
TETRAHYMENA PYRIFORMIS / PARAMECIUM / OTHER CILIATA	
	ix

Protozoa in General

References to Literature on the Protozoa

3. Phylum Porifera

Class Calcarea

LEUCOSOLENIA / SCYPHA

Class Demospongea

SPONGILLA

Other Porifera

CALCAREA / HYALOSPONGEA / DEMOSPONGEA

Sponges in General

References to Literature on the Porifera

4. Phylum Coelenterata

Class Hydrozoa

HYDRA / OBELIA / GONIONEMUS / OTHER HYDROZOA

Class Scyphozoa

AURELIA / OTHER SCYPHOZOA

Class Anthozoa

METRIDIUM / ASTRANGIA / OTHER ANTHOZOA

Coelenterata in General

References to Literature on the Coelenterata

5. Phylum Platyhelminthes

Class Turbellaria

DUGESIA / OTHER TURBELLARIA

Class Trematoda	270
OPISTHORCHIS SINENSIS / OTHER TREMATODA	
Class Cestoda	285
TAENIA / OTHER CESTODA	
Platyhelminthes in General	292
References to Literature on the Platyhelminthes	304
6. Phylum Aschelminthes	307
Class Gnathostomula	309
GNATHOSTOMULA	
Class Gastrotricha	312
CHAETONOTUS / OTHER GASTROTRICHA	
Class Rotifera	314
EPIPHANES SENTA / OTHER ROTIFERA	
Class Kinorhyncha	322
Class Nematoda	323
TURBATRIX ACETA / ASCARIS LUMBRICOIDES OTHER NEMATODA	
Class Nematomorpha	343
Aschelminthes in General	344
References to Literature on the Aschelminthes	349
7. Minor Phyla	352
Phylum Mesozoa	353
Phylum Ctenophora	354
Phylum Acanthocephala	360

<i>Phylum Rhynchocoela</i>	362
<i>Phylum Priapulida</i>	366
<i>Phylum Polyzoa</i>	367
PHYLACTOLAEMATA / STENOLAEMATA / GYMNOLAEMATA	
<i>Phylum Brachiopoda</i>	374
INARTICULATA OR ECARDINES / ARTICULATA OR TESTICARDINES	
<i>Phylum Phoronidea</i>	377
<i>Phylum Sipunculida</i>	377
<i>Phylum Chaetognatha</i>	378
<i>Phylum Pogonophora</i>	380
<i>Phylum Hemichordata</i>	383
ENTEROPNEUSTA / PTEROBRANCHIA	
<i>Phylum Chordata</i>	385
UROCHORDATA / CEPHALOCHORDATA / CHORDATES IN GENERAL	
<i>References to Literature on the Minor Phyla</i>	388

8. *Phylum Annelida*

<i>Class Polychaeta</i>	392
NEREIS VIRENS / OTHER POLYCHAETA	393
<i>Class Oligochaeta</i>	405
LUMBRICUS TERRESTRIS / OTHER OLIGOCHAETA	
<i>Class Hirudinea</i>	420
HIRUDO MEDICINALIS / OTHER HIRUDINEA	
<i>Class Echiuroidea</i>	426

Annellids in General	427
References to Literature on the Annelida	431
9. Phylum Mollusca	433
Class Amphineura	434
NEOPILINA GALATHEAE / OTHER AMPHINEURA	
Class Gastropoda	439
HELIX POMATIA / OTHER GASTROPODA	
Class Pelecypoda	454
ANODONTA / OTHER PELECYPODA	
Class Scaphopoda	467
Class Cephalopoda	468
LOLIGO PEALII / OTHER CEPHALOPODA	
Mollusks in General	471
References to Literature on the Mollusca	48
10. Phylum Arthropoda	48
Class Crustacea	41
THE CRAYFISH / ASELLUS / OTHER CRUSTACEA	5
Class Insecta	5
Class Chilopoda	5
Class Diplopoda	
Class Pauropoda	
Class Symphyla	
Class Onychophora	

Class Merostomata

Class Arachnoidea

THE SPIDER / OTHER ARACHNOIDEA

Class Pycnogonoidea

Class Tardigrada

Class Pentastomoidea

Arthropods in General

References to Literature on the Arthropoda

11. Class Insecta

Dissosteira carolina

Other Insecta

SUBCLASS APTERYGOTA / SUBCLASS PALEO-
PTERYGOTA / SUBCLASS EXOPTERYGOTA / SUBCLASS
ENDOPTERYGOTA

Insects in General

References to Literature on the Insecta

12. Phylum Echinodermata

Class Asteroidea

ASTERIAS / OTHER ASTEROIDEA

Class Ophiuroidea

Class Echinoidea

ARBACIA / OTHER ECHINOIDEA

Class Holothuroidea

THYONE / OTHER HOLOTHUROIDEA

Class Crinoidea

Fossil Echinoderms	689
Echinoderms in General	691
References to Literature on the Echinodermata	698
3. Invertebrates—An Overview	700
References	715
4. Application—The Deep-Sea Invertebrates	717
References to Literature on the Deep-Sea Invertebrates	731
Index	733



Zoology

Textbook of Zoology

T. Jeffery Parker &
William A. Haswell

226

1857

W.A.

Seventh Edition

LOW-PRICED EDITION

CONTENTS

PHYLUM CHORDATA	1
SUB-PHYLUM ADELOCHORDATA (HEMICHORDATA)	5
CLASS ENTEROPNEUSTA	5
External characters and coelom (p. 5); alimentary canal and associated structures (p. 8); stomochord (proboscis or buccal diverticulum) (p. 10); blood-vascular system (p. 10); nervous system (p. 11); locomotion (p. 11); reproductive organs (p. 11); development (p. 11); tornaria (p. 13).	
CLASS PTEROBRANCHIA	14
Blood-vascular system (p. 17); reproduction (p. 17); affinities (p. 20).	
SUB-PHYLUM TUNICATA (UROCHORDATA)	20
CLASS ASCIDIACEA	21
Example of the Class. (The Ascidian or Sea-squirt (<i>Ascidia</i>) (p. 21); body-wall and atrial cavity (p. 22); pharynx (p. 23); alimentary canal (p. 25); blood-vascular system (p. 25); excretion (p. 27); nervous system (p. 27); neural gland (p. 27); reproductive system (p. 27); development and metamorphosis (p. 28).	
General Organisation of Ascidians: General features (p. 34); composite ascidians (p. 36.)	
CLASS THALIACEA	36
Orders Doliolida (Cyclomyaria) (p. 36); Pyrosomida (p. 39); Salpida (Desmomyaria) (p. 41).	
CLASS LARVACEA (APPENDICULARIA)	44
General features, affinities (p. 46).	
SUB-PHYLUM ACRANIA (CEPHALOCHORDATA)	47
Example of the Sub-phylum. —The Lancelet (<i>Amphioxus</i>) (<i>Branchiostoma</i>) (p. 47); body-wall (p. 49); skeleton (p. 50); alimentary canal and associated structures (p. 51); atrium (p. 53); ingestion, digestion, and absorption (p. 53); coelom (p. 54); blood-vascular system (p. 54); excretory organs (p. 56); nervous system (p. 57); organs of special sense (p. 59); reproductive system (p. 59); development (p. 60); affinities (p. 67).	
GENERAL INTRODUCTION TO CRANIATE (VERTEBRATE) FORMS	69
Craniate Tissues: epithelial tissue (p. 70); connective tissue (p. 70); adipose tissue (p. 70); blood (p. 70); lymph (p. 71); cartilage (p. 71); bone (p. 71); muscle (p. 71); neural tissue (p. 71); ectodermal derivatives (p. 71); mesodermal derivatives (p. 71); endodermal derivatives (p. 71).	
The Craniate Body: External characters (p. 78); skeleton (p. 88); endoskeleton (p. 89); alimentary canal and associated structures (p. 102); organs of respiration (p. 105); blood-vascular system (p. 108); lymphatics (p. 115); nervous system (p. 116); somatic motor nerves (p. 130); branchial arch nerves (p. 130); sensory organs (p. 135); olfactory organ (p. 137); eye (p. 139); development of the eye (p. 142); apparatus of audition and equilibration (p. 143); endocrine organs (p. 147); urinogenital organs (p. 154); development (p. 160); metamerism (p. 161).	
SUB-PHYLUM CRANIATA (VERTEBRATA)	163

SUPER-CLASS AGNATHA	164
CLASS EUPHANERIDA	167
CLASS HETEROSTRACI (PTERASPIDA)	168
CLASS ANASPIDA	170
CLASS OSTEOSTRACI (CEPHALASPIDA)	171
COELOLEPIDA	174
CLASS PETROMYZONTIA	175
Example of the Class. —The Lamprey (<i>Petromyzon</i>)	176
External Characters (p. 177); endoskeleton (p. 180); muscles (p. 184); alimentary canal and associated structures (p. 184); respiratory organs (p. 185); circulatory system (p. 186); nervous system (p. 187); organs of special sense (p. 190); urino-genital system (p. 193); development (p. 194).	
CLASS MYXINOIDEA	197
Comparison of the Myxinoidea with the Lamprey	198
SUPER-CLASS GNATHOSTOMATA	203
CLASS PLACODERMI (APHETOHYOIDEA)	205
Sub-class Acanthodii	207
Sub-class Arthrodira	210
Sub-class Petalichthyida	212
Sub-class Antiarchi (Pterichthyomorphi)	214
Sub-class Rhenanida	216
Sub-class Palæospondylia	217
CLASS ELASMOBRANCHII (CHONDRICHTHYES) (SELACHII)	219
Orders Cladoselachi (Pleuropterygii) (p. 222); Pleuracanthodii (Ichthyotomi) (p. 224); Protoselachii (p. 224); Euselachii (p. 226).	
Example of the Class. —A Dogfish (<i>Scyliorhinus</i> (= <i>Scyllium</i>), <i>Squalus</i> , <i>Brachælorus</i> , etc.) (p. 229); general external features (p. 229); skeleton (p. 231); alimentary canal and associated structures (p. 237); respiration (p. 239); blood-vascular system (p. 240); nervous system (p. 245); organs of special sense (p. 249); endocrine organs (p. 251); excretion and osmoregulation (p. 252); reproduction (p. 254).	
Sub-class Bradyodonti	256
Order Holocephali	256
External characters (p. 258); endoskeleton (p. 259); alimentary canal (p. 261); respiratory organs, heart, brain (p. 262); urinogenital organs and reproduction (p. 263).	
General Organisation of Elasmobranchs: External characters (p. 265); integument (p. 267); endoskeleton (p. 267); skull (p. 268); electric organs (p. 271); alimentary canal and associated structures (p. 272); respiratory organs (p. 273); blood-vascular system (p. 273); brain (p. 274); organs of special sense (p. 274); audio-equilibration (p. 275); endocrine organs (p. 276); urinogenital organs and reproduction (p. 276); placentation (p. 278); development (p. 279).	
CLASS OSTEICHTHYES	282
Sub-class Actinopterygii	282
Super-order Chondrostei	285
Orders Palæoniscoidea (p. 285); Acipenseroides (p. 288); Polypterini (Cladistia) (p. 290).	
Super-order Holostei	291
Orders Semionotoidea (p. 292); Amioidea (p. 292).	
Super-order Teleostei	293
Soft-rayed orders (p. 296); Intermediate orders (p. 296); Spiny-rayed and allied orders (p. 297).	
Example of the Sub-class. —The Brook or Brown Trout (<i>Salmo fario</i>)	298
External characters (p. 298); skin and exoskeleton (p. 300); endoskeleton (p. 300); muscles (p. 309); coelom (p. 309); alimentary canal and associated structures	

CONTENTS

xiii

(p. 309); nervous system (p. 312); autonomic nervous system (p. 314); organs of special sense (p. 315); osmoregulation and excretion (p. 317); endocrine organs (see p. 346); reproduction (p. 318); development (p. 319).	
General Organisation of Actinopterygians: External form (p. 320); exoskeleton (p. 329); endoskeleton (p. 330); electric organs (p. 334); alimentary canal and associated structures (p. 335); respiratory organs (p. 337); swim-bladder (p. 339); blood-vascular system (p. 342); brain (p. 344); exteroception (p. 344); endocrine organs (p. 346); urinogenital organs (p. 347); reproduction (p. 349); development (p. 352).	
Sub-class Crossopterygii (Choanichthes)	
Classification (p. 354).	353
Order Rhipidistia	
Sub-orders Osteolepidoti (p. 354); Coelacanthini (Actinistia) (p. 356).	354
Order Dipnoi (Dipneusti, Dipneumones)	
Sub-orders Monopneumona (p. 364); Dipneumona (p. 365).	361
Example of the Sub-class. — <i>Protopterus aethiopicus</i>	
Endoskeleton (p. 367); alimentary canal and associated structures (p. 369); respiratory system (p. 370); blood-vascular system (p. 370); nervous system (p. 374); general metabolism and excretion (p. 375); reproduction (p. 376); development (p. 377).	365
General Organisation of Dipnoi	379
CLASS AMPHIBIA	
Example of the Class. —A Frog (<i>Rana</i>)	381
External characters (p. 389); endoskeleton (p. 391); alimentary canal and associated structures (p. 400); respiratory system (p. 403); blood-vascular system (p. 404); lymphatic system (p. 410); nervous system (p. 410); organs of special sense (p. 412); endocrine glands (p. 415); urinogenital organs (p. 415); reproduction (p. 416); development (p. 418).	389
Interrelationship of Amphibian Groups	421
Sub-class Apsidospondyli	421
Super-order Labyrinthodontia	422
Order Ichthyostegalia	423
Order Rhachitomi	424
Order Stereospondyli	425
Order Embolomeri	426
Order Seymouriamorpha	427
Super-order Salientia (Anura, Batrachia)	428
Sub-class Lepsospondyli	430
Order Aistopoda	430
Order Nectridia	430
Order Microsauria (Adelospondyli)	431
Order Phyllospondyli	431
Order Urodela (Caudata)	432
Order Apoda (Gymnophiona, Caecilia)	434
General Organisation of Amphibians: External characters (p. 435); exoskeleton (p. 437); endoskeleton (p. 438); musculature (p. 442); alimentary canal and associated structures (p. 442); nervous system and organs of special sense (p. 447); endocrine system (p. 450); urinogenital system and osmoregulation (p. 450); reproduction and development (p. 452).	
CLASS REPTILIA	457
Example of the Class. —A Lizard (<i>Lacerta</i>)	462
Exoskeleton (p. 463); endoskeleton (p. 463); alimentary canal and associated structures (p. 471); blood-vascular system (p. 474); respiratory system (p. 477); brain (p. 478); endocrine glands (p. 481); organs of special sense (p. 481); urinogenital system (p. 482).	
Interrelationship of Reptilian Groups	484

Sub-class Anapsida	486
Order Cotylosauria	486
Sub-orders Captorhinomorpha (p. 486); Diadectomorpha (p. 486).	
Order Chelonida	486
Sub-class Ichthyopterygia	490
Order Mesosauria	490
Order Ichthyosauria	491
Sub-class Synaptosauria	492
Order Protorosauria	492
Order Sauropterygia	492
Sub-orders Nothosauria (p. 492); Placodontia (p. 493); Plesiosauria (p. 493).	
Sub-class Lepidosauria	495
Order Eosuchia	495
Order Rhynchocephalia	495
Squamata	496
Sub-orders Lacertilia (p. 496); Ophidia (Serpentes) (p. 497).	
Sub-class Archosauria	498
Order Thecodontia	499
Order Crocodilia (Loricata)	499
Order Pterosauria (Pterodactyla)	502
Dinosaurs	504
Order Saurischia	505
Sub-orders Theropoda (p. 505); Sauropoda (p. 507).	
Order Ornithischia	507
Sub-orders Ornithopoda (p. 508); Stegosauria (p. 510); Ankylosauria (p. 511); Ceratopsia (p. 511).	
Sub-class Synapsida	513
Order Pelycosauria	513
Order Therapsida	514
Order Ictidosauria	517
General Organisation of Recent Reptiles: External features (p. 518); integument and exoskeleton (p. 522); endoskeleton (p. 524); alimentary canal and associated structures (p. 533); respiratory system and voice (p. 540); blood-vascular system (p. 541); nervous system (p. 542); organs of special sense (p. 543); endocrine glands (p. 548); excretion (p. 548); reproduction (p. 549); development (p. 551).	
CLASS AVES	555
Example of the Class. —The Common Pigeon (<i>Columba livia</i> , var. <i>domestica</i>)	565
External characters (p. 566); exoskeleton (p. 567); endoskeleton (p. 571); muscular system (p. 580); locomotion (p. 582); alimentary canal and associated structures (p. 583); respiratory and vocal organs (p. 585); thyroid, parathyroid, and thymus glands (p. 589); blood-vascular system (p. 589); lymphatic system (p. 592); nervous system and hypophysis (p. 592); organs of special sense (p. 594); excretory and reproductive organs, and adrenal glands (p. 596).	
General Organisation of Birds	598
Sub-class Archæornithes	599
Order Archæopterygiformes	599
Sub-class Neornithes	602
Super-order Odontognathæ	603
Orders Hesperornithiformes (p. 604); Ichthyornithiformes (p. 605).	
Super-order Palæognathæ	606
Orders Struthioniformes (p. 607); Rheiformes (p. 607); Casuariiformes (p. 607); Apterygiformes (p. 608); Dinornithiformes (p. 608); Apterygiformes (p. 609); Tinamiformes (p. 609).	
Super-order Impennæ	610
Order Sphenisciformes	610
Super-order Neognathæ	612
Orders Gaviiformes (p. 613); Podicipitiformes (p. 613); Procellariiformes (p. 613); Pelicaniformes (p. 614); Ciconiiformes (p. 614); Anseriformes (p. 614); Falconi-	

CONTENTS

xv

iformes (p. 614); Galliformes (p. 615); Gruiformes (p. 615); Diatrymiformes (p. 616); Charadriiformes (p. 616); Columbiformes (p. 617); Psittaciformes (p. 617); Cuculiformes (p. 617); Strigiformes (p. 618); Caprimulgiformes (p. 618); Apodiformes (p. 618); Coliiformes (p. 618); Trogoniformes (p. 619); Coraciiformes (p. 619); Piciformes (p. 619); Passeriformes (p. 620).
General Organisation of Neornithes: External characters (p. 620); pterylosis (p. 626); endoskeleton (p. 628); alimentary canal and associated structures (p. 636); respiratory and vocal organs (p. 638); circulatory organs (p. 639); nervous system and organs of special sense (p. 639); excretion (p. 643); reproduction (p. 644); development (p. 646).

CLASS MAMMALIA

Example of the Class.—The Rabbit (<i>Oryctolagus cuniculus</i>)	652
External characters (p. 654); skeleton (p. 655); coelom (p. 666); alimentary canal and associated structures (p. 666); blood-vascular system (p. 670); lymphatic system (p. 675); respiratory system (p. 676); nervous system (p. 678); spinal cord, cranial and spinal nerves (p. 682); autonomic nervous system (p. 682); organs of special sense (p. 684); urinogenital organs (p. 684); development (p. 686).	654
Sub-class Prototheria	687
Order Triconodonta	687
Order Symmetrodonta	687
Order Monotremata	687
Skeleton (p. 696); visceral anatomy (p. 700).	688
Sub-class Allotheria	701
Order Multituberculata	701
Sub-class Theria	703
Infra-class Pantotheria (Trituberculata)	703
Order Dryolestoides	703
Order Docodonta	703
Infra-class Metatheria (Marsupialia, Didelphia)	704
Super-families Didelphoidea (p. 711); Borhyaenoidea (p. 712); Dasyuroidea (p. 712); Peramelioidea (p. 715); Caenolestoides (p. 715); Phalangerioidea (p. 716). Endoskeleton of Metatheria (p. 719).	
Infra-class Eutheria (Placentalia, Monodelphia)	723
Introduction (p. 723).	
Cohort Unguiculata	726
Order Lipotyphla	726
Skeleton of the Lipotyphla (p. 730).	
Order Menotyphla	731
Order Primates	734
Sub-order Prosimii	736
Infra-orders Lemuriformes (p. 737); Lorisiformes (p. 738); Tarsiiformes (p. 739).	
Sub-order Anthropoidea	741
Super-family Ceboidea (Platyrrhina).	743
Super-family Cercopithecoidea.	743
Super-family Hominoidea	744
Families Pongidae (p. 744); Hominidae (p. 745). Skeleton of the Primates (p. 748).	
Order Dermoptera	753
Order Chiroptera	754
Sub-orders Megachiroptera (p. 756); Microchiroptera (p. 756). Skeleton of the Chiroptera	758
Order Taniodontia	760
Order Tillodontia	760
Order Edentata	760
Sub-orders Paeanodontia (p. 761); Xenarthra (p. 761). Skeleton of Xenarthra (p. 765).	

Order Pholidota	772
Cohort Glires	774
Order Rodentia	774
Skeleton of the Rodentia (p. 778).	
Order Lagomorpha	779
Cohort Mutica	779
Order Cetacea	780
Sub-orders Archæoceti (p. 782); Odontoceti (p. 783); Mysticeti (p. 784).	
Skeleton of Cetacea (p. 785); internal adaptations of Cetacea (p. 789).	
Cohort Ferungulata	791
Super-order Feræ	791
Order Carnivora	791
Sub-orders Creodonta (p. 792); Fissipedia (p. 793); Pinnipedia (p. 797).	
Skeleton of the Carnivora (p. 798).	
Super-order Protoungulata	801
Order Condylarthra	802
Order Tubulidentata	804
South American 'Ungulata'	805
Order Litopterna	805
Order Notoungulata	806
Order Astrapotheria	807
Super-order Pænungulata (Subungulata)	807
Order Hyracoidea	808
Order Embrithopoda	810
Order Proboscidea	811
Orders Pantodonta (Amblypoda) and Dinocerata	818
Order Pyrotheria	820
Order Sirenia	820
Skeleton of Sirenia (p. 823).	
Super-order Mesaxonia	824
Order Perissodactyla	825
Families Equidæ (p. 826); Brontotheriidae (Titanotheriidae) (p. 831); Chalicotheriidae (p. 832).	
Sub-order Ceratomorpha	833
Super-family Tapiroidea	833
Super-family Rhinoceroidea	834
Super-order Paraxonia	836
Order Artiodactyla	836
Sub-orders Suiformes (p. 837); Tylopoda (p. 838); Ruminantia (p. 839).	
General Organisation of Mammalia: Integument and general external features (p. 841); endoskeleton (p. 850); alimentary canal and associated structures (p. 862); blood-vascular system (p. 881); lymphatic system (p. 883); respiratory system (p. 884); nervous system (p. 884); organs of special sense (p. 887); endocrine organs (p. 888); urinogenital system (p. 888); breeding seasons (p. 896); development and associated phenomena (p. 898); post-natal behaviour in marsupials (p. 907).	

REFERENCES 909

General (p. 909); Protochordates (p. 914); Agnathans (p. 915); Placoderms and Fishes (p. 917); Amphibians (p. 920); Reptiles (p. 921); Birds (p. 921); Mammals (p. 923).

INDEX 927

TABLES

I. Ages (in million of years) of geological periods	3
II. Relationship of somites, muscles, nerves and visceral arches	134
III. Divisions of hypophysis	151
IV. Composition of milk	849